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TOXICITY OF COPPER AND CADMIUM ON GERMINATION AND SEEDLING GROWTH OF MAIZE (*Zea mays L.*) SEEDS

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ABSTRACT

The toxic effects of copper and cadmium on seed germination, seedling, root, shoot length and seedling dry biomass of maize was evaluated under laboratory conditions compared to control values. Copper and cadmium treatments at 50, 100, 150and 200 mg/L affected seed germination and seedling growth of maize as compared to control. Copper treatments at 50, 100, 150and 200 mg/L concentrations produced significant ($p<0.05$) effects on seed germination and seedling length of maize while copper treatment at 150 mg/L significantly affected root growth and seedling dry biomass as compared to control. Similarly, cadmium treatments from 50 to 200 mg/L affected the seed germination, root, shoot length and seedling dry biomass of maize as compared to control.. Cadmium treatments showed adverse effects on seedlings of maize as compared to copper. copper and cadmium treatments at 200 mg/L exhibited lowest percentage of tolerance in seedlings of maize as compared to control.

KEY WORDS: Copper, Cadmium, Toxicity, *Zea mays*

Heavy metals a group of density higher than 5.0 g cm^{-3} such as cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb), aluminium (Al), silver (Ag), tin (Sn) etc., are important environmental pollutants, particularly in areas where there is high anthropogenic pressure. Their presence in the atmosphere, soil and water- even in trace concentrations- can cause serious problems to all organisms, and heavy metal bioaccumulation in the food chain can be highly dangerous.

Cd is a non-essential element that negatively affects plant growth and development. Cd (density = 8.6 g cm^{-3}) is a widespread heavy metal, released into the environment by power stations, heating systems, metal-working industries, waste incinerators, urban traffic, cement factories and as a by-product of phosphate fertilizers. It is widely used in electroplating pigments, plastic stabilizers and nickel- cadmium batteries (Sanita di Toppi and Gabrielli; 1999). It is recognized as an extremely significant pollutant due to its high toxicity and large solubility in water. Baker et al.(1990) reported that Cd never occurs in isolation in natural environments, but mostly as a 'guest' metal in Pb/Zn mineralization. According to Wagner (1993) estimation, non polluting soil solutions contain Cd concentrations ranging from 0.04 to 0.32µM. Soil solutions which have a Cd concentration varying from 0.32µM to about 1µM can be regarded as polluted to a moderate level. Since Cd is fairly immobile element, its accumulations in soils can become dangerous to all kinds of organisms.

Copper, an essential micronutrient, plays a vital role in maintaining normal metabolism in higher plants. Cu at high levels becomes strongly phytotoxic to cells and causes inhibition of plant growth or even death (Mocquot et al., 1996; Chen et al., 2000). Photosynthesis is also sensitive to excessive Cu, and the pigment and protein components of photosynthetic embranes are the targets (Pätsikkä et al., 2002). In addition, Cu toxicity is related to disturbances in the uptake of other essential elements (Van Assche and Clijsters, 1990; Patsikka et al., 2002).

The increasing influx of heavy metals into water bodies from industrial, agricultural,and domestic activities is of global concern because of their well documented negative effects on human and ecosystem (Mataka et al.; 2006). Cadmium is heavy metal with high toxicity and has an elimination half-life of 10-30 years. People are exposed to cadmium by intake of contaminated food or by inhalation of tobacco smoke or polluted air (Järup et al.; 1998). High concentrations of cadmium in soils represent a potential threat to human health because it is incorporated in the food chain mainly by plant uptake (Alvarez-Ayuso; 2008). Influence of cadmium toxicity on germination and growth of some common trees were investigated by Iqbal & Mehmood (1991).

The aim of the present research was to investigate the effects of copper and cadmium on seed germination and seedling growth of maize (*Zea mays* L.)

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MATERIALS AND METHODS

The healthy seeds of maize were collected randomly from IARI, New Delhi. Seeds of maize (*Zea mays* L.) were sterilized with 1% Hgcl2 for 10 min, then washed several times with distilled water and germinated for 4 day in the dark on floating plastic net. Ten seeds were placed in Petri dishes (90 mm diameter) on filter paper (Whatman No. 42). Metal treatments of Cu and Cd were prepared using chromium chloride and cadmium chloride with concentrations of 50, 100,150 and 200 mg/L respectively. At the start of experiment, 3 ml of respective treatment was added to each set of Petri dish and at every 3rd day, the old solution were replaced with 2 ml of new solution. Add 2 ml of distilled water in control. There were five replicates per treatment and the Petri dishes were kept at room temperature (22±2°C) with 3 hourly light periods provided by 100 watt bulb and the experiment lasted for 10 days. The experiment was completely randomized. Germination was recorded and seedling dry biomass was determined by placing the seedling in oven at 80°C for 24 hours. The number of germinated seeds were counted after 14 days of treatment. Seedling dry biomass was measured with electrical balance (Remi). Maximum root, shoot and seedling length were also obtained.. The seed germination and seedling growth data were statistically analyzed by Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) to determine the level of significance at $p<0.05$.

RESULTS

Seed germination, root, shoot and seedling length, root shoot ratio and dry biomass of maize were highly decreased with the treatment of Cu and Cd at 50, 100, 150, and 200 mg/L as compared to control (Tables 1&2). Copper treatments at 50 mg/L concentration produced significant ($p<0.05$) effects on seed germination and seedling length as compared to control. Increase in concentration of copper to 100mg/L significantly affected seedling dry biomass of maize as compared to control. Further increase in the concentration of Copper upto 150 mg/L produced toxic effects on root growth. Similarly, Cadmium treatment at low concentration of 50 mg/L significantly ($p<0.05$) decreased seed germination, seedling and root length as compared to control (Table 2). Cadmium treatment at 100 mg/L produced significant ($p<0.05$) effects on root length of maize as compared with control (Table 2). The tolerance of maize seedlings to copper and cadmium gradually decreased with the increasing concentrations of copper and cadmium as compared to control. Copper treatments at 50, 100, 150 and 200 mg/L produced 94.12, 82.35, 74.51, 72.56 and 27.45% of tolerance in maize, respectively. Cadmium treatment at similar range of treatments produced 92.15, 80.39, 64.7, 41.18 and 11.76% of tolerance in maize respectively. According to tolerance indices, lead and cadmium treatments at 200 mg/L showed lowest percentage of tolerance in maize seedlings as compared to control. Cadmium treatment produced more toxic effects on maize seedlings than Copper treatment at all concentrations.

Table 1: Effect of different concentration of copper on seed germination, shoot length, seedling length, dry biomass, root/shoot ratio of maize (*Zea mays* L.)

Treatment (Cu)mg/L	Seed germination(%)	Root length(cm)	Shoot length (cm)	Seedling length(cm)	Seedling dry biomass(mg)	Root/Shoot ratio
00 mg/L	93±5.0	5.0±0.05	8.5±0.12	13.2±0.03	39.50±0.30	0.59±0.06
50 mg/L	82±5.2	4.4±0.18	8.1±0.08	13.0±0.15	38.02±0.03	0.45±0.04
100 mg/L	77±5.1	4.2±0.04	7.8±0.07	12.6±0.08	36.72±0.10	0.38±0.04
150 mg/L	72±4.9	3.6±0.10	7.4±0.15	11.5±0.11	35.11±0.06	0.29±0.03
200 mg/L	66±4.8	3.2±0.11	7.2±0.16	11.0±0.17	33.28±0.09	0.20±0.02

Table 2 : Effect of different concentration of cadmium on seed germination, shoot length, seedling length, dry biomass, root/shoot ratio of maize (*Zea mays* L.)

Treatment (Cd)mg/L	Seed germination(%)	Root length(cm)	Shoot length (cm)	Seedling length(cm)	Seedling dry biomass(mg)	Root/Shoot ratio
00 mg/L	94±3.0	5.0±0.04	8.6±0.08	13.5±0.11	39.40±0.32	0.60
50 mg/L	81±2.6	4.3±0.04	7.3±0.06	12.0±0.09	38.00±0.30	0.42
100 mg/L	64±5.0	3.8±0.04	7.0±0.07	11.2±0.09	36.12±0.35	0.22
150 mg/L	52±5.1	3.2±0.03	6.1±0.05	9.4±0.08	34.15±0.33	0.12
200 mg/L	35±3.4	2.7±0.03	4.8±0.03	7.0±0.06	30.22±0.14	0.07

DISCUSSION

Heavy metals have been widely recognized as highly toxic to plants. Plants can be affected directly by air pollutants, as well as indirectly through the contamination of soil and water. At the same time, plant is a part of food chain and may create a risk for man and animals through contamination of food supplies (Farga Šová,1994). copper and cadmium toxicity have become an important issue due to their constant increase in the environment. In the present investigation, seed germination and seedling growth of maize (*Zea mays* L.) gradually decreased with the increase in concentration of copper and cadmium. Copper and cadmium treatments significantly ($p<0.05$) decreased seed germination as compared to control. Seed germination and seedling growth inhibition by heavy metals has also been reported by many other workers (Morzek and Funicelli, 1982; Al-Helal, 1995; Azmat et al., 2005; Shafiq and Iqbal, 2005). The decrease in seed germination of maize (*Zea mays* L.) can be attributed to the accelerated breakdown of stored food material in seed by the application of copper and cadmium. (Kalimuthu and Siva, 1990) found reduction in seed germination in maize treated with 20, 50, 100 and 200 µg/ml lead acetate and mercuric chloride. Excessive amounts of toxic elements usually caused reduction in plant growth (Prodgers and Inskeep; 1981). Some elements such as Cu, Co, Fe, Mo, Mn, Ni and Zn are essential mineral nutrients. Others, such as Cd and Pb, however have no known physiological activity (Lasat; 2002). Significant reduction in root growth of maize (*Zea mays* L.) with the increase in concentration of cadmium treatment was also observed as compared to control. Cadmium is a highly toxic contaminant that affects many plant metabolic processes. Cadmium can also affect root metabolism, which shows sensitivity to Cd^{2+} toxicity by a reduction in lateral root size. This is due to reductions in both new cell formation and cell elongation in the extension region of the root (Prasad, 1995; Liu, et al., 2004)

The effects of heavy metals on plant depend on the amount of toxic substance taken up from a given environment. The seedlings of maize (*Zea mays* L.) also showed a gradual decrease in dry biomass as concentrations of copper and cadmium increased. Similar observations in crops had been observed by Hailing et al., (1991). The toxicity of some metals may be so severe that plant growth is reduced before large quantities of the element can be translocated (Haghiri, 1973).

According to the tolerance test, tolerance to copper and cadmium treatments in maize (*Zea mays* L.) was lower as compared with control. This information can be considered a contributing step in exploring and finding of the tolerance limit of maize (*Zea mays* L.) at different concentrations of treated metal. Cadmium is found highly toxic to seedling growth of maize (*Zea mays* L.) as compared to copper. Results of the findings can be useful indicator of metal tolerance to some extent for plantation of this species in metal contaminated area. How fairly low amounts of copper and cadmium absorbed over many years could lead to extinction of such an important plants species is unknown. In the metal contaminated areas, further research is needed to determine different levels of metals in the environment and various parts of the plants.

REFERENCES

Al-Helal A.A.,1995. Effects of cadmium and mercury on seed germination and early seedling growth of rice and alfalfa. Journal of the University of Kuwait (Science),: **22**: 76-82.

Alvarez-Ayuso E., 2008. Cadmium in soil-plant systems: an overview. International Journal of Environment And Pollution, **33**(2-3): 275-291.

Azmat R., Zill-e-Huma A., Hayat T., Khanum and R. Talat., 2005. The inhibition of bean plant metabolism by cadmium metal: Effects of cadmium metal on physiological process of bean plant and *Rhizobium* species. Pakistan Journal of Biological Sciences**,** **8**(3): 401-404.

Baker A.J.M., Ewart K., Hendry G.A.F., Thorpe P.C., Walker P.L., 1990. The evolutionary basis of cadmium tolerance in higher plants. In: 4th International Conference on Environmental Contamination, Barcelona, Spain: 23-29 .

Chen L.M., Lin C.C. and Kao C.H., 2000. Copper toxicity in rice seedlings: Changes in antioxidative enzyme activies, H2O2 level, and cell wall peroxidase activity in roots. Bot. Bull. Acad. Sin., **41**: 99-103.

FargaSova A.,1994. Effects of Pb, Cd, Hg, As, and Cr on germination and root growth of *Sinapis alba* seeds. Bulletin of Environmental Contamination and Toxicology, **52**(3): 452-456.

Haghiri, F., 1973. Cadmium uptake by plants. Journal of Environmental Quality, **2**: 93-96.

Hailing L.I.U., Qing L.I. and Peng Y., 1991. Effect of cadmium on seed germination, seedling growth and oxidase enzyme in crops. Chinese Journal of Environmental Science, **12**: 29-31.

Iqbal M.Z. and Mehmood T., 1991. Influence of cadmium toxicity on germination and growth of some common trees. Pakistan Journal of Scientific and Industrial Research, **34**:140-142.

Jarup L., Berglund M., Elinder C. Nordberg G.G. and Vahter M.,1998. Health effects of cadmium exposure a review of the literature and a risk estimate. Scandinian Journal of Work, Environment and Health, **24** (suppl 1):15.

Kalimuthu K. and Siva S.R., 1990. Physiological effects of heavy metals on *Zea mays* (maize) seedlings. Indian Journal of Plant Physiology, **33**: 242-244.

Lasat M.M., 2002. Phytoextraction of toxic metals. A review of biological mechanism. Journal of Environmental Quality, **31**: 109-120.

Liu D., Jiang W. and Gao X., 2004. Effects of cadmium on root growth, cell division and nucleoli in root tips of garlic. Physiologia Plantarum, **47**: 79-83.

Mataka L.M., Henry E.M.T., Masamba W.R.L. and Sajidun S.M., 2006. Lead remediation of contaminated water using *Moringa stenopetala* sp and *Moringa oleifera* sp., seed powder. International Journal of Environment Science and Technology, **3**(2):131-139.

Mocquot 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 enzyme activities. Plant Soil. **182**: 287-300.

Morzeck J.R.E. and Funicelli N.A.,1982. Effect of zinc and lead on germination of *Spartma alterniflora* Loisel seeds at various salinities. Environmental and Experimental Botany, **22**: 23-32.

Prasad M.N.V., 1995. Cadmium toxicity and tolerance in vascular plants. Environmental and Experimental. Botany, **35**: 525-545.

Patsikka, E, Kairavuo M., Sersen F., Aro E.M. and Tyystjärvi E., 2002. Excess copper predisposes photosysten II to photoinhibition in Vivo by out competing iron and causing decrease in leaf chlorophyll. Plant Physiol., **129**: 1359-1367.

Prodgers R.A. and Inskeep W.P., 1981. Heavy metals tolerance of inland salt grass *Distichlis spicata*. Great Basin Naturalist, **51**: 271-278.

Sanita` di Toppi L. and Gabbrielli R., 1999. Response to cadmium in higher plants. Environ. Exp. Bot., **41**: 105-130.

Shafiq M. and Iqbal M.Z., 2005. The toxicity effects of heavy metals on germination and seedling growth of *Cassia siamea*. Lamark. Journal of New Seeds, **7**: 95-105.

Van Assche F. and Clijsters H. 1990. Effects of metals on enzyme activity in plants. Plant Cell Environ.,**13**: 195-206.

Wagner G.J., 1993. Accumulation of cadmium in crop plants and its consequences to human health. Adv. Agron. **51**: 173-212.