Chapter 8

Effect of Heavy Metals (Cadmium & Nickel) on the Seed Germination, Growth and Metals Uptake by Chilli (Capsicum frutescens) and Sunflower (Helianthus annuus) Plants
8.1 INTRODUCTION

Among heavy metals Cd and Ni were considered to be among non essential elements needed for the healthy growth of plants, animals and soil microbes. However, the recent literature survey available on internet, “A periodic table of the elements from mineral institute” is suggesting that nickel is an essential element in many species of plants and animals. It interact with iron found in haemoglobin and helps in oxygen transport, stimulate the metabolism as well as being regarded as a key metal in several plants and animals enzymes systems. Rates raised on a nickel poor diet tend to develop liver damage in their biological systems. It has shown relief to the patients suffering an acute heart or asthma attack when this injected through their veins in emergency situations. However, the role of cadmium has been reported to be a toxic element and has a tendency to replace zinc biochemically, causes high blood pressure, kidney damage, destruction of testicular tissue and red blood cells, toxicity to aquatic biota and acts as effective enzyme inhibitors. It has affinity for sulfur containing ligands e.g. –SCH₃ and –SH in methionine and cysteine amino acids, which is the part of the enzyme structure. Metalloenzymes contain metal such as zinc in their structures. The action of zinc is inhibited when is replaced by atoms of similar size like Cd which leads to Cd toxicity.

Furthermore, these heavy metal accumulations is reported in variety of plants such as maize, fennel plants [1, 2]. The amount of P uptake is found to decrease in plant seedling as a result of Ni and Cd treatments [3]. The role of heavy metals on the plants growth and nutrients uptake reveal that their effect is not fixed but vary and depends on the nature of the metal and type of the plant species, physico-chemical properties of the soil such as pH, nature and extent of clay minerals, exchangeable cations and soil organic matter [4-9].

However, the work on these lines are limited and it was thought worthwhile to study the effect of Cd and Ni on the seed germination, growth and nutrients uptake by chilli (Capsicum frutescens) and sunflower (Helianthus annuus) plants, which is still lacking in literature.
8.2 EXPERIMENTAL

The soil sample (0-30 cm) used in these investigation was an illitic fine sandy loam collected from agricultural farm of Aligarh Muslim University, Aligarh (U.P.), India. The Physico-chemical properties of soil were determined as described in chapter 2. The values obtained are listed in Table 8.1.

Pot experiment was conducted to evaluate the physiological parameters of chilli and sunflower plants. For pot experiment, the soil was air dried, crushed and sieved through 100 mesh sieve (BSS) and then it was filled in earthenware pots (2 kg pot⁻¹) containing varying quantities (0, 75, 150, 300, 600 ppm) of aqueous solution of cadmium and nickel as their chloride and nitrate salt respectively. The difference of NO₃⁻ contents in different pots was balanced by adding requisite quantity of urea to avoid its effect on growth patterns. All the treatments were replicated three times and received a basal dressing of NPK at 0.5 g N, 0.5 g P, 0.5 g K kg⁻¹ soil. Fertilizer and treatment solutions were manually mixed in the soil. The soil, in each pot, was then wetted with distilled water to about 60% of its water holding capacity. Out of the certified seeds of chilli and sunflower procured from the Quarsi government agricultural farm, Aligarh, ten seeds of each variety were sown in each pot for every treatment in three replicates. The pots were kept at 35 ± 1° C in a green house, while maintaining moisture levels by adding distilled water when necessary. After seed germination, the sprouts were equally thinned and allowed to grow for a total period of 90 days. The physiological parameters such as seed germination, number of leaves, shoot length, root length; fresh shoot weight and dry shoot weight were examined.

Plants were removed from the pots and were properly washed with distilled water. After that, these were dried and grounded for the determination of Cd, Ni, and other metal nutrients such as Na, K, Ca, Mg, Cu, Zn, Mn and Fe. Out of these 1 g sample of each treatment was digested with 10 mL of acid mixture containing HNO₃ and HClO₄ (4:1). The digested samples were heated on a hot plate till the brown fumes ceased and the digested material is converted into a syrupy liquid with some white fumes [10]. The samples of the syrupy liquid were dissolved in 5 mL of conc.
HCl and diluted with distilled water. To obtain the clear solutions, they were filtered and then adjusted to a volume of 50 mL in each case. The amounts of metals uptake for Na, K and Ca were estimated from these solutions by using “Systronics” flame photometer. Iron by spectrophotometer. The quantity of calcium plus magnesium was determined by EDTA titration using eriochrome black “T” indicator at pH 10 [11]. The amount of magnesium was then calculated by subtracting the value of Ca from Ca plus Mg. The concentration of Cd, Ni, Cu, Zn and Mn were estimated by double beam atomic absorption spectrophotometer (GBC - 902).

8.3 RESULTS AND DISCUSSION

An examination of results (Fig. 8.1) shows that the growth of chilli plant decreased significantly as a result of increasing doses of Cd application throughout the entire range of its amendments in soil. The %age inhibition patterns for various physiological parameters being, seed germination: 8.88, 17.77, 25.5, 27.77; no. of leaves: 7.60, 13.58, 15.76, 18.47; shoot length: 18.89, 19.75, 22.01, 29.37; root length: 1.15, 10.26, 13.49, 18.80; fresh shoot weight: 17.36, 27.75, 33.94, 54.16; dry shoot weight: 25.95, 31.87, 37.94, 55.28 for varying concentrations (75, 150, 300, 600 ppm) of Cd treatments over control in respective treatments (Fig. 8.3). However, in case of Ni treatments the results (Fig. 8.2) on sunflower plants shows a beneficial effects of various parameters. The enhancement of growth in %age being, seed germination: 2.5, 22.5; no. of leaves: 10.0, 25.0; shoot length: 4.60, 9.53; root length: 17.66, 51.66; fresh shoot weight: 11.27, 92.81; dry shoot weight: 7.49, 42.23 at its lower concentrations (75, 150 ppm) and thereafter an inhibitory trend in growth are noticed. The %age inhibition in growth patterns were, seed germination: 6.25, 25.0; no. of leaves: 15.0, 12.5; shoot length: 8.22, 19.07; root length: 8.33, 67.33; fresh shoot weight: 13.15, 91.65; dry shoot weight: 18.82, 82.81 at its higher concentrations (300, 600 ppm) in soil over control respectively as shown in (Fig. 8.4). Thus, it was concluded that the toxicity order for these metals being Cd > Ni.

The results on the metals uptake (Tables 8.2 and 8.3) show the similar trends as indicated in the case of physiological parameters (Figs. 8.1 and 8.2) for both chilli and sunflower plants as a result of Cd and Ni treatments. The beneficial effect of Ni at its lower concentration (75 to 150 ppm) may be attributed due to their adsorption
over soil colloids on the exchangeable sites through ion exchange process capable of releasing plant nutrients elements in greater amounts required for healthy growth of plants and soil microbes with enhanced activity. However, Cd throughout the entire range (75 to 600 ppm) and Ni at higher concentration (300 to 600 ppm) become fatal for the soil microbes resulting in their diminished activity for releasing the plant nutrients [6, 12, 13]. The Cd uptake in case of chilli plant is more than the Ni in sunflower plant (Fig. 8.5) that might be due to its more stable complex forming or upholding tendencies with organic ligand than Ni, that followed the toxicity order Cd > Ni with the plant root sap as well as with the humic and fulvic acids fractions of soil organic matter contents. The results are in agreement with the findings of earlier workers [14, 15] who showed a similar view that the heavy metals toxicity and uptake depends upon the complex forming tendencies and its concentration with plant root sap. Thus, it was revealed that the soluble metal organic matter complexes in soil moved in to root zone and enter the root hairs as such [16] through cell membrane. The stability constants for most of the metals i.e. Na, K, Ca, Mg, Cu, Zn, Mn, Fe, Cd and Ni etc. were reported to be nearly equal in the fulvate model [17]. Thus, the competitive effects in the complexation of metals with the organic ligands play a vital role in their mobilization process into the plants and follow the selectivity rule [18, 19]. This suggests that the selectivity of ligand for a given metal is proportional to the product of relative stability constant for metal ligand complexes and the total molar concentration of metal. The K, Ca, Mg, Cu, Zn, Mn and Fe in sunflower plant competed the Ni at lower concentration (75 to 150 ppm) and become more selective for organic ligands to cause their increase in plants. While Cd throughout the entire range (75 to 600 ppm) and Ni at higher concentration (300 to 600 ppm) the selectivity of the metal nutrients complexation decreases and caused a reduction in their utilization by the plants and has resulted in their stunt growth.
REFERENCES


Table 8.1 Physico-chemical properties of the soil

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
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<td>pH (1:5, soil : water)</td>
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<td>EC (1:5, soil : water) (dSm(^{-1}))</td>
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<td>Mechanical composition (%)</td>
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<td>Ni</td>
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Table 8.2 Effect of cadmium on the metals uptake by chilli (*Capsicum frutescens*) plant

<table>
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<th>Doses of applied Cd (ppm)</th>
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<th>Zn</th>
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<th>Cu</th>
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<th>K</th>
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<td>25000</td>
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</table>

Values are mean of three replicates
Table 8.3 Effect of nickel on the metals uptake by sunflower (*Helianthus annuus*) plant

<table>
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<th>Metals concentration (ppm)</th>
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<tr>
<td>600</td>
<td>25.0</td>
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Values are mean of three replicates
Fig. 8.1 Effect of cadmium on the physiological parameters of chilli (*Capsicum frutescens*) plant
Fig. 8.2 Effect of nickel on the physiological parameters of sunflower
Fig. 8.3 Percent inhibition of growth as a function of applied cadmium concentration on chilli (*Capsicum frutescens*) plant.

Fig. 8.4 Percent inhibition of growth as a function of applied nickel concentration on sunflower (*Helianthus annuus*) plant.
Fig. 8.5 Effect of applied cadmium and nickel concentration and uptake by plants