

PHYTOTOXIC EFFECTS OF CADMIUM ON SOYBEAN PLANTS GROWN IN GREENHOUSE CONDITIONS

NICOLETA VRÎNCEANU, D.M. MOTELICĂ, M. DUMITRU,
EUGENIA GAMENT, ALEXANDRINA MANEA,
VERONICA TĂNASE, MIHAELA PEDA

National Research and Development Institute for Soil Science, Agrochemistry and
Environmental Protection of Bucharest

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Abstract

*This paper is focused on the cadmium accumulation by soybean (*Glycine max*) plants grown on Eutric Fluvisols material with different Cd contamination. The cadmium contents in soil material increased by 3, 5, 10, 15, 20 and 30 mg/kg Cd using cadmium acetate. The results of tests carried out to determine the content of cadmium in soil and soybean plants (roots, stalks, leaves and seeds) showed that the cadmium uptake in soybean plants increased with increasing total cadmium content in soil. An increase over 14 times of total cadmium content in the soil increased the cadmium content in different parts of the soybean plants (55 times in roots of 8 times in stalks and leaves and 24 times in seeds). The high cadmium content in soil does not induce highly significant reductions in seeds or biomass production of soybean plants.*

INTRODUCTION

Cadmium, a non-essential metallic element for the life cycle of living organisms, is known as one of the most dangerous pollutants in the environment. The continuous inputs of this element in biosphere, as a result of various industrial activities, may pose a risk to the health of ecosystems and people. Cadmium has high mobility, is poorly retained by the soil and is readily uptaken by plants [1].

Vegetal species, such as soybean represent a health risk if are grown on soils contaminated with cadmium, because these plants are able to accumulate large amounts of cadmium in their edible part. Although metal toxicity in plants is manifested only on heavily polluted soils, their accumulation in plant tissues, even at a lower level than phytotoxic level, is a concern. Serious diseases have been reported to be related with ingestion of food and/or water contaminated with Cd even if the cadmium concentration in food is still considered low [2].

This paper is focused on the cadmium accumulation by soybean (*Glycine max*) 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 soil material was used collected from the upper horizon of Eutric Fluvisol from bottomland of the 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 a flame atomic absorption spectrometer in hydrochloric solution resulted by digestion of soil samples in acid mixture. The concentrations of mobile Cd in soil were determined following Na₂EDTA extraction method.

Plants were harvested at maturity. Plants material divided in to roots, stalks, leaves and seeds 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 soybean plants.

It is noted that, for 9 of the 12 studied characteristics, changes were statistically assured. Extremely statistically significant changes were established for five of the studied characteristics: the total content of cadmium in soil, potential mobile cadmium content in soil (Na₂EDTA-extractable form) and cadmium contents in soybean plant. Very significant values of Fisher test were determined for two characteristics: total biomass of above-ground part of soybean plants and total nitrogen content in soil material (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 (Na₂EDTA extractable form). For the soil treatment with maximum amount of cadmium acetate, the cadmium content in soil in soluble form has come to represent 90% of the total cadmium content. Similar results were obtained by [3] who found that mobile cadmium content in soil represent 70-80% of the total cadmium content if metal pollution was induced artificially by incorporating a soluble salt of cadmium.

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 soybean plant

Soybean plant characteristic / Soil material characteristic	Fisher Test significances
Total biomass of above-ground part of soybean plant	**
Soybean stalks and leaves weight	NS
Soybean pods weight	*
Soybean seeds weight	*
pH of soil material	NS
Organic carbon content in soil material	NS
Total nitrogen content in soil material	**
Total cadmium content in soil material	***
Na ₂ EDTA-extractable cadmium content in soil material	***
Cadmium content in soybean roots	***
Cadmium content in soybean stalks and leaves	***
Cadmium content in soybean seeds	***

NS - Not Significant ($p > 0.05$)

*Significant ($0.01 < p \leq 0.05$)

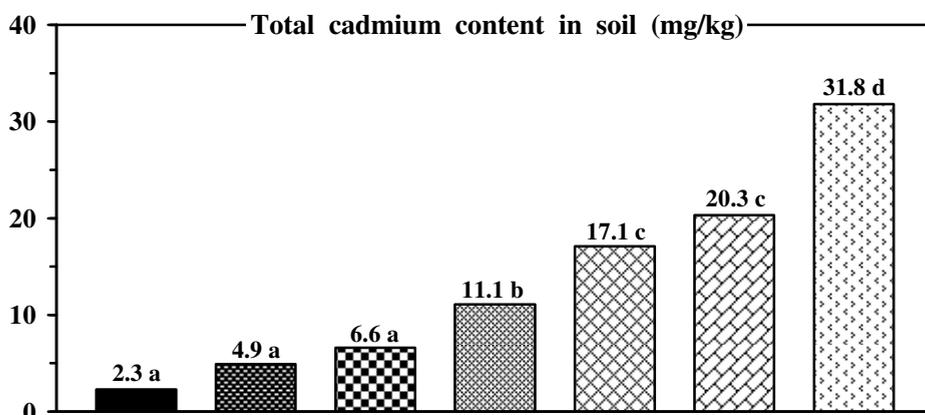
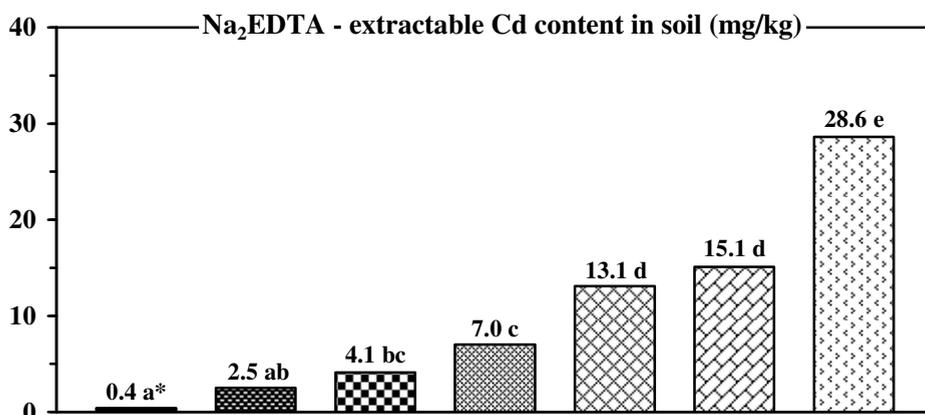
**Very significant ($0.001 < p \leq 0.01$)

***Highly significant ($p \leq 0.001$)

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

The higher bioavailability of cadmium in soil enables the soybean plants to uptake and to accumulate higher metal concentration in their tissues.

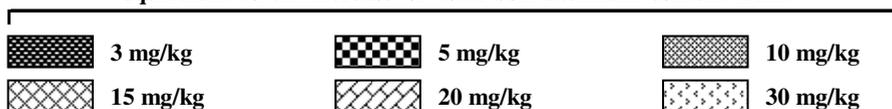
For the plants grown on cadmium polluted Eutric Fluvisols, the cadmium content determined in roots ranged from 0.2 mg/kg (control) to 10.9 mg/kg (maximum polluted soil). The values of cadmium content in roots were statistically significant as compared to the control starting with the treatment appropriate to an increase with 15 mg/kg of total cadmium content in soil (Figure 2).



Control

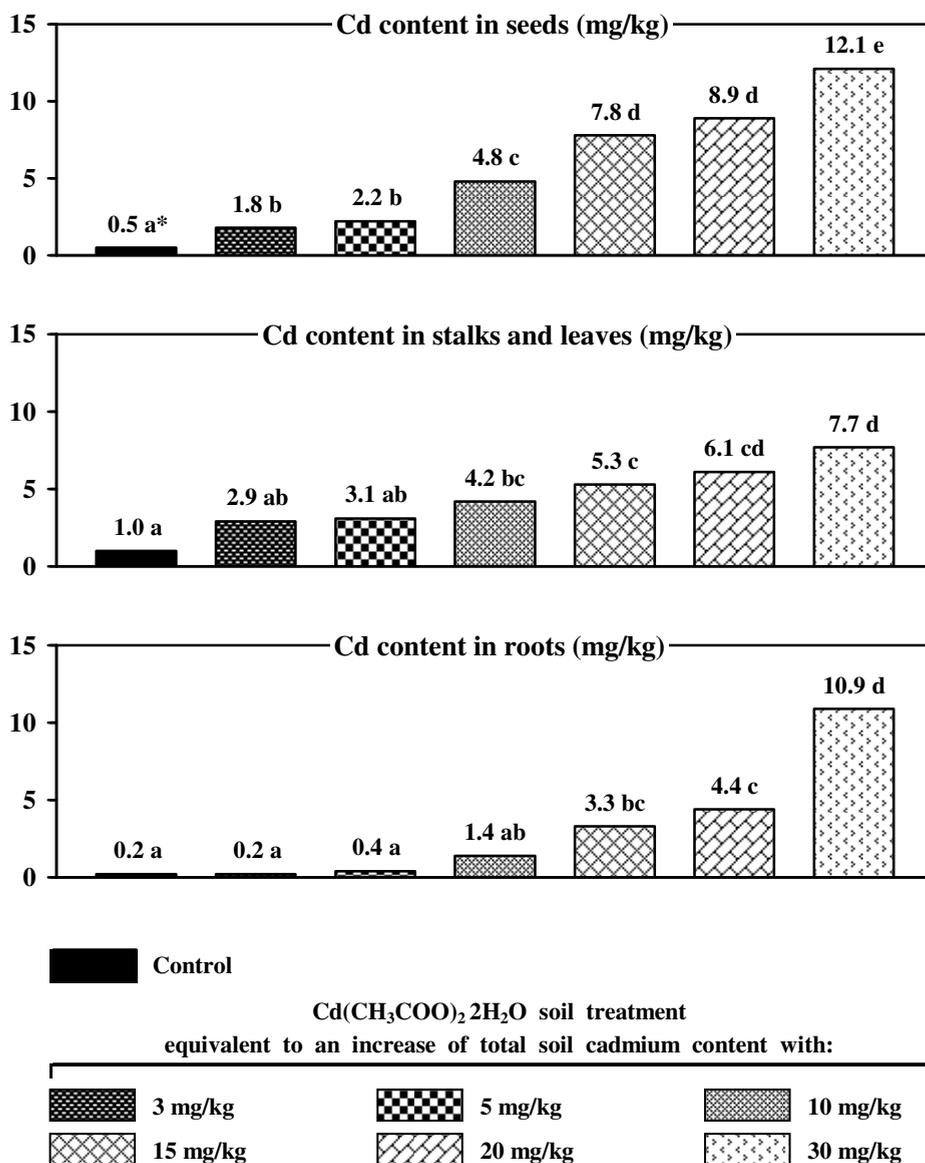
$\text{Cd}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$ soil treatment

equivalent to an increase of total soil cadmium content with:



* 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 $\text{Cd}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$ 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(CH₃COO)₂·2H₂O soil treatment on cadmium content in soybean plants grown on soil materials from upper horizon of an Eutric Fluvisols

The values of cadmium content in stalks and leaves of soybean plants grown on polluted soil material ranged from 1 mg/kg in control to 7.7 mg/kg for plant grown on soil treated with the maximum amount of cadmium acetate (Figure 2).

The cadmium content in soybean seeds increased from 0.5 mg/kg (control) to 12.1 mg/kg (treatment with highest amount of cadmium acetate). The results showed, that if the average content of cadmium in soil was 31.8 mg/kg, the cadmium content of grains was about 24 times higher than that determined in the seeds of control plants.

CONCLUSIONS

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

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