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HEAVY METAL DYNAMICS IN SOIL-PLANT SYSTEM UNDER MICRO-NUTRIENT APPLICATION

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Abstract

Knowledge of metal-plant interaction is important for the safety of the environment, but also for reducing the risks associated with the introduction of the trace metals into the food chain. Among all metal-metal interactions Cd × Zn interaction is one of the most important interaction as Indian soils especially Indo-Gangetic soils are deficient in zinc while cadmium is much high than its permissible limits in these polluted soils. Keeping this in mind, the cadmium and zinc interaction on growth yield and nutrient dynamics was selected for the study, however in this paper only one aspect is covered. The experiment was carried out at experimental farm of Sheila Dhar Institute of Soil Science (University of Allahabad) situated at Lajpat Rai Road, Allahabad (U.P.), India. The experiment was laid out in a factorial design (R.B.D.) in a micro plot of $1 \times 1m^2$. The two factors were- cadmium and zinc. Cadmium and zinc levels were combined into 9 treatments and replicated thrice. Cadmium was applied at 0, 10 and 20 ppm in the form of cadmium chloride ($CdCl_2$) and zinc was applied at 0, 30 and 60 ppm in the farm of zinc sulphate ($ZnSO_4.7H_20$). Almost high concentration of zinc and cadmium remained in soil with application of high dose of zinc and cadmium, respectively. The content of zinc in plant parts (root and leaves) got a negative relationship with level of cadmium application. Zinc application without Cd also showed less Cd content and high content of zinc in plants and similarly cadmium content in plants also reduced by zinc application. It was also found that Cd content in plants leaves is much lower than plants roots.

Key words : Cadmium, zinc, soil contamination, heavy metals, Metal-Plant Interaction.

Introduction

Rapid urbanization, with the consequent increase in population and building construction has resulted in the reduction of lands for the wastes to be disposed. Every year solid wastes are increasing tremendously all over the world, depending upon the living standards of the people. Moreover, as everyday passed, the garbage in the street corner bin spilled over sooner than it could be emptied. Several hazardous chemicals and the mountains of wastes are ultimately dumped on the lands. Dumping of industrial and municipal wastes causes toxic substances to be leached and seep into the soil and affects the ground water course. Modern agricultural practices introduce numerous pesticides, fungicides, bactericides, insecticides, biocides, fertilizers and manures, resulting in sever biological and chemical contamination of land.

Today, the most commonly anticipated problem is the contamination of soil with toxic chemicals. Fifty three of the ninety naturally occurring elements are heavy metals. Among these metals, Fe, Mo and Mn are important as micro nutrients, while Zn, Ni, Cu, Co, Va and Cr are toxic elements, with high or low importance as trace elements. Ag, As, Hg, Cd, Pd and Sb have no known function as nutrients and seem to be more or less toxic to plants and microorganism.

Knowledge of metal-plant interaction is important for the safety of the environment, but also for reducing the risks associated with the introduction of the trace metals into the food chain. Among all metal- metal interactions Cd × Zn interaction is one of the most important interaction as zinc is essential to plant as micronutrient and deficient in Indian soils whereas, cadmium has no role in plant physiology and their nutrition, while it is toxic somewhere in plants and for human health.

Cadmium ranks 64th in order of abundance in the earth's crust, with an average concentration of 0.2 ppm, which is less than that of zinc, copper, lead and chromium. Cadmium also occurs in various other natural materials such as magnetic rocks, shales, sandstones, limestones and sediments in varying amounts. Cadmium is not

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essential for plants and animals. Therefore, cadmium in environment can cause only harm and no gains (Singh, 2006).

Anthropogenic activities are the main sources responsible for cadmium contamination. Cadmium is mainly used in industries involved in electroplating, nickel cadmium battery manufacture, pigment manufacture galvanising plastic manufacture, alloy manufacture and glass manufacture cadmium enters air, water, soils, sediments, humans and aquatic and terrestrial organism via atmosphere, water, suspended sediments, land application of sewage material and phosphate fertilizer and by waste dumping. About 20% of released cadmium comes from zinc mining and smelting operations and another 30% from manufacture, use and disposal of cadmium products. The remaining 50% is dispersed as a contamination in other substances, including phosphatic fertilizers, sewage effluents and sewage sludge. The combustion of fossil fuels also releases cadmium in the atmosphere (Sekhon, 2002).

Zinc is a micronutrient and ranges in soil from 10 to 300 ppm with average approximately 50 ppm and ranges in plants is 25 to 150 ppm. Zinc in the soil solution is very low, ranging between 2 ppm to 70 ppb. Deficiency of zinc is usually associated with concentration of less than 20 ppm and toxicities will occur at more than 350 ppm.

Zn is important in the synthesis of trytophane, a component of some protein and a compound needed for the production of growth hormones (Auxin) like IAA and involved in many enzymatic activities and a constituent of a number of enzymes *e.g.* carbonic anhydrase, alcohol dehydrogenase and various peptides. It also involved in metabolism of GA_3 and synthesis of RNA. Reduced growth hormones production in Zn deficient plants causes the shorting of inter nodes and smaller than normal leaves. It also act as a catalyst in chlorophyll formation. Because of its preferential binding to sulphydryl group, Zn plays an important role in the stabilization and structural origination of the membrane proteins (Tisdale *et al*., 2002).

Zn deficiencies are widespread in the United State and throughout the world, especially in the rice crop land of Asia. Indian soils especially Indo-Gangetic soils are also deficient in zinc.

The study of metal-plant interaction is important not only for the safety of the environment, but also for reducing the risks associated with the introduction of the trace metals into the food chain. Among all metal- metal interactions Cd × Zn interaction is one of the most important interaction which must be carried out as a scientific investigation (Brady and Weil, 2004).

The reason behind selecting Cd × Zn interaction can be stated as, Indian soils especially Indo-Gangetic soils are deficient in zinc, while Cd is much high than its permissible limits in these polluted soils. Thus, Cd × Zn interaction helps to find out the answer whether Cd and Zn are interacting with each other or not? If they are interacting their interaction is synergistic or antagonistic. If their interaction is antagonistic then which one element could become a limiting factor for other element?

Because Cd has tendency to concentrate first in root then shoot and then grain whereas zinc role concerned to shoot and its deficiency could be judged through leaves. Thus species belongs to the brassicaceae or cruciferae family, which is well represented among the reported metal hyperaccumulators was used as test crop for this study.

Materials and Methods

A field experiment was conducted at experimental farm of Sheila Dhar Institute of Soil Science (University of Allahabad) situated at Lajpat Rai Road, Allahabad (U.P.), India. The climate of Allahabad is known for its cold winter and almost intolerable summers. The average rainfalls here is about 82.0 cm and mean annual temperature varies from 3°C and 46°C and average 25-25°C. The soil of Sheila Dhar Institute Research farms alluvial (Entisols), having a good water holding capacity and medium organic carbon content. The texture of soils is sandy clay loam. The experiment was laid out in a factorial design (R.B.D.) in a micro plot (1 × $1m^2$) and given treatment having three replication and 2 factors as cadmium and zinc. Cadmium and zinc levels were combined into 9 treatments and replicated thrice. Cadmium was applied @ 0, 10 and 20 ppm in the form of cadmium chloride ($CdCl_2$) and zinc was applied @ 0, 30 an 60 ppm in the farm of zinc sulphate ($ZnSO_4.7H_20$). The pre and post soil-plant analysis was carried out by using the method described by the Chopra and Kanwar (2002). The details of two factors as combination in 9 treatments are given below:

Table 1 : Combination of treatments.

S. no.	Symbol	Treatments
1.	T_0	$CdCl_2$ (0) + $ZnSO_4.7H_2O$ (0)
2.	T_1	$CdCl_2$ (0) + $ZnSO_4.7H_2O$ (30)
3.	T_2	$CdCl_2$ (0) + $ZnSO_4.7H_2O$ (60)
4.	T_3	$CdCl_2$ (10)+$ZnSO_4.7H_2O$ (0)
5.	T_4	$CdCl_2$ (10)+$ZnSO_4.7H_2O$ (30)
6.	T_5	$CdCl_2$ (10)+$ZnSO_4.7H_2O$ (60)
7.	T_6	$CdCl_2$ (20)+$ZnSO_4.7H_2O$ (0)
8.	T_7	$CdCl_2$ (20)+$ZnSO_4.7H_2O$ (30)
9.	T_8	$CdCl_2$ (20)+$ZnSO_4.7H_2O$ (60)

Table 2 : Details of pre trail soil analysis.

S. no.	Soil parameter	Values
1.	Soil texture	Sandy clay loam
2.	pH	7.3
3.	Organic carbon	0.69
4.	Organic matter	1.03%
5.	EC (dsm^{-1} @ 25 0C)	0.38
6.	CEC	25
7.	Total nitrogen	0.08%
8.	Available nitrogen	0.04%
9.	Total phosphorus	0.07%
10.	Available phosphorus	0.03%
11.	Total potash	0.02%
12.	Available potash	0.01%
13.	Available zinc	15 ppm
14.	Available cadmium	0.03 ppm

Results and Discussion

The interaction of Cd × Zn was investigated and results are presented herein as follows:

Effect of Cd × Zn interaction on zinc content in soil

Glancing through the data presented in fig. 1, it was observed highly significant influence of Zn and significant effect of Cd on the on the available zinc content in soil. While, non-significant effect was found by the interaction of Cd × Zn in Zn content of soil. Treatment $\mathbf{T_6}$ and $\mathbf{T_3}$ was recorded 11.11% and 2.22% decrease, respectively than the control sets. Treatment $\mathbf{T_6}$ and $\mathbf{T_3}$ containing nil dose of zinc and variable dose of cadmium (*i.e.* 20 ppm in $\mathbf{T_6}$ and 10 ppm in $\mathbf{T_3}$) decreased the Zn content in soil in both. It might be a result of its antagonistic interaction with Zn. The highest amount of available Zn recorded in treatment $\mathbf{T_6}$ having full dose of Zn (60 ppm) and nil dose of Cd, which was calculated 119.55% increase over control again pointed out that due to absence of Zn, antagonistic interaction was not prevailing. Full doses of Zn and full doses of Cd in treatment $\mathbf{T_5}$ lies second in order of response achieved 91.11% increase over control also pointed out the negative interaction between Cd×Zn.

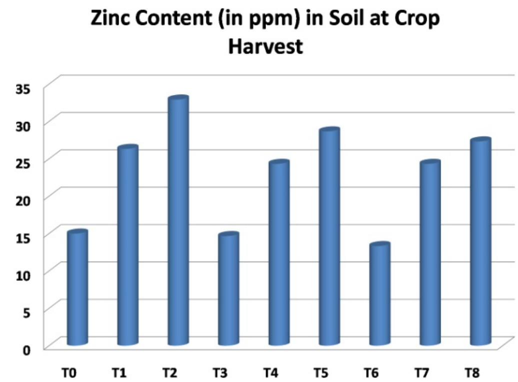

Fig. 1 : Zinc content in soil at harvest.

Effect of Cd × Zn interaction on cadmium content in soil

Fig. 2 clearly indicated the highly significant effect of Cd and Zn and significant effect of Cd × Zn interaction on total zinc content of turnip root and shoot. Treatment $\mathbf{T_2}$ gave maximum Zn uptake up to 5.05 ppm and calculated 73.68% and 53.97% extra over the control by root and shoot respectively, might be due to full dose application of zinc and absence of cadmium. Whereas, $\mathbf{T_6}$ gave minimum Zn uptake 2.77 ppm and calculated 12.63% and 15.87% decreased than the control by root and shoot respectively, might be due to full dose of Cd and nil dose of Zn. It was seemed that negative interaction prevailing between Cd and Zn. Almost similar results have been reported by Hart *et al*. (2002). Data according to $\mathbf{T_5}$ and $\mathbf{T_8}$ showed that low amount of Cd stimulate the Zn uptake by plants root ($\mathbf{T_5}$) whereas, high dose of Cd reduces the zinc uptake by plant roots. Almost similar finding has also been reported by Dudka *et al.* (1994).

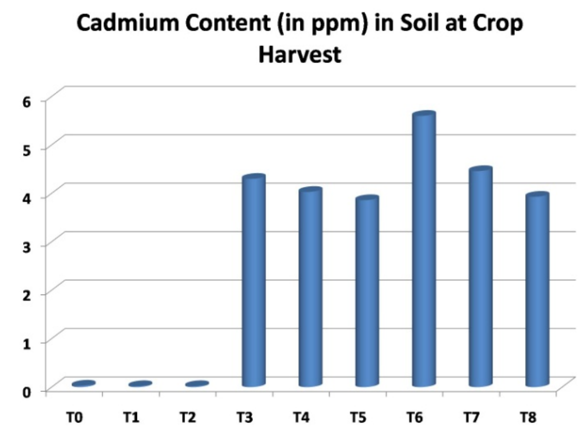

Fig. 2 : Cadmium content in soil at harvest.

Effect of Cd × Zn on zinc mobilization in turnip plant system

Data illustrated in fig. 3 clearly indicated the highly significant effect of Cd and Zn and significant effect of Cd × Zn interaction on total zinc content of turnip root

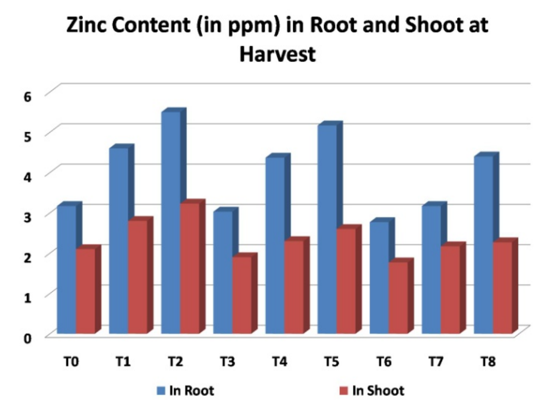

Fig. 3 : Zinc content in turnip plant system.

and shoot. Treatment T_2 gave maximum Zn uptake up to 5.05 ppm and calculated 73.68% and 53.97% extra over the control by root and shoot respectively, might be due to full dose application of zinc and absence of cadmium. Whereas, T_6 gave minimum Zn uptake 2.77 ppm and calculated 12.63% and 15.87% decreased than the control by root and shoot respectively, might be due to full dose of Cd and nil dose of Zn. It was seemed that negative interaction prevailing between Cd and Zn. Almost similar results have been reported by Hart *et al*. (2002). Data according to T_5 and T_8 showed that low amount of Cd stimulate the Zn uptake by plants root (T_5) whereas, high dose of Cd reduces the zinc uptake by plant roots. Almost similar finding has also been reported by Dudka *et al*. (1994).

Effect of Cd × Zn on cadmium mobilization in turnip plant system

The data incorporated in fig. 4 also indicated the highly significant effect of Cd and Zn and significant effect of Cd × Zn interaction on cadmium content of turnip root. Treatment T_2 gave minimum response in presence of high Zn content whereas, treatment T_6 gave maximum response due to full dose of Cd and nil dose of Zn which was recorded about 26 times increase over the control in turnip root. This might be resulted due to absence of any antagonistic relation between Cd × Zn because of nil dose of Zn. Treatment T_7 containing full dose of Cd with half dose of Zn came next in order of response after T_6 securing about 24 times increase over the control when, it was compared with T_8 containing full dose of Cd and Zn and which securing 19 times increase over control. It seemed that high concentration of Zn in soil enhanced uptake of Cd by plants as also corroborated by Dudka *et al*. (1994), Hart *et al*. (2092) and Wu *et al*. (2005).

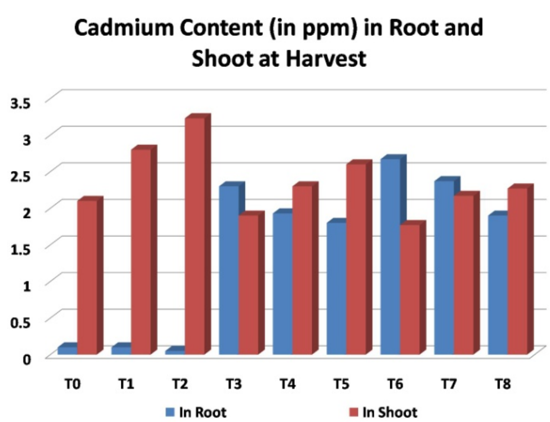

Fig. 4 : Cadmium content in soil at harvest.

In case of turnip shoot/leaves the highly significant effect of Cd and significant effect of Zn was observed although Cd x Zn interaction was found non-significant. Treatment T_2 containing full dose of Zn and nil dose of Cd gave minimum response whereas, treatment T_6 containing full dose of Cd and nil dose of Zn recorded about 13 times increase over control sets. The data of treatment T_7 and T_9 showed that high Zn content reduced the Cd content in plant. While, high Cd content in soil increased the Cd uptake and content in plant leaves. Almost similar results have been reported by Sharma and Agrawal (2006) and Wu *et al.* (2005).

Conclusion

The study reveals that although cadmium is neither essential nor beneficial element for plant but still plant uptake it in well quantity which may be harmful for the human and the ecosystem. As zinc is well reported deficient in Indo-Gangetic soil thus application of zinc not only may increase the crop production but also may decrease the heavy metal content in plant-system through its antagonistic affect with cadmium.

References

Brady, N. C. and R. R. Weil (2004). *The nature and properties of soils*. Prentice-Hall of India Private Limited, New Delhi.

Chopra, S. L. and J. S. Kanwar (2002). *Analytical Agricultural Chemistry*, Kalyani Publishers, New Delhi.

Dudka, S., M. Piotrowska and A. Chlopecka (1994). Effect of elevated concentrations of Cd and Zn in soil on spring wheat yield and the metal contents of the plants. *Water Air and Soil Pollution*, **76** : 333-341.

Hart, J. J., R. M. Welch, S. A. Norvell and L. V. Kochian (2002). Transport interactions between cadmium and zinc in roots of bread and durum wheat seedlings. *Physiologia Plantarum*, **116** : 73-78.

Mazumdar, D., S. S. Das and S. K. Patra (2006). Remediation of Soil Cadmium Toxicity Using Cd-Zn Interaction for Sustainable Agriculture. 18th World Congress of Soil Science, July 9-15-2006, Philadelphia, Pennsylvania, U.S.A. 164-167.

Sekhon, G. S. (2002). Fundamentals of Soil Science. Indian Society of Soil Science. Division of Soil Science and Agricultural Chemistry. IARL New Delhi : 931.

Sharma, R. K. and M. Agrawal (2006). Single and Combined Effect of Cadmium and Zinc on Carrot: Uptake and bioaccumulation. *Journal of Plant Nutrition*, **29**:1791-1804.

Singh, B. K. (2006). *Environmental Chemistry*, Krishna Publication. Media Pvt. Ltd., Meerut.

Tisdale, S. K., W. L. Nelson, J. D. Beaton and J. L. Havlin (2002). *Soil Fertility and Fertilizers*. Prentice-Hall of India Private Limited, New Delhi : 319-325.

Wu, F.B., J. Dong, Q.Q. Qian and G.P. Zhang (2005). Subcellular distribution and chemical form of Cd and Cd-Zn interaction in different barley genotypes. *Chemosphere*, **60(10)** : 1437-46.