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PHYTOTOXIC EFFECTS OF CADMIUM ON MAIZE PLANTS GROWN UNDER GREENHOUSE CONDITIONS

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Abstract

This paper is focused on the cadmium accumulation by maize (Zea mays) plants grown on Eutric Fluvisols material with different Cd contamination. The cadmium contents in soil material were increased by 3, 5, 10, 15, 20 and 30 mg/kg Cd using cadmium acetate. Results of tests carried out to determine the content of cadmium in soil and maize plants (roots and aboveground parts) showed that the cadmium uptake in maize plants increased with increasing total cadmium content in soil. An increases more than 14 times of total cadmium content in the soil increased the cadmium content in different parts of maize plants (185 times in roots and 54 times in aboveground parts). The high cadmium content in soil does not induce highly significant reductions of above-ground biomass of maize plants.

INTRODUCTION

Heavy metals such as cadmium enter the ecosystem chiefly as the result of human activities. The accumulation of heavy metals in the soil is dangerous for most living organisms. High concentrations of cadmium have been demonstrated to have carcinogenic and mutagenic effects in numerous animal species [1].

Exposure to high levels of these metals has been linked to adverse effects on human health and wildlife. In plant, cadmium is one of the most readily adsorbed and most rapidly transferred heavy metal, which explains why it exerts strong toxicity even at relatively low concentrations [4].

Plant uptake of cadmium is depended on the soil cadmium concentration and its availability. Cadmium metal itself does not break down in the soil but it can change into different forms. This transformation and therefore the availability of cadmium in soil, is influenced by factors such as pH, soil temperature, soil organic matter, calcium concentration and chlorine salinity, oxidation-reduction reactions and the formation of complexes [2, 3].

Crops like maize (*Zea mays*) show high tolerance to cadmium pollution. These plants are able to grow and develop on high polluted soils. There are some maize

cultivar which might be considered as “Cd - shoot excluders” with cadmium accumulated at higher concentrations in roots than in shoots. This behavior is considered one of several strategies of tolerance to cadmium [4].

This paper is focused on the cadmium accumulation in the maize (*Zea mays*) plants grown on Eutric Fluvisols material with different Cd contamination.

MATERIAL AND METHODS

This experiment was conducted in the Greenhouse of INCDPAPM-ICPA Bucharest. For pot experiments was used soil material collected from the upper horizon of Eutric Fluvisol from bottomland of Dâmbovița River. The soil was air dried, crushed and passed through a 2-mm sieve prior to analysis and filling the pots. This soil material was artificially spiked with cadmium acetate to make its final total concentration as 3, 5, 10, 15, 20 and 30 mg/kg Cd.

The total content of cadmium was measured with flame atomic absorption spectrometer in hydrochloric solution resulted by digestion of soil samples in acid mixture. Concentrations of mobile Cd in soil were determined following Na_2EDTA extraction method.

Plants material divided in roots and above-ground parts (stalks and leaves) was washed in distilled water and dried at 65°C until constant mass. Dried plant material was mineralized using nitric-perchloric acids mixture and the content of Cd determined by atomic absorption spectrometry.

The experimental design was entirely randomized with 3 replications. The effects of the treatments were studied by analysis of variance and average test (Tukey).

RESULTS AND DISCUSSION

The controlled increases of total cadmium content in soil changed some soil chemical characteristics and maize plants.

It is noted that in 4 of the 9 studied characteristics changes were statistically assured. Highly statistically significant changes were established for four of the studied characteristics: the total content of cadmium in soil, potential mobile cadmium content in soil (Na_2EDTA-extractable form) and cadmium contents in maize plants (Table 1).

The treatments involving the addition of cadmium acetate produced statistically significant increases of total cadmium content in soil material used for pot experiment (Figure 1).

Also, using a cadmium salt with high solubility in order to increase the total cadmium content resulted in an increase of mobile form of cadmium in soil (Na_2EDTA extractable form).

For the soil treatment with maximum amount of cadmium acetate, the cadmium content in soil in soluble form has come to represent 89.7% of the total cadmium content. The values of mobile cadmium content in soil ranged between 0.4 mg/kg (control) and 28 mg/kg (highly polluted soil).

Table 1

Fisher test significances established by analysis of variance to reveal the changes produced by increasing of cadmium content in soil on some characteristics of soil material and maize plant

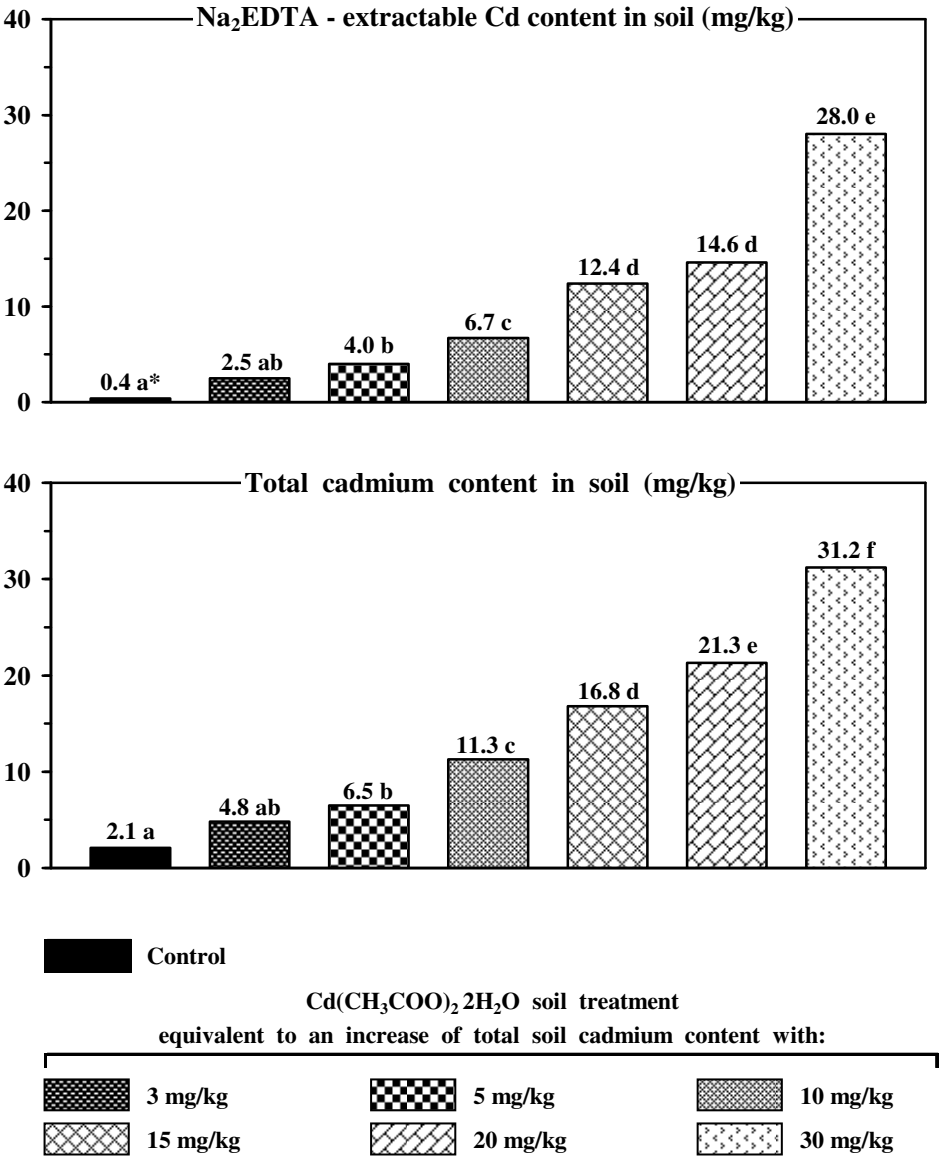
Maize plant characteristics / Soil material characteristics	Fisher Test significances
Total biomass of above-ground part of maize plant (stalks and leaves)	NS
Maize roots weight	NS
pH of soil material	NS
Organic carbon content in soil material	NS
Total nitrogen content in soil material	NS
Total cadmium content in soil material	***
Na_2EDTA-extractable cadmium content in soil material	***
Cadmium content in maize roots	***
Cadmium content in maize stalks and leaves	***

NS - Not Significant ($p > 0.05$)
*Significant ($0.01 < p \leq 0.05$)
**Very significant ($0.001 < p \leq 0.01$)
***Highly significant ($p \leq 0.001$)

The augmentation of total cadmium content by incorporating equivalent amounts of cadmium salt (cadmium acetate) favored maintaining of significant metal amounts in soil solution, with direct effects on the cadmium content of plants.

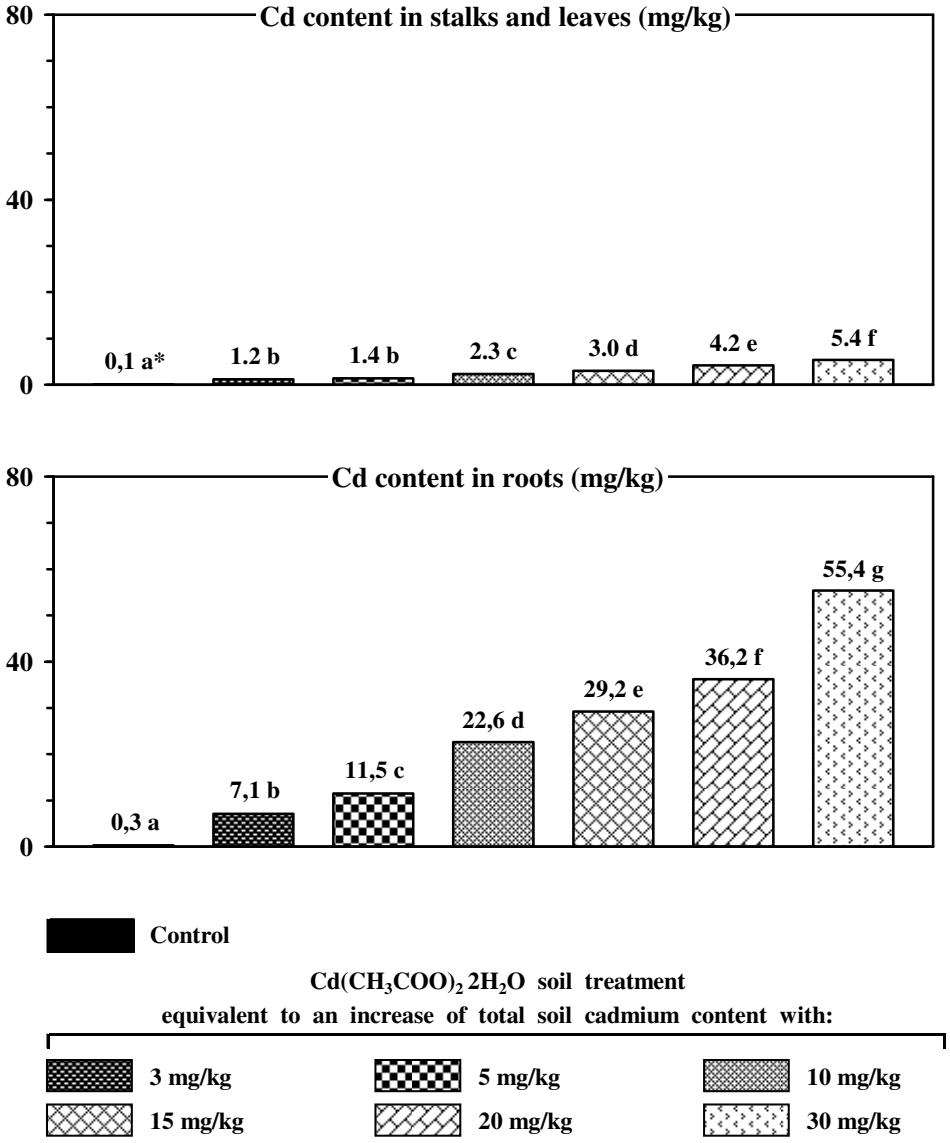
The level of cadmium uptake in higher plants is determined by the cadmium concentration of the soil and by its biological availability. The higher bioavailability of cadmium in soil enables the maize plants to uptake and to accumulate higher metal concentration in their tissues.

For the plants grown on cadmium polluted Eutric Fluvisols, the cadmium content determined in roots ranged from 0.3 mg/kg (control) to 55.4 mg/kg (maximum polluted soil). The values of cadmium content in roots were statistically significant as compared to control starting with the treatment appropriate to an increase with 3 mg/kg of total cadmium content in soil (Figure 2).



* Values followed by the same letter (a, b, ...) did not differ at the 0.05 significance level using Tukey's honestly significant difference procedure.

Fig. 1. Effects of $Cd(CH_3COO)_2\ 2H_2O$ soil treatment on cadmium content (total and Na_2EDTA-extractable) of soil material used in pot experiment



* Values followed by the same letter (a, b, ...) did not differ at the 0.05 significance level using Tukey's honestly significant difference procedure.

Fig. 2. Effects of $Cd(CH_3COO)_2\ 2H_2O$ soil treatment on cadmium content in maize plants grown on soil materials from upper horizon of an Eutric Fluvisols

The values of cadmium content in stalks and leaves of maize plants grown on polluted soil material ranged between 0.1 mg/kg in control and 5.4 mg/kg for plant grown on soil treated with the maximum amount of cadmium acetate (Figure 2).

The critical concentration for the phytotoxicity of cadmium was reported in the range 5-20 mg/kg fresh weight in plant tissues depending on plant species [5].

The results showed if average content of cadmium in soil was 31.2 mg/kg, cadmium content of maize roots was about 185 times higher than that determined in the roots of control plants. Also the cadmium content of maize above-ground parts was about 54 times higher than that determined in the stalks and leaves of control plants. These results support the hypothesis that the maize is a "Cd – shoot excluder" that develops a defense mechanism at root level.

CONCLUSIONS

1. The Eutric Fluvisols has the capacity to limit the uptake of cadmium in plants mainly due to weak alkaline reaction so that, the high cadmium content in soil does not induce highly significant reductions in biomass production of maize plants or other obvious symptoms of phytotoxicity.
2. Regarding the distribution of cadmium in different parts of studied plants, it is noted that maize limit the uptake of cadmium in stalk and leaves, leading to the accumulation of significant quantities of cadmium in roots.

REFERENCES

1. Das P., S. Samantaray, G.R. Rout, 1997. *Studies on cadmium toxicity in plants: a review*. Environmental Pollution, vol. 98 (pp. 29-36).
2. Dorris J., H. Bassam, 2002. *Cadmium uptake by radishes from soil contaminated with nickel-cadmium batteries: toxicity and safety considerations*. Toxicology Mechanisms and Methods, vol. 12 (pp. 265-276).
3. Moustakas N.K., K.A. Akoumianakis, H.C. Passam, 2001. *Cadmium accumulation and its effect on yield of lettuce, radish and cucumber*. Communications in Soil Science and Plant Analysis, vol. 32 (pp.1793-1802).
4. Pal M., E. Horvath, T. Janda, E. Paldi, G. Szalai, 2006. *Physiological changes and defense mechanisms induced by cadmium stress in maize*. J. Plant Nutr. Soil Sci. vol. 169 (pp. 239-246).
5. ***Environmental Agency, 2009. *Supplementary information for the derivation of SGV for cadmium*. Science report: C0500021/Technical review cadmium, ISBN: 78-1-84911-072-3.