

# **Cadmium and Zinc Interaction Effects on Growth of *Mangifera indica* L**

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**ABSTRACT:** The present study was conducted to evaluate the interactive effects of different concentrations of cadmium with zinc on growth of *Mangifera indica* L. seedlings. Two months old seedlings were transplanted in soil amended with these two heavy metals in combination. A control was also kept without any amendment of metals with soil. The growth parameters such as plant height, number of leaves, canopy, basal area were measured at two months interval upto the age of 8 months. The results indicated that the combined treatment of low concentration of cadmium with zinc showed positive influence on the growth of plant as compared to control. The negative impact on growth was enhanced with increase in cadmium concentration with zinc. The study concludes that at low concentration of cadmium, zinc antagonizes its phytotoxic effect but at high concentration of Cd, plant growth was adversely affected indicating synergistic effect. The present study has scientific bearing especially for those areas where both the heavy metals are constantly rising in the natural as well as in agricultural environment causing phytotoxicity.

**KEYWORDS:** *Mangifera indica*, heavy metal, cadmium, zinc, phytotoxic.

## **I. INTRODUCTION**

From most of the emitting sources, more than one pollutants/heavy metals are emitted simultaneously. Trace metals are emitted into the atmosphere mainly as a consequence of high temperature process such as combustion, roasting and metallurgical operations. Air-borne heavy metals may contaminate soil and water courses even in areas situated far away from site of emission.

It has been estimated that anthropogenic released Hg, Pb, Zn, Cd, and Cu are between one and three orders of magnitude higher than natural fluxes [1]. The entry of heavy metals in food chain resulted in accumulation in human organs and causes several health hazards [2]. Municipal solid waste (MSW) often contain metals such as Zn, Al, Cd, Pb, Fe, Cu, Mn, and Mo that may be phytotoxic or, if accumulated in the fruit, pose a health risk to humans [3].

Metal toxicity often depends on other elements present in soil. In plants, it may be the result of interactions between toxic ions and other essential and non essential ions. Heavy metals such as zinc (Zn) and cadmium (Cd) are present in many different forms with different levels of solubility in soil. These forms include soluble-exchangeable, comprised of hydrated free metal ions and soluble complexes, specifically sorbed, metals primarily complexed or co-precipitated with Fe, Mn, oxides or phosphates, and residual metals held in the primarily mineral matrix [4, 5]. Mohanty [6] observed that cadmium is highly toxic for plants and any type of discharge of cadmium into the environment or availability in the environment is hazardous. Since Cd is non essential ion, it is toxic at a lower concentration than Zn [7]. Cadmium and zinc may be both antagonistic and synergistic, and their imbalanced reactions may cause a real chemical stress in plants [8].

There is scanty information about the cadmium and zinc effects on *Mangifera indica* seedling grown in pot conditions. Since release of Cd most often accompanied by Zn, this part of study was an effort to investigate the interactive effects of Cd and Zn on growth of seedlings of *M. indica*.

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## II. RELATED WORK

The interactive effects of Cd and Zn on plants were studied by many authors [9-13]. Catalado and Wildung [14] observed that the effects of Zn on plant Cd uptake depend on plant species, plant tissue and external Cd and Zn concentration levels.

In many areas, soils are most often contaminated with both Cd and Zn, due to the similar geochemical behaviour of these metals [15]. McKenna *et al.* [9] concluded that in sites that were highly contaminated with Cd, high soil Zn concentrations did not significantly lower Cd concentrations in the edible tissues of lettuce and spinach. There is an antagonistic effect of Zn on Cd uptake only at low levels of Cd contamination.

In a similar study Bunluesin *et al.* [16] observed that interaction between Zn and Cd on the accumulation of both metals in *Ceratophyllum demersum* were complex and dependant on the concentration of the metals in growth medium. Turner [17] observed that the effect of Cd treatments of leaf Zn concentrations depended on plant species, having a synergistic effect in some plant species and antagonistic in others. At lower concentration, Zn, being an essential ion, was nontoxic to the plant, and could not interact with or lower the toxicity of Cd [18].

## III. METHODOLOGY

### Pot experiment:

The present study was designed to examine the effects of cadmium and zinc on growth of seedlings of *Mangifera indica* L. This species is an economic fruit crop of India and found in and around the city of Udaipur. The uniform sized two months old plant species were collected from nursery of Forest Department, Udaipur.

Three concentrations of cadmium (used as  $\text{CdCl}_2 \cdot 2\frac{1}{2} \text{H}_2\text{O}$ ) i.e. 10, 15 and 20 mg Cd  $\text{Kg}^{-1}$  of soil and one concentration of zinc (used as  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ ) i.e. 700 mg Zn  $\text{Kg}^{-1}$  of soil were prepared by taking corresponding amount (calculated on the basis of its atomic weight) of the salt of the metal per Kg of air dried soil. The salts were mixed thoroughly in the soil. The concentration of heavy metals used is representative of contaminated soil. The physico-chemical characteristics of the soil used for transplant studies were as pH 7.80, organic-C 1.04%, total-N 0.095%, available-P 0.007%, sulphate-S 0.003%, exchangeable-K 0.093%, cation exchange capacity 13.0 m eq  $100\text{g}^{-1}$ , Cd 1.5 mg  $\text{Kg}^{-1}$  and Zn 50.1 mg  $\text{Kg}^{-1}$ . Seedlings of the species were transplanted in pots filled with salt and soil mixture.

The experiment consisted of four sets including control. Plants without metals supplement served as control (T), plants grown in soil supplemented with 10 mg Cd  $\text{Kg}^{-1}$  and 700 mg Zn  $\text{Kg}^{-1}$  served as treatment 1 ( $T_1$ ), plants grown in soil supplemented with 15 mg Cd  $\text{Kg}^{-1}$  and 700 mg Zn  $\text{Kg}^{-1}$  served as treatment 2 ( $T_2$ ) and plants grown in soil supplemented with 20 mg Cd  $\text{Kg}^{-1}$  and 700 mg Zn  $\text{Kg}^{-1}$  served as treatment 3 ( $T_3$ ) respectively. Five replicates were maintained for each set of treatment. Watering was done on alternate days in summer and twice in a week in winter to maintain adequate water supply and soil moisture.

### Plant growth analysis:

The experimental plants measured bimonthly; at the beginning at the age of 2 months and at the age of 4, 6 and 8 months respectively. Morphological parameters such as plant height, number of leaves and branches, canopy, basal area and leaf area injury were recorded for all individual plants. Plant leaves critically examined for foliar injury. The leaf injury measured by graph paper method as described in Pandey and Sharma [19]. Values recorded were the average of five replicates.

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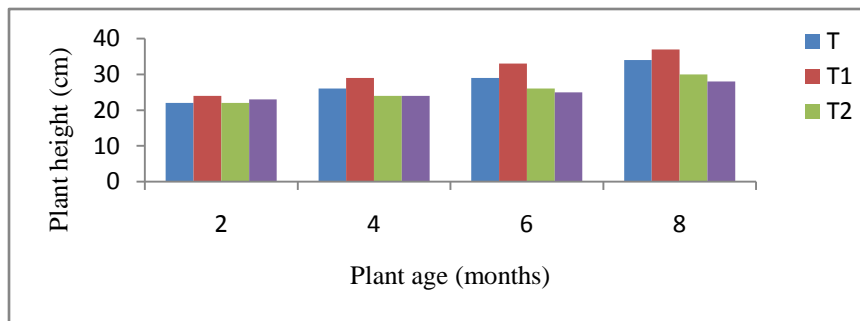
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### Soil analysis:

Dried and sieved soil samples were used for determination of mineral and metal content. Physico-chemical characteristics like pH, organic carbon, total-N, available-P, sulphate-S, exchangeable-K, cation exchange capacity, heavy metal cadmium and zinc of the soil were determined.

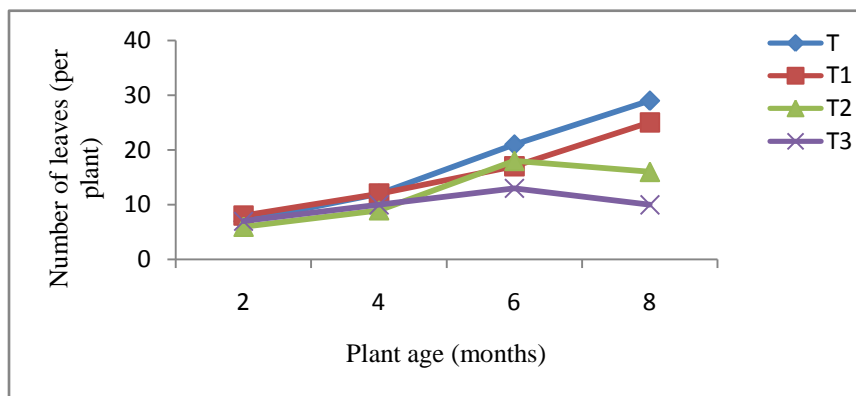
### IV. RESULTS AND DISCUSSION

The data on the interactive effect of different concentrations of cadmium (10, 15 and 20 mg Kg<sup>-1</sup>) with zinc (700 mg Kg<sup>-1</sup>) on plant height of *Mangifera indica* seedling was recorded [Fig. 1(a)]. Plant height increased with plant age in control and treated plants. However the increment in height was more in T<sub>1</sub> plants treated with 10 mg Kg<sup>-1</sup> Cd and 700 mg Kg<sup>-1</sup> Zn as compared to control. At high concentration of cadmium (15 and 20 mg Kg<sup>-1</sup>) with zinc, the increment in height slowed down in T<sub>2</sub> and T<sub>3</sub> plants with increase in plant age. The highest decrease in plant height was observed in T<sub>3</sub> plants with increase in concentration of metals and plant age. The increase in number of branches with plant age was observed only in control plants.



(a)

The observation on the interactive effect of cadmium and zinc on number of leaves of the treated plant is shown in fig.1 (b). The number of leaves showed progressive trend in control and T<sub>1</sub> plants with age. After 4 months of plant age, there was gradual increase in leaves number in T<sub>1</sub> plants as compared to control. The number of leaves showed increment upto 6 months of age but declined by in T<sub>2</sub> and T<sub>3</sub> plants.



(b)

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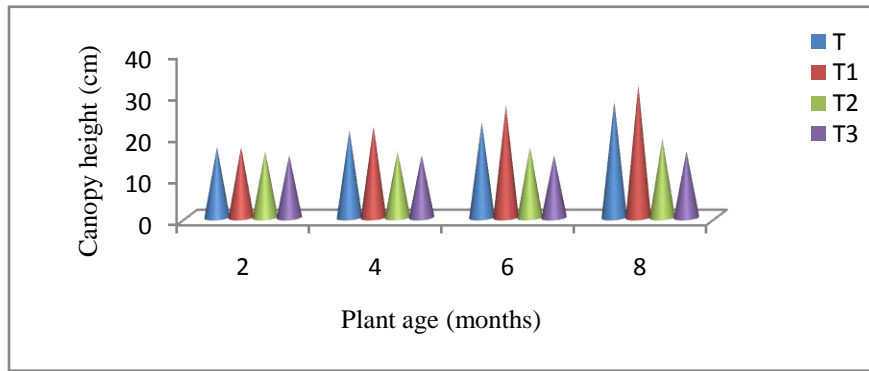
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T: control plants, T<sub>1</sub>: Cd (10 mg Kg<sup>-1</sup>) + Zn (700 mg Kg<sup>-1</sup>), T<sub>2</sub>: Cd (15 mg Kg<sup>-1</sup>) + Zn (700 mg Kg<sup>-1</sup>), T<sub>3</sub>: Cd (20 mg Kg<sup>-1</sup>) + Zn (700 mg Kg<sup>-1</sup>)

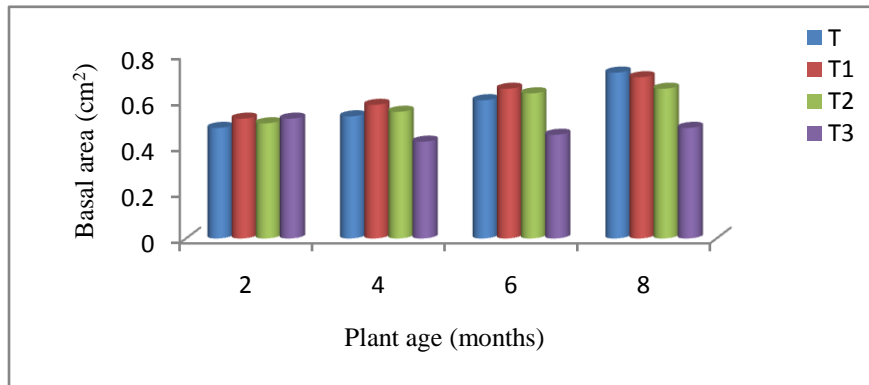
Fig. 1: Effect on (a) plant height and (b) number of leaves of *Mangifera indica* seedling grown in soil amended with cadmium and zinc. Values are the average of five replicates.

Interactive effect of cadmium and zinc on canopy height of *M. indica* seedling is presented in fig.2 (a). Canopy height increased in T<sub>1</sub> plants but reduced markedly in T<sub>2</sub> and T<sub>3</sub> plants as compared to control. With increase in plant age and concentration of metals duo, the leaves fell due to their senescence. As a result, the canopy height decreased and canopy depth increased of the plants treated with higher concentration of Cd with Zn.



(a)

The results presented in fig.2 (b) indicated that the interactive effect was variable on the basal area of the plants treated with metal duo. Basal area increased in control and T<sub>1</sub> plants treated with Cd and Zn (10+700 mg Kg<sup>-1</sup>). However the increment slowed down in T<sub>1</sub> plants at the age of 8 months. The increase in basal area with plant age was also observed in T<sub>2</sub> plants treated with 15 mg Cd Kg<sup>-1</sup> and 700 mg Zn Kg<sup>-1</sup> of soil. However the gradual decline in basal area was observed in T<sub>3</sub> plants at 4 months of age and then it further increased with plant growth.



(b)

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T: control plants, T<sub>1</sub>: Cd (10 mg Kg<sup>-1</sup>) + Zn (700 mg Kg<sup>-1</sup>), T<sub>2</sub>: Cd (15 mg Kg<sup>-1</sup>) + Zn (700 mg Kg<sup>-1</sup>), T<sub>3</sub>: Cd (20 mg Kg<sup>-1</sup>) + Zn (700 mg Kg<sup>-1</sup>)

Fig. 2: Effect on (a) canopy height and (b) basal area of *Mangifera indica* seedling grown in soil amended with cadmium and zinc. Values are the average of five replicates.

The foliar injury symptoms appeared earlier in the plants treated with high concentration of the metals. In T<sub>3</sub> plants chlorosis and curling of leaf which became necrotic after few days were visible at 8 months of plant age (Plate 1). The leaves became necrotic and finally dropped off. The foliar injury increased by 9% and 18% in T<sub>2</sub> and T<sub>3</sub> plants at 8 months of plant age.



Plate 1: Curling and necrosis of the leaf in seedling of *M. indica* treated with 20 mg Kg<sup>-1</sup> Cd and 700 mg Kg<sup>-1</sup> Zn at the age of 8 months.

Several studies have conducted to evaluate the toxic effects of cadmium and zinc on growth of plants grown under natural and controlled conditions. In present study, the plant height decreased at higher concentration of Cd treated with Zn. Similar results were reported for *Daucus carota* L. (carrot) at combined treatment of Cd and Zn [11]. The gradual increase in number of leaves observed in T<sub>1</sub> plants after 4 months of age indicates the fertilizing effect of zinc on plant growth. Some researchers found that Zn supply inhibit Cd adsorption and lowers Cd concentration in plants [20]

There was positive influence on growth parameters of the plants treated with 10 mg Kg<sup>-1</sup> Cd and 700 mg Kg<sup>-1</sup> zinc. It seems to have antagonistic effect of zinc on cadmium uptake at this concentration of the metals. This was also observed by Long *et al.* [10] and Akay and Koleli [12].

In T<sub>3</sub> plants, the basal area declined sharply at 4 months of plant age indicates the toxic effect of cadmium at higher concentration. It indicates that zinc could not antagonize its toxic effect at this concentration. There was little increment observed in this parameter with further growth of plant. However, Zn and Cd are chemically very similar, they compete for binding and adsorption sites in the plants [21]. As the concentration of both these metals increased, the growth parameters showed reduction with age and time of treatment. It indicates the synergistic effect of these metals on plant growth which resembles the findings of Liu *et al.* [22] and Chen *et al.* [23].

Foliar injury symptoms such as chlorosis, necrosis and senescence observed in the plants treated at higher concentration of Cd with Zn. The symptoms observed in present study resembled earlier findings of Haghiri [24] and Kabata-Pendias and Pendias [25]. The study reveals that reduction in number of leaves and canopy height attributes to decrease total chlorophyll which affects the growth of plant. Investigators such as Sivakumar *et al.* [26] observed that heavy metals including Zn and Cd decrease leaf total chlorophyll, leaf area and number of leaves drastically. The results suggest that Cd and Zn interaction effects on plants depend on the concentration of metals present in the soil.

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## V. CONCLUSIONS

The study clearly demonstrate that Zn and Cd (as soil amendment) when considered together may impose variable effects on growth of plant. Although at lower concentration, Cd and Zn have been shown to be antagonistic to each other but at high concentration, the interactive effects may be close to synergistic. Antagonistic effect was observed in plants treated with 10 mg Kg<sup>-1</sup> Cd and 700 mg Kg<sup>-1</sup> Zn. Highest decrease in growth parameters was found in plants treated with 20 mg Kg<sup>-1</sup> Cd and 700 mg Kg<sup>-1</sup> Zn. This type of changing behaviour of toxic responses of combination of heavy metals has great scientific bearing, especially for those areas where both the heavy metals are constantly rising in the natural as well as in agricultural environment.

## VI. ACKNOWLEDGEMENT

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