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Cadmium as an Environmental Pollutant Study of Evolution of Cadmium, its Effects on Beans (*Phaseolus Vulgaris*) and its Interaction with Zinc

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Abstract: Cadmium like other heavy metals is known to be a serious toxic element and one of the most hazardous environmental pollutants not only to soil and plants, but also to humans and animals. The increasing emission of Cd from a variety of sources because it is commonly used in many fields created a great interest about the possible movement of Cd and other heavy metals into the atmosphere, water and food chain as a result of plant uptake. The presence of a number of heavy metals creates interactions between them in soil or within the plant. This summarizes the various effects of Cd on beans (*Phaseolus Vulgaris*) and its responses by studying the behaviour of the element in bean plants as reduced by Zn competition with Cd chosen for the purpose of minimizing potential damage that could result from the exposure to cadmium. Analyses were carried out using spectroscopic techniques and the results obtained have shown the great toxicity of Cd and the fragile resistance of the plant indicated by the quick response to the various concentrations of the element and the antagonistic relation with Zn added at different concentrations. The study also indicates the direct effect of pH on the availability and the bioaccumulation of the element into the plant.

Key words: Eenvironmental pollutants, availability, bioaccumulation, toxicity, uptake, antagonism, spectroscopic

INTRODUCTION

Trace metals are considered as important environmental pollutants and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons (Benavides *et al*., 2005). They are known to exert a positive or negative influence on soil, plants and animals and the presence of both essential and non essential heavy metals in the atmosphere, soil and water in excessive amounts, can cause serious problems to all organisms. Through this work, an attempt will be made to answer some questions concerning the behaviour and effects of Cd which is considered as one of the very toxic trace metals due to its high mobility, its large solubility in water (Pinto *et al*., 2004). Cadmium is known to be a non-essential element that negatively affects plant growth and its development. It is released into the environment by power stations, heating systems, metal-working industries or urban traffic. It is widely used in electroplating, pigments, plastic stabilizers and nickel-cadmium batteries (Sanitá and Gabrielli, 1999) Excess Cd causes a number of toxic symptoms in plants, such growth retardation, inhibition of photosynthesis, induction and inhibition of enzymes (Hall, 2002). As far as trace metals in biological systems and in soil are concerned, great progress was made during the last decade in the studying of interactions between trace metals, amino-acids, proteins, enzymes and other molecules. In soils, the main sources of trace metals are the rocks and many plants and animals rely on soil for their major requirement of trace metals. As far as Cd is concerned, the element is present in all the rocks and particularly in sedimentary rocks (Baize, 1997). Many research works also confirmed that the availability and distribution of trace metals are affected by organic matter, redox potential, microbial activity, and trace metal interactions. In the present study emphasis has been put on metals interactions.

Interactions between trace elements: Interactions between elements considered as a major factor affecting the behaviour of trace metals are described as antagonisms, synergistic or additive and very little is known about mechanisms involved. This aspect of interaction between elements has been a matter of interest and investigated for many years by numerous research workers. The investigation on the interrelation between Cd and Zn attracted great attention and was a subject of research because of the importance of Zn in soil, in biological systems and also because of the closed chemical similarities between the two elements (Adriano, 2001). The primary objective of studying the interaction of Cd and Zn was to obtain some information on the Cd and Zn relationship in animals and plants to determine whether additional Zn would alleviate the Cd toxicity shown in many cases. With the growing interest of the effects of cadmium on plant systems, emphasis on studying its bahaviour, effects and its interrelation with other elements was also growing and studies on cadmium-interaction with other elements were developed to investigate cadmium response to the presence of other elements in soils, plants and animals. Experiments undertaken for this purpose gave significant results and suggestions which made significant contribution in solving many problems related to Cd and Cd-toxicity in the three systems quoted above. Das *et al.* (1997) has hypothesized that elements whose physical and chemical properties are similar will act antagonistically to each other biologically. This aspect has also been studied in soil-crop systems under field conditions (Nan *et al.*, 2002) who confirmed the Competitive inhibition of Cd uptake by Zn and the role of Zn in antagonizing Cd toxicity. The inhibitory effect of Zn on Cd was also reported by Parameswaran *et al.* (2005) when studying *C. demersum*. Shaw *et al.* (2004) also worked on Cd/Zn interactions and found that addition of amounts of Zn reduces Cd effect and prevent proteins damage. Investigations on various aspects focusing on the biochemistry of Cd-Zn interactions were also undertaken by Aravind and Prasad (2003, 2004), Koleli *et al.* (2004), Zhao *et al.* (2005).

MATERIALS AND METHODS

Seeds of beans were first germinated in vermiculite for a period of 12 until plants reached a mature stage then transferred to separate 100 mL flasks containing the nutrient solution and different concentrations of Cd and Zn. Cd was added as $(Cd(No_3)_2)$ at different levels in total µg 0, 20, 60,100,140 and 180; that of Zn: 0, 2000, 6000 and 10,000 µg. The culture of beans in the hydroponic solution lasted between 7 and 12 days before being harvested, dried and filtered then analyzed by the SAA technique. Furthermore, daily check and observation were carried out during the experiment and the pH range of the solution was maintained at about 5 to 6 considered to be adequate for the growth of several species.

Growth conditions: Temperature (20±4°C), Relative humidity (80%) and a photoperiodic regime of 16 h light and 8 h darkness.

RESULTS AND DISCUSSION

Experiment 1 was carried out fixing the amounts of Cd (100,140 and 180 µg total) and varying those of Zn [2000, 6000 and 10,000 µg total). The experiment is aimed at demonstrating the mutual effect of the two elements and its implications on their uptake by bean plants (Table 1). Experiment 2 was carried out fixing the amount of Zn (2000, 6000, 10.000 µg total) and varying those of Cd (20, 60, 100, 140, 180 µg total) (Table 2).

Table 1: The two elements and its implications on their uptake by bean plants

Sample µg Zn($\times10^3$)	D.W gr	µg Zn taken up	µg Zn in rem sol
100 µg total Cd			
2	0.20±0.03	348.3±31.66	1530.0±149.6
6	0.24±0.01	1025.0±103.7	4305.0±366.1
10	0.29±0.04	1446.0±59.5	7049.0±397.0
140 µg total Cd			
2	0.18±0.03	141.3±19.48	1727.0±69.9
6	0.20±0.03	547.6±40.1	4620.0±211.0
10	0.23±0.02	675.0±39.5	7983.0±384.0
180 µg total Cd			
2	0.18±0.02	74.02±3.22	1776.0±78.0
6	0.18±0.03	380.64±39.5	5199.0±244.0
10	0.24±0.04	887.6±88.9	8088.0±455.0

Table 2: The amount of Zn and varying those of Cd

Sample µg Cd total	D.W` gr	µg Cd taken up	µg Cd in rem sol
2.10^3 µg total Zn			
20	0.27±0.03	10.05±0.98	6.98±2.42
60	0.26±0.01	23.70±3.03	30.99±3.28
100	0.23±0.04	22.22±0.41	65.50±3.33
140	0.18±0.02	24.46±3.70	96.67±8.31
180	0.21±0.01	29.94±1.87	126.00±5.57
6.10^3 µg total Zn			
20	0.22±0.02	8.16±1.17	9.83±1.23
60	0.22±0.03	14.68±1.25	40.70±4.18
100	0.18±0.04	19.67±0.78	76.21±3.36
140	0.20±0.03	18.64±1.42	109.70±5.14
180	0.14±0.03	32.93±2.39	124.10±14.83
10.10^3 µg total Zn			
20	0.25±0.05	7.13±0.87	10.79±1.24
60	0.24±0.05	10.04±0.66	44.72±3.13
100	0.28±0.03	21.72±1.77	69.01±2.55
140	0.23±0.03	18.07±2.37	115.00±5.73
180	0.24±0.03	21.34±2.53	142.40±11.74

CONCLUSION

For the first experiment using only Cd, considerable decrease in plant growth was observed especially in plants containing more than 60 μg of total Cd added, compared with the control plants. Plants containing less that 60 μg of Cd did not show any obvious sign of Cd effects (no zinc was added) whereas those containing 100, 140 and 180 μg of Cd presented a complete chlorosis. Roots did not appear to be greatly affected by these Cd levels and stems showed symptoms of Cd effect expressed as necrosis.

For the second experiment using combined Cd/Zn simultaneously as mentioned in tables above, Zn had an antagonistic effect on Cd uptake by plants at all Zn levels (2000, 6000 and 10.0000 μg total). Besides these results, a supportive experiment was realized adding sufficient amounts of iron (600 μg) to confirm that chlorosis was caused by Cd toxicity rather than Fe deficiency. The interaction between the two elements may be seen as competition for sites on the surface of the roots and could also be due to the chemical and stereochemical similarities between them. Therefore, these similarities will be used to explain the action of Cd and Zn and the type of bonding occurring.

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