CADMIUM AND ZINC UPTAKE OF RYE-GRASS AS RELATED TO SOIL TYPE AND DIFFERENT LAND USE

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Abstract: The results of a small-pot experiment of cadmium-loading (5 $mg \cdot kg^{-1}$) with the addition of zinc (5 $mg \cdot kg^{-1}$) carried out are introduced in this paper. For this, soil samples were taken from 4 sites of plough-land, grassland and forest land-use types. Accumulation characteristics of the two metals as well as their interaction with the soil properties were analysed. The results show that land-use has significant effect on zinc uptake. There is close correlation between the zinc and cadmium uptake of plants as well as that cadmium concentration of soils plays an important role in it. Zinc shows positive correlation while cadmium shows negative correlation with organic matter. Beside organic colloids, inorganic colloids i.e. clay fraction also showed close correlation.

Keywords: zinc, cadmium, accumulation, ryegrass, land-use

Introduction

Due to the production activities of mankind, a number of pollutants impacting living organisations to a various degree, are emitted to the environment. The type of their impact is highly dependent on the toxic characters of the very materials as well as on what level they can enter organisms (Bíró and Takács, 2007; Rabnecz et al. 2007; Rékási and Filep, 2006). A significant proportion of pollutions can come from inorganic contaminants including heavy metals. Metals can enter the food-chain and accumulate in living organisms to such a degree that may have a harmful influence on their physiological processes (Rékási et al. 2006). As a result of biomagnification, concentration increases as reaching the top of the food-pyramid. Metal uptake by plants are studied in field and small-pot experiments, during which it the amount of metal accumulated by a given plant in given circumstances and its potential toxic effect can be determined (Kádár, 1991). Each plant is susceptible to such effects to a various degree and accumulate metals in a various level even according to genotypes. Cadmium is, even in small quantity, a toxic element that accumulates in plants without visible signs. It tends not to be washed-out from the soil, thus as a consequence of the use of phosphate fertilisers, sewage sludge disposal and industrial emission, its concentration can increase and can also enter the food-chain (Kádár and Kastori, 2006; Wu et al. 2002). In the environment cadmium and zinc usually occur together and they compete for the same binding places on the colloid surface.

An experiment of cadmium-zinc loading aiming to compare the role of the endowments of 4 habitats and 3 land-use categories in plant accumulation was carried out. The aim was to study the influence of different soil types and land use on heavy metal uptake of a test plant.

Materials and methods

Soil samples were collected to the experiment from 4 areas (from the Hajdúhát [Chernozem] and Hevesi-homokhát [Arenosol] regions and from two areas of the Bükkalja Region [Cambisol]) with 3 land-use types (from plough-land, grassland and forest). Average samples consisting of 10 sub-samples for each land use types were collected from the upper 20 cm layer of soils from all habitats, of which after homogenisation 0.5 kg was used in each small-pot. 4 repetitions were applied with ryegrass (*Lolium perenne*) as test plant in the experiment. Both a control and a treated small-pot sequence were set. To the treatment, 5 $mg \cdot kg^{-1}$ Cd ($ZnCl_2$) and 5 $mg \cdot kg^{-1}$ Zn ($Cd(NO_3)_2$+$4H_2O$) were used. It should be noticed that the additional amount of zinc means a small quantity (it was about the 1/10 of the soil zinc content) but in the case of cadmium it was relevant, about 50 times of cadmium content like in soil. Plants were irrigated under controlled circumstances with distilled water. Plants were cut in the stage of their intensive tillering four weeks after their starting up, they were dehumified and the dry samples were weighed. Following this, the metal content of plant samples were detected. Granulometrical composition, organic matter content (OM), humus quality, pH_{H2O}, pH_{KCl}, HAC, EAC and U% were determined from the soil samples. Heavy metal content (Al, Ca, Cd, Cr, Cu, Fe, Mg, Mn, Ni, P, Pb, Zn) of the soil and plant samples were determined with cc. H_2O_2+HNO_3-digestion, ICP-AES method according to *MSZ-08-1722-3:1989* Hungarian Standard. Statistical analysis was carried out using ANOVA (Tukey HSD) and correlation analysis with SPSS software. Normality was tested with Kolmogorov-Smirnov test.

Results and discussion

The habitats regarding the studied soil characteristics are significantly different from each other ($p<0.05$) with the exception of the two Cambisols where except of the pH no difference was found. In the case of land use, significant difference was found between the ploughland and forest types ($p<0.05$), as organic matter content and HAC were higher while pH was lower in the case of forests.

The amount of zinc and cadmium taken up by plants is shown in Figure 1 and 2. Characterisation was carried out by soil types and land use categories.

No significant difference was found in the control samples regarding either the zinc or the cadmium taken up in the plants for the studied soil types. Following treatment, however, significant difference was detected. Zinc content of the individuals grown on Arenosol did not show significant difference ($p<0.05$) from the remaining three types nor Chernozem differed ($p<0.05$) from Cambisol II. In the case of cadmium, Chernozem did not show difference ($p<0.05$) from Cambisol I, but a difference was found for all the other types. By the metal concentration uptake of plants, by soil types, no sequence can be set for cadmium except for the treated sequence: here, plants grown on Cambisol I and Chernozem soils accumulated 2.5 $mg \cdot kg^{-1}$, whereas those grown on Cambisol II and Arenosol accumulated 4.2 $mg \cdot kg^{-1}$. For zinc, in the control sequences, individuals grown on Cambisol I and Arenosol soils it amounted ca. 50 $mg \cdot kg^{-1}$, whereas 80 $mg \cdot kg^{-1}$ for Cambisol II and Chernozem soils; in the treated sequence, the order was modified and became more destinctive: Cambisol I (102 $mg \cdot kg^{-1}$), Arenosol (149 $mg \cdot kg^{-1}$), Chernozem (170 $mg \cdot kg^{-1}$) and Cambisol II (195 $mg \cdot kg^{-1}$).

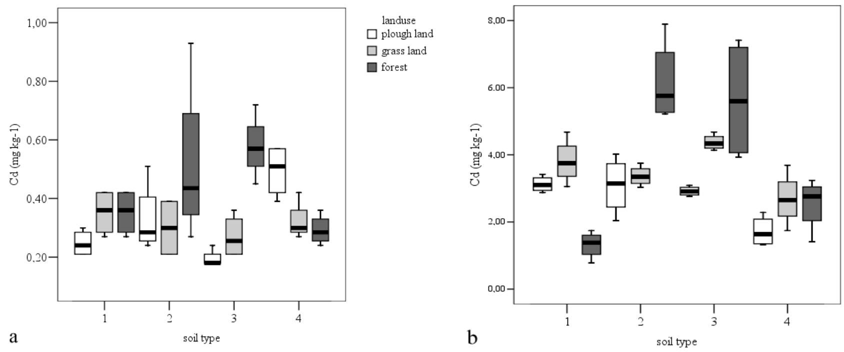

Figure 1. Cadmium uptake of ryegrass by soil types and land-use categories (a: control; b: treated; 1: Cambisol I.; 2: Arenosol; 3: Cambisol II; 4: Chernozem)

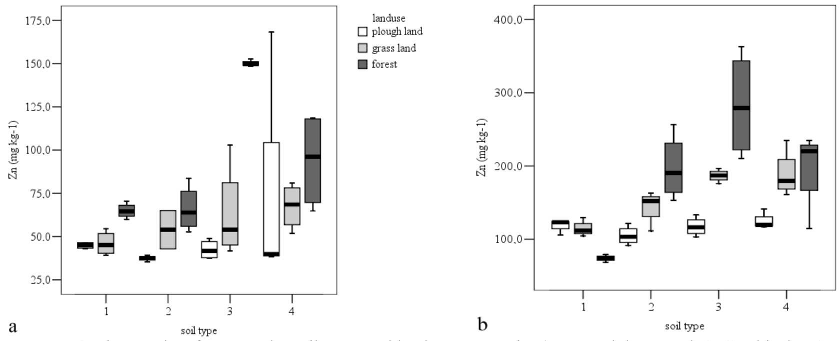

Figure 2. Zinc uptake of ryegrass by soil types and land-use categories (a: control; b: treated; 1: Cambisol I.; 2: Arenosol; 3: Cambisol II; 4: Chernozem)

By land-use, in the case of the control samples, zinc content of the individuals grown on the soils of ploughlands and grasslands was significantly different ($p<0.05$) compared to that of forests whereas in the case of the loaded samples, significant difference was only found between the plants grown on the soils of ploughlands and forests. Land-use did not influence the cadmium content of plants: no significant difference was found either in the case of the control samples or in that of the treated samples. Regarding quantity, a series of plough-land<grassland<forest can be set for both metals (control: Cd $[mg\cdot kg^{-1}]$: 0.31<0.31<0.42; Zn $[mg\cdot kg^{-1}]$: 49<58<90; treated: Cd $[mg\cdot kg^{-1}]$: 2.71<3.55<3.91; Zn $[mg\cdot kg^{-1}]$: 116<158<187 respectively). Thus it can be concluded that the amount of zinc taken up by plants was the lowest in the soils of plough-lands whereas the highest was in the case of the soils of forests.

A correlation analysis was carried out on the amount of metals taken up and soil characteristics. Correlation between zinc and cadmium taken up by the plants was found to be close ($r=0.84$, $p<0.05$), due to the similar characteristics of the two metals. This was later on, controlled by partial correlation. According to the results of the partial correlation study (controlled for Cd and Zn), the correlation of cadmium with the organic matter content is negative ($r_{plantCd\text{-}OM.Zn}=-0.64$; $p<0.05$), whereas that of zinc is positive ($r_{plantZn\text{-}OM.Cd}=0.71$; $p<0.05$). According to this, cadmium is bound by the organic matter, i.e reduces its accessibility for plants also furthering the uptake of zinc. This phenomenon can be explained by the fact that the most of the zinc (60-75%) are bound by fulvic acid and thus – as fulvic acid is less stable – even root acids are able to mobilise these chelates (Livens, 1991). In contrast to this, cadmium is bound more strongly than zinc and tends to be bound to polymerised humus materials with longer coal chain from which it can be mobilised with great difficulty, (it is in accordance with Piotrowicz et al. 1984 and Sedlacek et al. 1989). This claim is supported by the sign of correlation in our experiment for the polymerised, NaF-soluble humic acids ($r_{plantCd\text{-}NaF.Zn}=-0.67$; $p<0.05$ and $r_{plantZn\text{-}NaF.Cd}=0.58$; $p<0.05$). The uptake of both metals is reduced by clay content, i.e. inorganic colloids (clay minerals) play an important role in this process ($r_{plantCd\text{-}clay\%.Zn}=-0.78$; $p<0.05$ and $r_{plantZn\text{-}clay\%.Cd}=-0.70$; $p<0.05$).

Conclusions

From the results of the experiment it can be concluded that both the habitat and the soil type found there have an important influence on the amount of metal uptake up, being an especially remarkable influencing factor in the case of zinc. Both the concentrations of zinc and that of cadmium were influenced by what area of land-use the soil in the small-pot was from. Land-use has an infulence on the physical and chemical parameters of the soil (e.g. organic matter accumulation), thus the availability of certain metals may vary. Closely connected to this, it was proved that zinc and cadmium contents are evincibly affected by the decomposition level of humus materials (quality) as well as clay content.

References

Bíró, I., Takács, T. 2007. Study of heavy metal uptake of *Populus nigra* in relation to phytoremediation. Cereal Research Communications **35**: 2. 265-268.

Kádár I. 1991. A talajok és növények nehézfémtartalmának vizsgálata. Környezet- és természetvédelmi kutatások, KTM – MTA TAKI, Budapest, 104 p.

Kádár, I., Kastori, R. 2006. Mikroelem-terhelés hatása a tritikále termésére és elemfelvételére karbonátos csernozjom talajon. Agrokémia és Talajtan **55:** 2. 449-460.

Livens, F. R. 1991. Chemical reactions of metals with humic materials. Environmental Pollution **70:** 3. 183-208.

Piotrowitz, S. R., Harvey, G.R., Boran, D.A., Weisel, C.P., Springer-Young, M. 1984. Cadmium, copper, and zinc interactions with marine humus as a function of ligand structure. Marine Chemistry **14:** 4. 333-346.

Rabnecz Gy., Papp, B., Vegvary, Gy. 2007. Comparison of heavy metal deposition by large scale biomonitoring in Europe and tropical Africa. Cereal Research Communications **35:** 2. 961-965.

Rékási, M., Filep, T. 2006. Effects of microelement loads on the element fraction of soil and plant uptake. Agrokémia és Talajtan **55:** 1. 213-222.

Rékási M., Filep T., Morvai B. 2006. Effect of communal sewage sludge loads on Zn and Cu content of soils and plant uptake. Cereal Research Communications, **34:** 1. 271-274.

Sedlacek, J., Gjessing, E.T., Källquist, T. 1989. Influence of difference humus fractions on uptake of cadmium to alga *Selenastrum capricornutum Printz*. The Science of The Total Environment **81-82:** 711-718.

Wu, J., Norwell, W.A., Hopkins, J.G., Welch, R.W. 2002. Spatial variability of grain cadmium and soil characteristics in a durum wheat field. Soil Science Society of America Journal **66:** 1. 268-275.