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Effect of lead and chromium on germination and seedling growth of tomato (*Solanum lycopersicum*) and eggplant (*Solanum melongena*)

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ABSTRACT

A study was conducted to determine the effect of different concentrations of lead and chromium on seed germination and seedling growth of tomato (*Solanum lycopersicum* L.) and eggplant (*Solanum melongena* L). Seeds were grown under laboratory conditions at five concentration levels each of Pb (0, 2.5, 5.0, 7.5 and 10 ppm) and Cr (0, 0.1, 0.5, 2.5 and 7.5 ppm). Both lead and chromium treatments showed toxic effects on various growth indices of tomato and eggplant. The results of the present study have indicated that as Pb concentration increased from 0 to 5.0 ppm, the germination percentage, plumule and radicle length, fresh and dry weight decreased in tomato from 94 to 19%, 6.78 to 0.88 cm, 5.77 to 1.16 cm, 0.49 to 0.10 mg and 0.05 to 0.01 mg, respectively, while in eggplant, the decrease in the corresponding parameters was from 93 to 20%, 5.76 to 1.23 cm, 5.20 to 1.89 cm, 0.46 to 0.11 mg and 0.05 to 0.01 mg, respectively. In case of Pb, the tomato and eggplant seedlings did not germinate at 7.5 to 10 ppm concentrations. A similar trend was observed for germination and seedling growth parameters in case of Cr at 7.5 ppm concentration. On the basis of the results obtained, it was concluded that tomato was more sensitive than eggplant. As far as the relative response to the two heavy metals is concerned, it was clear that lead is less toxic than chromium. The uptake of lead by plant is also very low. An attempt was made to quantify the response of the seedlings of the two crops to varying Pb and Cr concentrations. The models used were linear, quadratic, and polynomial of degree 3. The responses could be described very satisfactorily by the polynomial of degree three with R^2> 99% for all the parameters.

Key words: Chromium, Eggplant, Germination and seedling growth parameters, Irrigation water, Lead, Tomato

As a consequence of unplanned and uncontrolled development, a wide range of pollutants have been introduced into the environment through various anthropogenic activities such as industry, mining, transportation, etc. Despite the fact that it is almost impossible to visualize a soil without trace levels of heavy metals and most of the heavy metals are essential elements for living organisms, their excess amounts are generally harmful to plants, animals and human health (Azevedo and Lea 2005, Jarup 2003). Plants are important component of the ecosystems as they transfer the metals from abiotic into biotic environments (Mocquot *et al.* 1996, Chojnacki *et al.* 2005). The metals may enter the food chain either through water supplies and aquatic organisms or through arable produce and grazing animals (Thornton 1991). In recent years, the consumption of vegetables has increased substantially, particularly in the urban areas. In these areas, most of the vegetables grown are very much prone to Pb, Cr, Ni and other heavy metal toxicity. The level of heavy metals in sewage-irrigated grown vegetables could be 2 to 40 times higher than that grown with tube well water (Alam *et al.* 2003, Faizan *et al.* 2012, Gautam *et al.* 2014). Some heavy metals at low doses are essential micronutrients for plants, but at higher doses may cause metabolic disorders and growth inhibition (Fernandes and Henriques 1991).

In several other countries including India, wastewater is being increasingly used for irrigating crops such as vegetables, fruits, cereals, flowers and fodder.Wastewater irrigated vegetables take up heavy metals and accumulate them in their edible parts (Singh *et al.* 2010, Yahia *et al.* 2013) and inedible parts in quantities high enough to cause clinical problems both to animals and human beings consuming these metal-rich plants (Alam *et al.* 2003).The present study was therefore, conducted to understand the effects of Pb and Cr on the germination and seedling growth of tomato (*Solanum lycopersicum* L.) and eggplant (*Solanum melongena* L.) seedlings in order to quantify their responses as they are two essential vegetables in the daily diet.

MATERIALS AND METHODS

The experiment was conducted in the Division of Seed Science and Technology, Indian Agricultural Research Institute, New Delhi. The seeds of two vegetables crops, viz., tomato (Pusa Rohini) and eggplant (Pusa Upkar), were procured from the Division of Vegetable Science, Indian

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Agricultural Research Institute, New Delhi. The parameters studied included germination percentage, plumule length, radicle length, fresh weight and dry weight. For this experiment, the petri dishes were first washed with distilled water and sterilized in an oven at 100 °C for 12 hr before their use. For the germination studies, uniformly large and healthy seeds of tomato and eggplant were taken and their surface sterilized with 0.1% mercuric chloride solution for five minutes to check fungal growth. The sterilized seeds were then rapidly washed thoroughly with distilled water. Seed were grown under laboratory conditions at five concentration levels each of Pb (0, 2.5, 5.0, 7.5 and 10 ppm) and Cr (0, 0.1, 0.5, 2.5 and 7.5 ppm) and then kept in petridishes on sterilized filter paper for germination at 25°±0.2°. Lead acetate basic [Pb3 (H_2O) $(CH_3COO)_2$] for Pb and chromium sulphate $Cr_2(SO_4)_3.6H_2O$ for Cr were used as the source for preparing solution of different concentrations. The protrusion of radical through the seed coat was as the criteria considered for germination. Thereafter, the germinated seeds were counted on 9th (eggplant) and 11th (tomato) day after initiation of germination. Germination percentage, plumule length, radicle length, fresh weight and dry weight of eggplant and tomato of seedlings were measured. Germination percentage and reduction in germination growth (%) were worked out by the following formulae:

$$Gp = S_g/S_t*100 \quad ...(1)$$

where Gp is the germination percentage of seeds, $S_g$is the number of germinated seeds and S_t is the total number of seeds for the experiment.

Reduction in percentage of all growth data was determined in treated water solution of the Pb and Cr relative to control (0 ppm) using the following formula:

$$G_r = (G_c - G_t)*100 / G_c \quad ...(2)$$

where G_r, Reduction in germination growth (%); G_c, germination in control; G_t, germination in treatment.

The above two equations were used for the other parameters mentioned earlier.

Models are tools which are used to convert discrete data into a continuous function. This enables estimating the optimum or threshold values of parameters from the experimental data more precisely. A well calibrated and validated model can be used for both interpolation and extrapolation. An attempt was made to quantify the impact of Pb and Cr concentrations on the various attributes related to seedling germination. The models used were as follows:

Llinear: $y = a + bx$ ...(3)

Quadratic: $y = a + bx + cx^2$ ...(4)

Polynomial of degree 3 $y = a + bx + cx^2 + dx^3$ .....(5)

In all the equations, 'y' is either the seed germination percentage, radicle length, plumule length, fresh or dry weight , 'x' is Pb or Cr concentration, 'a' is the constant and 'b', 'c', 'd' are regression coefficients having different values in the different equations.

All the data were statistically analyzed using SAS version 9.2.

RESULTS AND DISCUSSION

The results of the experiments have been described and discussed in the following sections.

Effect of lead and chromium on seedling growth and related parameters

The results of seedlings of tomato and eggplant exposed to increasing Pb and Cr concentrations have revealed that there were significant reductions in germination percentage, plumule and radicle length, fresh and dry weight (Table 1). When the Pb concentration increased from 0 to 5 ppm, the germination percentage, plumule and radicle length, fresh and dry weight decreased in tomato from 94 to 19%, 6.78 to 0.88 cm, 5.77 to 1.16 cm, 0.49 to 0.10 mg and 0.05 to 0.01 mg, respectively.Their inhibition increased from 29 to 80%, 47 to 87%, 24 to 80%, 35 to 80% and 45 to 81% when

Table 1 Effect of different concentrations of Pb and Cr seedling germination attributes* of tomato and eggplant seedlings

Parameter	Crop	Pb T_0	Pb T_1	Pb T_2	Pb T_3	Pb T_4	CD (P=0.01)	Cr T_0	Cr T_1	Cr T_2	Cr T_3	Cr T_4	CD (P=0.01)
Germination (%)	Tomato	94	67	19	0	0	8.76	95	92	74	40	0	6.52
	Eggplant	93	71	20	0	0	9.52	87	81	75	70	0	19.77
Plumule length (cm)	Tomato	6.78	3.62	0.88	0.00	0.00	0.39	12.37	7.18	3.43	1.87	0.00	0.25
	Eggplant	5.76	4.52	1.23	0.00	0.00	0.13	5.01	4.06	4.00	2.44	0.00	0.12
Radicle length (cm)	Tomato	5.77	4.40	1.16	0.00	0.00	0.09	7.05	5.63	2.67	1.57	0.00	0.34
	Eggplant	5.20	4.27	1.19	0.00	0.00	0.06	3.50	3.02	2.45	2.02	0.00	0.05
Fresh wt. (mg)	Tomato	0.49	0.32	0.10	0.00	0.00	0.01	0.23	0.18	0.15	0.01	0.00	0.01
	Eggplant	0.46	0.32	0.11	0.00	0.00	0.02	0.29	0.26	0.24	0.10	0.00	0.03
Dry wt. (mg)	Tomato	0.05	0.03	0.01	0.00	0.00	0.01	0.06	0.05	0.03	0.01	0.00	0.01
	Eggplant	0.05	0.03	0.01	0.00	0.00	0.01	0.39	0.02	0.01	0.01	0.00	0.01

*Significant at P = 0.01. Pb: T_0, 0 ppm; T_1, 2.5 ppm; T_2, 5 ppm; T_3, 7.5 ppm; T_4, 10 ppm. Cr: T_0, 0 ppm; T_1, 0.1 ppm; T_2, 0.5 ppm; T_3, 2.5 ppm; T_4, 7.5 ppm

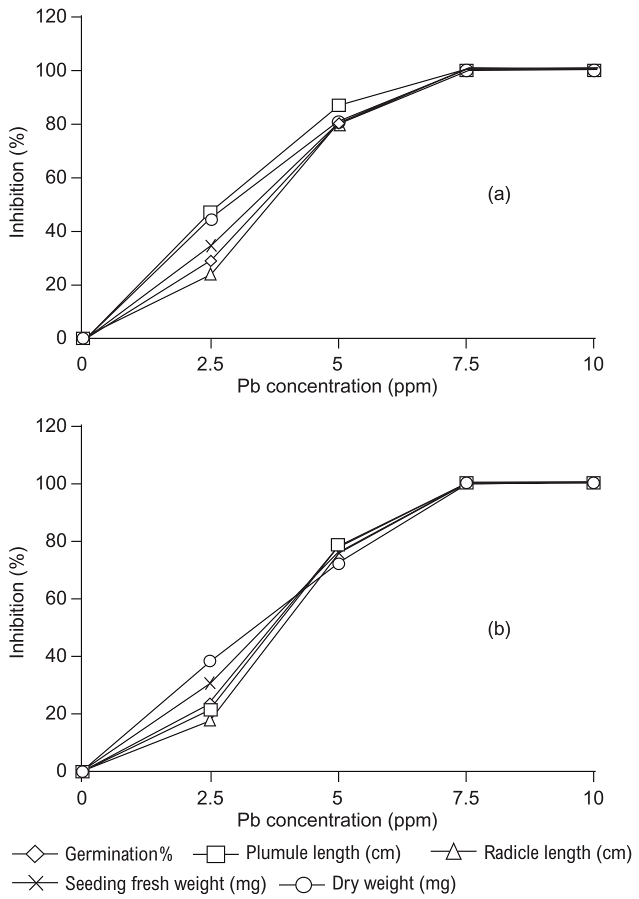

Fig 1 Impact of Pb concentration on inhibition rate in growth attributes of (a) tomato and (b) eggplant compared to control

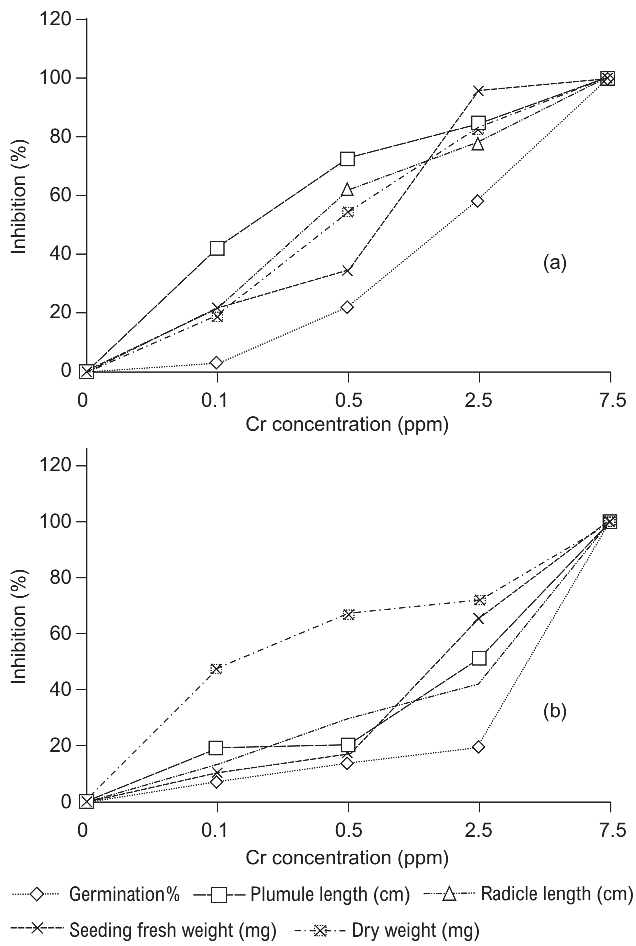

Fig 2 Impact of Cr concentration on inhibition rate in growth attributes of (a) tomato and (b) eggplant compared to control

concentration of Pb increased from 2.5 to 5.0 ppm, respectively. In case of eggplant, the decrease for the corresponding parameters was from 93 to 20%, 5.76 to 1.23 cm, 5.20 to 1.19 cm, 0.49 to 0.10 mg and 0.05 to 0.01 mg, respectively, and their inhibition increased from 24 to 78%, 21 to 79%, 18 to 77%, 31 to 76% and 38 to 72% for the corresponding change in concentrations (Fig 1).

In case of Cr, the germination percentage, plumule and radicle length, fresh and dry weight decreased in tomato from 94 to 40%, 12.37 to 1.87 cm, 7.05 to 1.57 cm, 0.23 to 0.01 mg and 0.06 to 0.01 mg, respectively, and their inhibition increased from 3 to 78%, 42 to 85%, 20 to 78%, 22 to 96% and 19 to 83% when concentration of Cr increased from 0.1 to 2.5 ppm, respectively. In case of eggplant, the decrease for the corresponding parameters was from 87 to 70%, 5.01 to 2.44 cm, 3.50 to 2.02 cm, 0.29 to 0.10 mg and 0.04 to 0.01 mg, respectively, and their inhibition increased from 7 to 20%, 19 to 51%, 14 to 42%, 10 to 66% and 47 to 72% for the corresponding change in concentrations (Fig 2).

The performances of the various models for the two crops have been presented in Table 2 and 3, and evaluated in terms of Coefficient of Determination (R^2) values. In the case of Pb, R^2 values ranged from 0.858 to 0.904 in tomato and between 0.898 to 0.917 in eggplant when the linear model (eq 3) was used. The use of quadratic model (eq 4) resulted in R^2 values ranging from 0.956 to 0.997 in tomato, and from 0.940 to 0.994 in eggplant which was a significant improvement over eq 3. The use of polynomial of degree 3 (eq 5) resulted in R^2 values ranging from 0.988 to 0.999 in tomato and between 0.987 to 0.999 in eggplant, a marked improvement over eq 4. The best fit was obtained by the polynomial of degree 3 in both the crops with the quadratic form performing slightly better than the linear form.

In case of Cr, the R^2 values ranged from 0.909 to 0.0.987 in tomato and 0.676 to 0.915 in eggplant when the linear model (eq 3) was used (Table 3). The use of quadratic model (eq 4) resulted in R^2 values ranging from 0.926 to 0.999 in tomato, and from 0.904 to 0.979 in eggplant. The use of polynomial of degree 3 (eq 5) resulted in R^2 values ranging from 0.954 to 0.999 in tomato and 0.980 to 0.999 in eggplant. As in case of Pb, the best fit was obtained by the polynomial of degree 3 in Cr also for both the crops.

In the present investigation, lead and chromium treatment decreased seed germination and seedling growth of tomato and eggplant. Seedling growth is considered as an indicator of metal stress on plant ability to survive. The toxicity of some of the metals may be large enough that, plant growth is retarded before large quantities of the element can be transferred (Haghiri 1973). We have investigated how heavy metal mixture treatment affected

Table 2 Performance of various models (*) used for on seedling germination attributes in case of Pb

Crop	Parameters	Models											
		Linear			Quadratic				Polynomial (3)				
		a	b(x)	R^2	a	b(x)	$c(x^2)$	R^2	a	b(x)	$c(x^2)$	$d(x^3)$	R^2
Tomato	Germination (%)	–25.500	112.500	0.902	154.000	–61.071	5.929	0.971	98.000	17.595	–24.071	3.333	0.993
	Plumule length (cm)	7.410	–1.718	0.858	11.500	–5.224	0.584	0.997	10.856	–4.319	0.239	0.038	0.998
	Radicle length (cm)	7.048	–1.594	0.897	9.458	–3.66	0.344	0.956	5.216	2.299	–1.928	0.253	0.988
	Fresh weight (mg)	0.572	–0.130	0.904	0.802	–0.327	0.033	0.985	0.592	–0.032	–0.08	0.013	0.997
	Dry weight (mg)	0.057	–0.013	0.898	0.082	–0.033	0.004	0.994	0.068	–0.015	–0.004	0.001	0.999
Egg–	Germination (%)	113.900	–25.700	0.903	151.400	–57.843	5.357	0.957	82.800	38.524	–31.393	4.083	0.990
plant	Plumule length (cm)	7.114	–1.604	0.898	0.3243	–3.549	9.384	0.950	4.792	2.901	–2.136	0.273	0.9878
	Radicle length (cm)	6.530	–1.466	0.898	8.406	–3.075	0.268	0.940	3.736	3.486	–2.233	0.278	0.987
	Fresh weight (mg)	0.550	–0.124	0.917	0.740	–0.287	0.027	0.979	0.488	0.067	–0.107	0.015	0.998
	Dry weight (mg)	0.057	–0.013	0.899	0.008	–0.034	0.004	0.994	0.068	–0.015	–0.004	0.001	0.999

All R^2 values are *significant at $P \leq 0.05$ level, 'a' is the constant and 'b', 'c',' d' are regression coefficients

Table 3 Performance of various models (*) used for on seedling germination attributes in case of Cr

Crop	Parameters	Models											
		Linear			Quadratic				Polynomial (3)				
		a	b(x)	R^2	a	b(x)	$c(x^2)$	R^2	a	b(x)	$c(x^2)$	$d(x^3)$	R^2
Tomato	Germination (%)	132.800	–24.200	0.909	87.800	14.371	–6.429	0.999	75.200	32.071	–13.179	0.750	0.999
	Plumulelength (cm)	13.984	–3.005	0.937	18.400	–6.790	0.631	0.995	20.858	–10.244	1.948	–0.146	0.998
	Radicle length (cm)	8.832	–1.816	0.978	9.612	–2.485	0.111	0.983	8.114	–0.380	–0.691	0.089	0.986
	Fresh weight (mg)	0.303	–0.063	0.925	0.288	–0.050	–0.002	0.926	0.134	0.166	–0.085	0.009	0.954
	Dry weight (mg)	0.075	–0.016	0.987	0.078	–0.018	0.001	0.988	0.055	0.014	–0.012	0.001	0.999
Egg–	Germination (%)	118.100	–18.500	0.676**	54.6	35.929	–9.071	0.904	145.6	–91.905	39.679	–5.417	0.987
plant	Plumulelength (cm)	6.594	–1.164	0.878	4.354	0.756	–0.320	0.971	6.832	–2.725	1.008	–0.148	0.992
	Radicle length (cm)	4.598	–0.800	0.877	3.127	0.461	–0.210	0.961	5.232	–2.497	0.918	–0.125	0.992
	Fresh weight (mg)	0.400	–0.074	0.911	0.270	0.037	–0.019	0.979	0.228	0.096	–0.041	0.003	0.98
	Dry weight (mg)	0.043	–0.009	0.915	0.053	–0.018	0.002	0.951	0.081	–0.057	0.017	–0.002	0.999

All R^2 values are *significant at $P \leq 0.05$ level, 'a' is the constant and 'b', 'c',' d' are regression coefficients

germination and early growth stage of safflower plant. Rahman *et al.* (2010) also observed a reduction in seed germination and seedling growth in chickpea treated with 50, 100, 200 and 400 ppm of nickel and cobalt. The reduced germination of seeds under Cr stress could be a depressive effect of Cr on the activity of amylases and on subsequent woansport of sugars to the embryo axes (Zeid 2001). Kalimuthu and Siva (1990) found reduction in seed germination in corn treated with 20, 50, 100 and 200 µg/mL lead acetate. Treatment of wheat with lead at 1, 2, 5, 10 and 20/mL reduced the germination process showing gradual reduction in germination with increase in concentration (Hasnain *et al.* 1995). Excessive amount of toxic element usually caused reduction in plant growth (Prodgers and Inskeep 1981). Sharma and Agrawal (2010) found that bioaccumulation of both Zn and Cd adversely affected the growth, biochemical and physiological characteristics that resulted in reduced biomass production lady's finger. Similar results were obtained by several workers who had evaluated the impact of Pb concentration on root/shoot and leaf growth, and fresh-dry biomass, viz. *Paspalum distichum* and *Cynodon dactylon* (Shua *et al.* 2002), tomato (Jaja and Odomena 2004) and *Plantago major* (Kosobrukhov *et al.* 2004). Yaqvob *et al.* (2011) conducted a study to evaluate the response to two tomato varieties (Barakat and Local tomato) to ordinary heavy metals (Fe, Pb and Cu) in northern Iran. They observed that some heavy metals in higher doses may cause metabolic disorders and growth inhibition for most of the plant species. Cr in irrigation water significantly decreased growth and development, culminating in the reduction of yield and total dry matter as a consequence of poor production,translocation and partitioning of assimilates from source to the economic parts of the plant (Gautam *et al.* 2014).

Germination percentage, plumule and radicle length, fresh and dry weight reduced as the Pb concentration increased from 0 to 5 ppm. In case of Cr a similar trend was observed when the concentration increased from 0 to 2.5 ppm. The reason of reduced seedling length in metal treatments could be due to the reduction in meristematic cells present in this region and some enzymes contained in the cotyledon and endosperm. Cells become active and begin to digest and store food which is converted into soluble form and transported to the radicle and plumule tips for enzyme amylase which converts starch into sugar and protease act on protein. So when activities of hydrolytic enzyme are affected, the food does not reach to the radicle and plumule affecting the seedling length.

As far as modelling the response of Pb and Cr on the various parameters used for seed germination studies are concerned, this is perhaps the first attempt made to model them.

CONCLUSION

This study revealed that presence of Pb and Cr in irrigation water significantly decreased the germination percentage, plumule and radicle length, fresh and dry weight in both tomato and eggplant crops. The results also showed that in case of Pb, tomato and eggplant seeds did not germinate at concentration of 7.5 to 10 ppm. A similar trend was observed for germination and seedling growth parameters in case of Cr at 7.5 ppm concentration. It was observed that between the two crops, tomato was relatively more sensitive than eggplant. The polynomial of degree 3 was very effective in quantifying the impact of Pb and Cr on the various parameters.

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REFERENCES

Alam M G M, Snow E T and Tanaka A. 2003. Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. *Science of the Total Environment* **308:** 83–96.

Azevedo R A and Lea P J. 2005. Toxic metals in plants. *Brazilin Journal of Plant Physiology* **17:** 1.

Chojnacka K, Chojnacki A, Gorecka H and Gorecki H. 2005. Bioavailability of heavy metals from polluted soils to plants. *Science of the Total Environment* **337:** 175–82.

Faizan S, Kausar S and Perwean Q. 2012. Variation in growth, physiology and yield of four chickpes cultivation exposed to cadmium chloride. *Journal of Environmental Biology* **33:** 1 137–42.

Fernandes J C and Henriques F S. 1991. Biochemical, physiological, and structural effects of excess copper in plants. *Botanical Review* **57***:* 246–73.

Gautam M, Singh A K and Johri R M. 2014. Influence of Pb toxicity on yield, yield attributing parameters and photosynthetic pigment of tomato (*Solanum lycopersicum*) and eggplant (*Solanum melongena*). *Indian Journal of Agricultural Sciences* **84(7):** 808–15.

Haghiri F. 1973. Cadmium uptake by plants. *Journal of Environment Quality* **2:** 93–6.

Hasnain S H, Saleem F and Sari N. 1995. *Biotechnology for Environment and Agriculture*. University of Karachi, Karachi, Pakistan.

Jaja E T and Odoemena C S I. 2004. Effect of Pb, Cu and Fe compounds on the germination and early seedling growth of *L. esculentum* varieties. *Journal of Applied Sciences and Environmental Management* **8(2):** 51–3.

Jarup L. 2003. Hazard of heavy metal contamination. *British Medical Bulletin* **68:** 167–82.

Kalimuthu K and Siva S R. 1990. Physiological effects of heavy metals on *Zea mays* (maize) seedlings. *Indian Journal of Plant Physiology* **33:** 242–4.

Kosobrukhov A, Knyazeva I and Mudrik V. 2004. *Plantago major* plants responses to increase content of lead in soil, growth and photosynthesis. *Plant Growth Regulation* **42:** 145–51.

Mocquit B, Vangronsveld J, Clijsters H and Mench M. 1996. Copper toxicity in young maize (*Zea mays* L.). Plants effects on growth, mineral and chlorophyll contents and enzymes activities. *Plant and Soil* **182:** 287–310.

Prodgers R A and Inskeep W P. 1981. Heavy metals tolerance of inland salt grass *Distichlisspicata*. *Great Basin Naturalist* **51:** 271–8.

Rahman K M and Mahmud K M. 2010. Effect of varying concentration of nickel and cobalt on the plant growth and yield of chickpea. *Australian Journal of Basic Applied Science* **4(6):** 1 036–46.

Sharma R K and Agrawal S B. 2010. Responses of *Abelmoschus esculentus* L. (lady's finger) to elevated levels of Zn and Cd. *Tropical Ecology* **51**(2S): 389–96.

Sobukola O P and Dairo O U. 2007. Modeling drying kinetics of fever leaves (*Ocimum viride*) in a convective hot air dryer. *Nigerian Food Journal* **25**(1): 145–53.

Shua W S, Yeb Z H, Lana C Y, Zhanga Z Q and Wongb M H. 2002. Lead, zinc and copper accumulation and tolerance in populations of *Paspalum distichum* and *Cynodon dactylon*. *Environmental Pollution* **120:** 445–53.

Thornton I. 1991. Metal contamination in soils of urban areas. (*In*) *Soils in the Urban Environment,* pp 47–75. Bullock P and Gregory P J (Eds). Blackwell, Oxford

Yahia Y I and Almagrabi O A E. 2013. Heavy metal accumulation in some vegetables irrigated with treated wastewater. *International Journal of Green Chemistry* **2(1):** 81–90.

Yaqvob M, Golale A, Masoud, S and Ghorbani H R. 2011. Influence of different concentration of heavy metals on the seed germination and growth of tomato. *African Journal of Environmental Science and Technology* **5**(6): 420–6.

Zeid I M. 2001. Responses of *Phaseolus vulgaris* to chromium and cobalt treatments. *Journal of Plant Biology* **44:**111–1.