Indian J. Hort. 69(2), June 2012: 205-208

Root morphology of tomato and brinjal as influenced by Cr toxicity

Mamta Gautam, Anil Kumar Singh* and Rajiv Mohan Johri
Department of Botany, M.M.H. College, Ghaziabad 201 009, Uttar Pradesh

ABSTRACT

A pot experiment was conducted to study the effect of chromium on root morphology of two important vegetables crops, *viz.,* tomato (*Lycopersicon esculentum*) and brinjal (*Solanum melongena*), irrigated with water having four different concentrations of Cr (0.1, 0.5, 2.5 and 7.5 ppm). Plants irrigated with normal water were used as control (0 ppm). Presence of Cr in irrigation water adversely affected all the parameters used for characterizing root growth, namely, root biomass, root length, root surface area, root length density, root volume, number of root forks, crossings and tips. Root fresh weight of tomato decreased by 80% in 7.5 ppm Cr treatment as compared to control, while in brinjal, it decreased by 63% for the corresponding treatments. In case of root length density also, it decreased from 528.10 cm/m^3/pot in control to 133.46 cm/m^3/pot in 7.5 ppm treatment in tomato, and 428.76 to 176.31 cm/m^3/pot in the corresponding treatments in brinjal. Similar trends were observed in all other morphological parameters including the number of root forks, crossings and tips. The reduction in all root parameters characters was more pronounced beyond the concentration of 0.1 ppm in tomato and brinjal. Over all, tomato was more sensitive to Cr than brinjal.

Key words: Irrigation, chromium, root characteristics, tomato, brinjal.

INTRODUCTION

The rapid pace of urbanization, industrialization and associated developmental activities as a consequence of the multifarious demands of the ever growing population, is resulting into the release of many pollutants including heavy metals into the natural water bodies. Additionally, the unplanned municipal waste disposal, mining, use of pesticides extensively and other agro-chemicals are also damaging the environment significantly. Chromium is recognized as an essential element for humans and animals (Mertz, 11) but not for plants (Liu *et al*., 10) although some earlier investigations land reported that it is beneficial to plant growth (Zheng *et al*., 15). It is found in all parts of the environment, including air, water and soil. It occurs naturally in soil ranging from 10 to 50 mg/kg depending on the parental material. It was reported that Cr concentration reached up to 125 mg/kg, in ultramafic soils (serpentine) (Adriano, 1). The industrial processes discharge large quantities of Cr compounds in the form of liquid, solid and gaseous wastes into the environment which can ultimately have significant adverse biological and ecological effects.

In spite of a 268% simple growth rate and a 78.91% increase in production during the last four decades, India still remains deficient in vegetables production (Kalloo and Pandey, 9). Currently, India's share in the world's total vegetable production is 13.6 per cent (Gopalakrishna, 6) but the requirement is projected to rise to 170 million tonnes by the year 2025 (Ali, 2). Tomato and brinjal are the two most popular vegetables in the country occupying the second and third position, respectively, amongst vegetable crops. As waste waters are being extensively used around cities for irrigation of vegetables, in particular, by the farmer and roots of the plants are first organs that interact with the polluted soil/water, it was felt necessary to carry out a study to understand the adverse impact of Cr on the root morphological parameters of these two important crops.

MATERIALS AND METHODS

An experiment was conducted in the net house of the Water Technology Centre, Indian Agricultural Research Institute, New Delhi on two vegetables crops, *viz.,* tomato (Pusa Rohini) and brinjal (Pusa Upkar) 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%, clay14%). The initial pH, EC, organic carbon, available nitrogen, phosphorus and potassium contents 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. Recommended doses of fertilizers were applied to both the crops in all the treatments. In tomato, the dosage 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/

*Corresponding author's present address: Krishi Anusandhan Bhawan II, Indian Council of Agricultural Research, Pusa Campus, New Delhi 110012; E-mail: aksingh.icar@gmail.com

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 (SSP) for phosphorus and muriate of potash (MOP) for potassium, respectively. Chromium in the form of $Cr_2(SO_4)_3 6H_2O$ was added to the water in four different concentrations (0.1, 0.5, 2.5 and 7.5 ppm) in addition to control (0 ppm).

The experiment was laid out in a completely randomized block design (CRD) with three replications. The first irrigation was given with normal water at the time of transplanting but subsequent irrigations were with Cr enriched water at 5 day intervals in both tomato and brinjal crops. The root samples were collected after the harvest of fruits, by carefully washing the soil around the roots. After washing, the roots were cleaned and fresh weight of root biomass was measured gravimetrically. For dry biomass, the root samples were oven-dried at 80°C for 24 h. After drying, the samples were analyzed for their root characteristics by a root scanner (Epson Model EU-22) using Win Rhizo software.

RESULTS AND DISCUSSION

Chromium in irrigation water significantly decreased the number of root tips, forks and crossings as compared to that in control. There was a drastic reduction in the number of tips in tomato by 56% while in brinjal it was 37% in the treatment (7.5 ppm) compared to the control. In the same treatment, in case of root forks, the number declined by 90% in tomato and 80% in brinjal as compared to control. In case of root crossings, the number decreased by more than 94% in tomato, while in brinjal the decrease was 85% as compared to control. This indicates that tomato is more sensitive than brinjal to Cr toxicity.

Chromium in irrigation water significantly decreased the root length and surface area also as compared to the control at all concentrations (>0.5 to 7.5 ppm). Root length decreased by 75% in tomato under 7.5 ppm Cr, while in brinjal it decreased by about 59% for the same treatment compared to control. As far as the root surface area was concerned, 78 and 71% reduction was recorded in tomato and brinjal, respectively. Over all, the reduction in root length and surface area was more pronounced beyond the concentration of 0.1 ppm in both the crops. The reduction in root volume was 85% in tomato and 76% in brinjal, while it case of root length density it was by about 59 and 75%, respectively, in 7.5 ppm Cr treatment compared to control. While the reduction in root volume and length density was more pronounced beyond the concentration of 0.1 ppm in tomato, in brinjal the differences between treatments with regard to root volume was not significant in either 2.5 or 7.5 ppm treatment. A drastic reduction in fresh weight of tomato by 80% was recorded under 7.5 ppm Cr, where as the reduction was only 63% in case of brinjal compared to the control treatment. In case of root dry weight, the decrease was more pronounced, 85% reduction in tomato and 71% in brinjal. Our results have indicated that the decrease in root fresh weight and dry weight was also relatively more in tomato compared to brinjal implying that tomato is more sensitive than brinjal.

In absolute quantity terms, the root length, root surface area, root volume and root length density were always less in brinjal compared to tomato but when fresh weight or dry weight was considered, it was equal or more in brinjal compared to tomato. Several reports (Liu *et al.*, 10; Kleiman and Cogliatti, 8) have exemplified visible symptoms of Cr toxicity in plants growing in nutrient solution or in potted soil (Joshi *et al.*, 7). The roots of young seedlings in contact with soil/water containing Cr, collapse and are eventually unable to absorb water (Bishnoi *et al.*, 3; Corradi *et al.*, 5). Prasad *et al.* (14) reported that the order of metal toxicity to new root primordia in *Salix viminalis* is Cd>Cr>Pb, whereas root length was more affected by Cr than by the other heavy metals. Excess supply of Cr reportedly inhibits the uptake of Fe, induces the Fe deficiency type response and changes the plant water relations, resulting in decreased physiological availability of water (Pandey and Sharma, 13). Decrease in root growth due to heavy metals is a well-documented effect in trees and crops. In the present study also, the root length and number of tips showed a decreasing trend with increased Cr concentration in irrigated water. Chen *et al.* (4) reported that the total root weight and root length of wheat was affected by 20 mg Cr (VI) kg^{-1} soil as $K_2Cr_2O_7$. Panda and Patra (12) found that 1 µM of Cr increased the root length in seedlings growing under nitrogen (N) nutrition levels; higher Cr concentrations however, decreased root length, in all the N treatments. In general, response of decreased root growth due to Cr toxicity could be due to inhibition of root cell division/ root elongation or to the extension of cell cycle in the roots.

The present study revealed that presence of Cr in irrigation water significantly decreased root biomass, length, surface area, length density and volume as well as number of root tips, forks and crossings in both tomato and brinjal crops (Fig. 1). Among the various root morphological parameters studied, root forks and crossing were most adversely affected by Cr. Based on the crop response, it could be concluded that, tomato was relatively more sensitive than brinjal to Cr toxicity.

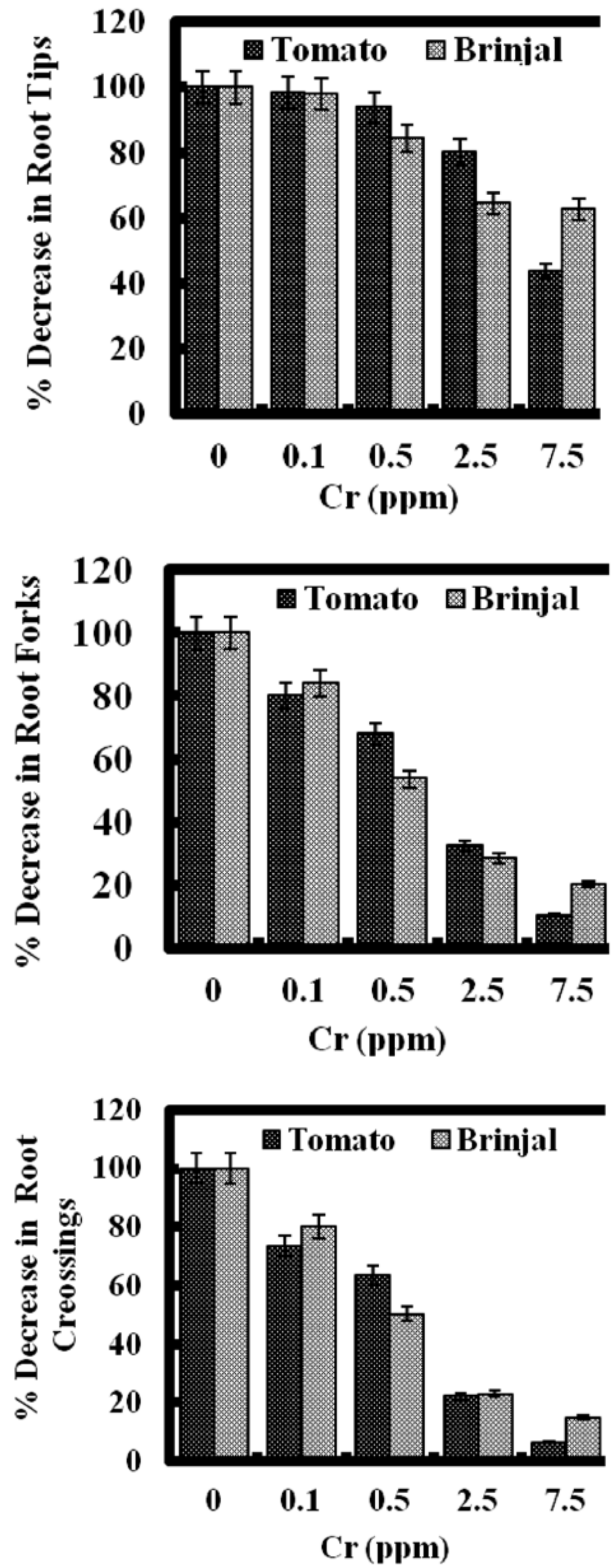

Fig. 1. Effect of Cr concentration on the number of root tips, forks and crossings in tomato and brinjal.

ACKNOWLEDGEMENTS

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

REFERENCES

1. Adriano, D.C. 1986. *Trace Elements in the Terrestrial Environment*. New York Springer-Verlag, pp. 105-23.

2. Ali, M. 2000. Dynamics of vegetables in Asia: A synthesis. **In**: *Dynamics of Vegetable Production, Distribution and Consumption in Asia*, Ali, M. (Ed.). AVRDC, Shanhua, Taiwan, pp. 1-29.

3. Bishnoi, N.R., Dua, A., Gupta, V.K. and Sawhney, S.K. 1993. Effect of chromium on seed germination, seedling growth and yield of peas. *Agric. Ecosys. Env*. **47**: 47-57.

4. Chen, N.C., Kanazawa S., Horiguchi, T. and Chen, N.C. 2001. Effect of chromium on some enzyme activities in the wheat rhizosphere. *Soil Microorg.* **55**: 3-10.

5. Corradi, M.G., Bianchi, A. and Albasini, A. 1993. Chromium toxicity in *Salvia sclarea*. I. Effects of hexavalent chromium on seed germination and seedling development. *Env. Exp. Bot*. **33.** 405-13.

6. Gopalakrishnan, T.R. 2007. *Vegetable Crops-Solanaceous Fruits and Vegetables*, Horticulture Science Series-4, New Delhi, pp. 68-69.

7. Joshi, V.N., Rathore, S.S. and Arora, S.K. 1999. Effect of chromium on growth and development of cowpea (*Vigna unguiculata L.*). *Indian J. Env. Prot*. **19**: 745-49.

8. Kleiman, I.D. and Cogliatti, D.H. 1998. Chromium removal from aqueous solutions by different plant species. *Env. Tech*. **19**: 1127-32.

9. Kalloo, G. and Pandey, A.K. 2002. Commendable progress in research. **In**: *The Hindu Survey of Indian Agriculture 2002*, S.N. Ravi (Ed.). Publ. Rangarajan, Chennai, India, pp. 159-63.

10. Liu, D.H., Jiang, W.S. and Li, M.X. 1992. Effects of trivalent and hexavalent chromium on root growth and cell division of *Allium cepa. Hereditas*, **117**: 23-29.

Table 1. Effect of varying levels of Cr irrigation water on root morphological characters of tomato and brinjal.

Parameter	Crop	Cr conc. (ppm)					CD
		0	0.1	0.5	2.5	7.5	($p<0.05$)
Root length (cm/pot)	Tomato	5809.1	5492.0	4373.4	3059.2	1468.1	65.0
	Brinjal	4716.3	4643.9	3181.2	2287.7	1939.5	60.6
Root surface area (cm^2/pot)	Tomato	1626.1	1534.2	1068.8	712.4	352.0	17.7
	Brinjal	1210.1	1055.5	619.2	410.9	350.0	8.4
Root vol. (cm^3/pot)	Tomato	43.9	34.3	21.5	13.2	6.6	0.8
	Brinjal	23.5	18.8	9.3	5.8	5.7	0.8
Root length density (cm^2/m^3/pot)	Tomato	528.1	499.3	397.6	278.1	133.5	5.9
	Brinjal	428.8	422.2	289.2	208.9	176.3	5.5
Root FW (g)	Tomato	34.1	32.8	17.9	9.7	6.8	1.1
	Brinjal	34.6	32.9	19.6	15.9	12.8	0.9
Root DW (g)	Tomato	3.9	3.7	1.5	0.8	0.6	0.1
	Brinjal	4.8	4.7	2.1	1.9	1.4	0.2

11. Mertz, W. 1967. Biological role of chromium. *Fed. Proc*. **26**: 186-93.

12. Panda, S.K. and Patra, H.K. 2000. Nitrate and ammonium ions effect on the chromium toxicity in developing wheat seedlings. *Proc. Natl. Acad. Sci. India B*. **70**: 75-80.

13. Pandey, N. and Sharma, C.P. 2003. Chromium interference in iron nutrition and water relations of cabbage. *Env. Exp. Bot*. **49**: 195-200.

14. Prasad, M.N.V., Greger M. and Landberg, T. 2001. *Acacia nilotica* L. bark removes toxic elements from solution: corroboration from toxicity bioassay using *Salix viminalis* L. in hydroponic system. *Int. J. Phytoreme*. **3**: 289-300.

15. Zheng, Z.Q., Feng, W.H., Bian, S.P., Zheng, J.M., Zhang, L.Z and Xing, S.L. 1987. Study on fate of pollutant chromium in the agro-ecosystem. *J. Env. Sci*. **8**: 14-19.

Received: October, 2011; Revised: March, 2012;
Accepted: April, 2012