Indian J. Hort. 68(4), December 2011: 512-515

Impact of lead contaminated water on root morphology of tomato and brinjal

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ABSTRACT

A pot study was conducted to investigate the impact of heavy metal (lead) content in waste waters on root growth of two important vegetables crops, namely, tomato and brinjal. The treatments consisted of four concentrations of Pb, 2.5, 5.0, 7.5 and 10 ppm. The soil used in the study was sandy loam. Normal water was used as control (0 ppm). The root morphological parameters investigated were: fresh weight, dry weight, length, surface area, root length density, volume, as well as number of root forks, crossings and tips. The presence of Pb in irrigation water had a significant impact on all the root related morphological parameters. The root fresh weight got decreased from 22.56 g/pot recorded in control to 5.82 g/pot in 10 ppm treatment in tomato. In brinjal, it decreased from 21.11 g/pot in control to 5.86 g/pot in 10 ppm treatment. In case of root length density also, it decreased from 495.72 cm/m^3/pot in control to 44.76 cm/m^3/pot in 10 ppm treatment in tomato and 417.76 to 97.48 cm/m^3/pot in the corresponding treatments in brinjal. A similar trend was observed for all other morphological parameters. From the results, it was shown that tomato was more sensitive to Pb compared to brinjal.

Key words: Irrigation water, lead, root morphological parameters, tomato, brinjal.

INTRODUCTION

Heavy metal contamination of the environment is currently of global interest with respect to the toxicological importance, health of vegetation, wildlife and human beings (Azevedo and Lea, 2). Industrial wastes are a major source of soil pollution and originate from mining, chemical, metal processing and other industries. These wastes include a variety of chemicals including heavy metals, phenolics etc. (van Assche and Clijsters, 17). Lead (Pb), cadmium (Cd), and nickel (Ni) are significant environmental pollutants. Anthropogenic activities, such as agriculture, industry and urban life styles increase Pb, Cd, and Ni contents of soils and waters, thus enhancing heavy metal content in vegetables (Alegria *et al*., 1) and eventually, entering the food chain. Animals and humans are very sensitive to it. Presence of more than 100 µg/l of Pb in children's blood adversely affects their growth and development, and an overdose of Pb may cause kidney problems and high blood pressure in adults (Peng *et al*., 9).

Use/dumping of industrial effluent and sewage sludge on agricultural land, particularly in and around cities, has become a common practice in India and a host of other countries as a result of which these toxic metals are extracted from soil, transferred to and concentrated in the plant tissues. The highest level of metal persistence was observed in soil substrates, and the uptake being non-substrate specific, resulted in very high uptake by plants through the roots (Tomáš *et al*., 16). Plants respond to pollution stress and metabolize pollutants differently (Zhu, 20; Ramana *et al*., 10) by varying mechanisms of uptake, translocation and accumulation (Salt *et al*., 13; Rehman *et al*., 11). Houshmandfar and Moraghebi (5) observed the toxic effects of a combination of heavy metals on germination and seedling growth of safflower. Inhibition of germination and retardation of plant growth has been reported due to lead toxicity (Sharma and Dubey, 14). Flexibility in biomass allocation, root morphology and root distribution pattern is an important adaptive mechanism to extract nutrients (Rengel and Marschner, 12). Root growth is directly related with the growth and biomass yield of shoots. As stated earlier, there are several studies related to the impact of heavy metals on above ground plant growth parameters but similar studies on root characteristic are very scanty although roots play an important role in the soil-water-plant system (Lynch *et al*., 7). Since the impact of heavy metal concentration is experienced by the root system first (Kollmeier *et al*., 6), it will be the root morphological and physiological parameters which would be affected significantly. It was, therefore, felt worthwhile to conduct a study on these parameters.

MATERIALS AND METHODS

The experiment was conducted in the net house of Water Technology Centre, Indian Agricultural Research Institute, New Delhi. Two vegetable crops, *viz.,* tomato cv. Pusa Rohini and brinjal cv. Pusa Upkar, were

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grown in the winter season of 2009. Fifteen-day -old seedlings were transplanted in pots. The soil used in the experiment was sandy loam in texture (sand 76%, silt 10%, clay 14%). Initial pH, EC, organic carbon, available nitrogen, phosphorus and potassium content were 7.8, 0.72 dS m^{-1}, 0.48%, 228 kg ha^{-1}, 22.2 kg ha^{-1} and 358 kg ha^{-1}, respectively. The experiment was laid out in Completely Randomized Block Design with three replications. The four concentrations of Pb in irrigation water were 2.5, 5.0, 7.5 and 10 ppm in addition to control (0 ppm). Recommended doses of fertilizers were applied to both the crops in all the treatments. In tomato, the dose was 150 kg N/ha (3.28 g N/pot), 60 kg P_2O_5/ha (3.77 g P_2O_5/pot) and 60 kg K_2O/ha (1 g K_2O/pot) while in brinjal, the dose was 50 kg N/ha (1.09 g N/pot), 370 kg P_2O_5/ha (23.23 g P_2O_5/pot) and 100 kg K_2O/ha (1.67 g K_2O/pot) through urea for nitrogen, single super phosphate for phosphorus and muriate of potash for potassium, respectively. Lead acetate basic $[Pb_3(H_2O)(CH_3COO)_2]$ was used as the source of Pb. The first irrigation was given with normal water at the time of transplanting but subsequent irrigations were with Pb enriched water at 5 day intervals in both tomato and brinjal crops. The root samples were taken at the time of fruiting in both the crops. The root samples were washed with water. After washing, the roots were cleaned and dried and then analyzed for their characteristics using root scanner Epson Model EU-22 using Win Rhizo. Data were analyzed statistically using SAS version 9.2. The data in decimal figures were rounded off for table.

RESULTS AND DISCUSSION

The impact of lead on the fresh and dry weight has been shown in Fig.1. The impact of Pb resulted in a significant ($p \leq 0.05$) reduction in fresh and dry weight of roots compared to the control. In case of root fresh weight, it declined from 22.56 g/pot in control to 5.82 g/pot in 10 ppm Pb treatment in tomato. In brinjal, it declined from 21.11 g/pot in control to 5.86 g/pot in 10 ppm treatment. In case of root dry weight, it declined from 4.63 g/pot in control to 0.65 g/pot in 10 ppm treatment in tomato while in brinjal, it declined from 3.5 g/pot in control to 0.65 g/pot in 10 ppm treatment. This signified a drastic reduction in fresh weight of tomato by 74%. In brinjal, the reduction was 72% compared to the control. In case of root dry weight in tomato, it decreased by 86%, while in brinjal it decreased by 81% compared to the control. Our results have indicated that the decrease in root fresh weight and dry weight was relatively more in tomato compared to brinjal implying that tomato is more sensitive than brinjal. The reduction in root fresh weight was more pronounced beyond the concentration of 2.5 ppm but the impact on dry weight was significant even at 2.5 ppm Pb concentration.

The impact of lead on the root length and surface area has been presented in Table 1. Root length and surface area are two parameters of the crops that directly affect uptake of ions from the soil solution. As was observed in root fresh weight and dry weight, Pb significantly reduced root length and surface area also. In case of root length, it declined from 5453 cm/pot in control to 492 cm/pot in 10 ppm treatment in tomato. In brinjal, it declined from 4562 cm/pot in control to 1073 cm/pot in 10 ppm treatment. In case of root surface area, it declined from 1264 cm^3/pot in control to 155 cm^3/pot in 10 ppm treatment in tomato, while in brinjal, it declined from 1035 cm^3/pot in control to 241 cm^3/pot in 10 ppm treatment. In case of root length in tomato, it decreased by 91% in 10 ppm treatment, while in brinjal it decreased by around 76% compared to control. As far as the root surface area is concerned, in tomato it decreased by 88% while in brinjal it decreased by the less than 77% compared to control. These results further confirm that tomato is more sensitive than

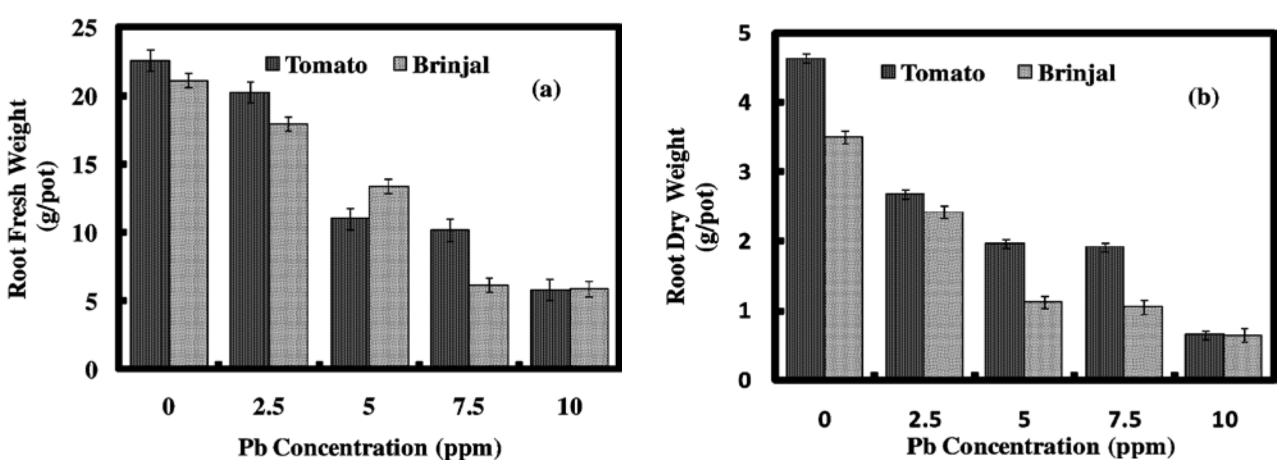

Fig. 1. Effect of lead concentration on (a) Root fresh weight and (b) Root dry weight.

Table 1. Effect of varying levels of lead (Pb) containing irrigation water on root morphological characters of tomato cv. Pusa Rohini and brinjal cv. Pusa Upkar in pot culture experiment during winter seasons.

Pb (ppm)	Root length (cm $plant^{-1}$)		Root surface area (cm^2 $plant^{-1}$)		Root volume (cm^3 $plant^{-1}$)		Root length density (cm^2/m^3 $plant^{-1}$)		Root tips ($plant^{-1}$)		Root forks ($plant^{-1}$)		Root crossings ($plant^{-1}$)	
	Tomato	Brinjal	Tomato	Brinjal	Tomato	Brinjal	Tomato	Brinjal	Tomato	Brinjal	Tomato	Brinjal	Tomato	Brinjal
0	5453	4562	1264	1035	23	19	496	418	13304	11723	20586	16943	7912	6798
2.5	3289	2684	765	556	14	10	299	244	10415	8633	12250	7498	4350	2406
5	1582	2547	364	521	7	9	144	232	5216	8430	3325	6872	881	2132
7.5	1073	2077	282	395	6	6	98	189	3680	6734	1871	5482	374	1925
10	492	1073	155	241	4	4	45	97	2020	3244	508	1558	178	420
CD ($p \leq 0.05$)	42.97	71.25	1.86	6.12	1.14	0.21	3.90	6.47	154.42	140.84	103.16	90.53	14.74	46.38

brinjal as far as Pb toxicity is concerned. The reduction in root length and surface area was more pronounced beyond the concentration of 2.5 ppm in the case of tomato but in brinjal, the treatment differences in both the parameters was not significant in either 2.5 or 5.0 ppm treatment.

Exposure of Pb to both the crops resulted in significant ($p \leq 0.05$) decline in root volume and root length density compared to the control (Table 1). The impact of Pb was significant ($p \leq 0.05$) when the concentration increased from 0 ppm to the level of 10 ppm. In tomato, the root volume declined from 23 cm^3/pot in control to 4 cm^3/pot in 10 ppm treatment, while in brinjal, it declined from 19 cm^3/pot in control to 4 cm^3 /pot in 10 ppm treatment. In case of root length density, it declined from 496 cm/m^3/pot in control to 45 cm/m^3/pot in 10 ppm treatment. In brinjal, it declined from 418 cm/m^3/pot in control to 97 cm/m^3/pot in 10 ppm treatment. In tomato, the root volume decreased by 83%, while in brinjal it decreased by around 77% compared to the control. As far as root length density is concerned, in tomato it decreased by 91%, while in brinjal it decreased by the less than 76% in 10 ppm treatment compared to the control. These results further confirm that tomato is more sensitive than brinjal. A similar trend had been observed in root length and surface area.

The impact of lead on the root tips, forks and crossings has been presented in Table 1. The presence of Pb at all concentrations resulted in a significant ($p \leq 0.05$) reduction in number of root tips, forks and crossings compared to the control. The number of root tips, declined from 13304/pot in control to 2020/pot in 10 ppm treatment in tomato. In brinjal, they declined from 11723/pot in control 3244/pot in 10 ppm treatment. In case of root forks, the number declined from 20586/pot in control to 508/pot in 10 ppm treatment in tomato. In brinjal, the number declined from 16943/pot in control to 1558/pot in 10 ppm treatment. In case of root crossings, the number declined from 7912/pot in control to 178.00/pot in 10 ppm treatment in tomato. In brinjal, the number declined from 6798/pot in control to 420/pot in 10 ppm treatment. This signified a drastic reduction in tips of tomato by 85% while in brinjal it was 72% compared to the control. In case of root forks, the number declined by 98% in tomato while in brinjal it was 91% compared to the control. In case of root crossings, the number decreased by 98% in tomato while it decreased by 94% in brinjal compared to control. Our results also indicated that the decrease in root tips, forks and crossings was relatively more in tomato at all levels of Pb concentrations compared to brinjal, once again confirming that tomato is more sensitive than brinjal. In case of brinjal, the treatment at 2.5 and 5 ppm level showed no significant difference.

Root morphological changes under varied environmental stress directly influence the plant population structure, above ground parts and their biomass composition (Zhang *et al.*, 20). Verma and Dubey (18) had reported that when rice seedlings were raised in sand cultures for 10 and 20 days in nutrient medium containing 500 and 100 µM ($Pb(NO_3)_2$, root growth was reduced by 22 to 42% and shoot growth by 25%. Decrease in root growth is a well-documented effect due to uptake of heavy metals by plants (Breckle, 4; Obroucheva *et al.*, 8; Tang *et al.*, 15). Growth inhibition was concentration dependant and exhibited a positive correlation with the reduction in the viability of root cells. The inhibition of root growth in term of volume can be attributed in part to the inhibition of mitosis, reduced synthesis of cell wall components, damage to Golgi apparatus and changes in the polysaccharide metabolism, while browning is caused by suberin deposits (Berkelaar and Hale, 3). Our results are also consistent with those reported by researchers working on *Elsholtzia* species (Peng *et al.*, 9).

This study revealed that presence of Pb in irrigation water significantly decreased root fresh weight, root dry weight, root length, root surface area, root length density and root volume as well as number of root forks, root crossings and root tips in both tomato and brinjal crops. Among the various root morphological parameters studied, root crossing and root forks were most adversely affected by Pb. It was observed that between the two crops, tomato was relatively more sensitive than brinjal.

ACKNOWLEDGEMENTS

The senior author acknowledges the Director, Indian Agricultural Research Institute, New Delhi for providing necessary facilities and University Grants Commission, New Delhi for providing Senior Research Fellowship.

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Received: January, 2011; Revised: September, 2011; Accepted : November, 2011