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POSSIBILITES OF CADMIUM UPTAKE LOWERING BY SEEDS OF LEGUMES WITH THE APPLICATION OF Zn^{2+} INTO THE SOIL

MOŻLIWOŚĆ ZMIEJSZENIA POBRANIA KADMU PRZEZ NASIONA ROŚLIN STRĄKOWYCH DZIĘKI APLIKACJI JONÓW Zn^{2+} DO GLEBY

Abstract: Cadmium is toxic, carcinogenic element naturally occurring in soil in concentration of about 1 mg · kg^{-1}. High concentrations of cadmium increase its uptake by the plants and lower the yields. One of the ways how to manage with the phytotoxicity of cadmium could be the antagonistic system of cadmium with cations Zn^{2+}, Ni^{2+} and Mn^{2+}.

The system Cd^{2+} and Zn^{2+} was created and added into the soil. We observed the ability of Zn^{2+} cation to eliminate the negative affecting of cadmium in plant nutrition and to lower the cadmium in the dry matter. The gained results show that the addition of single Cd^{2+} ions into the soil (B variant) had negative effect also on the yield amount as well as on observed qualitative parameters of soya and faba beans. In C variant, when both Cd^{2+} and Zn^{2+} cations were added, there was slight yield increasing in both crops observed. By the assessing of Cd content in dry matter of soya and faba beans by the application of both elements (C variant) there was awaited effect of content lowering in the case of cadmium in both crops. While the single Cd^{2+} addition enhanced the content of this metal in soya beans on the value 3.41 mg · kg^{-1}, by common application of Cd^{2+} and Zn^{2+} ions this value presented 0.2 mg · kg^{-1}. In the case of faba in B variant the value 2.45 mg Cd kg^{-1} was determined, but by the application of both Cd^{2+} and Zn^{2+} ions the content was lowered on 1.33 mg Cd kg^{-1}.

Keywords: soya bean, faba bean, cadmium, zinc, accumulation

Compounds of toxic elements belong to harmful substances which could easily get into the soil. Especially cadmium, mercury and arsenic are the most dangerous toxic elements from ecological standpoint [1]. Biological essential microelements in nature could also have toxic effects if they enhance certain concentration [2]. Ecological risks from cummulation of heavy metals in soil are reflected on soil ability to provide hygienic safe foodstuffs.

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The risky elements content in plants is directly dependent on their concentration and availability in the environment and also on the exposure length. Heavy metals affect plants as stress factors. They induce changes or even species extinction. There are some plants which are able to grow on such soils where the concentration of heavy metals is high [3].

Some methods were suggested for the elimination of negative effects of heavy metals in soils. For example, the lowering of heavy metals solubility by pH value increasing, complex melioration based on re-covering of contaminated soil by the layer of non-contaminated soil.

The obvious attention is focused not only to the content of individual heavy metals in the system soil – plant – food, but also to their mutual interactions among individual heavy metals [4].

Cadmium from the health point of view belongs to the heavy metals group whose toxic properties are manifested at relatively low contents. It is glossy white metal, chemically similar to zinc. The food chain contamination by cadmium is associated mainly with the soil contamination [1]. The soil reaction pH and redox potential are crucial factors for the mobility and thus for biological utilisation for plants. Relative mobility of Cd increases in acid and oxidant environment. The physiological effect of abundant amount of cadmium is connected with damage of the photosynthesis process and changes of nitrogen compounds. The Cd^{2+} cations form compounds with cysteine and proteins with structure of methionine. The thiol group of cysteine helps to bind Cd in plants at 11–34 % (at 71 % in corn), the other form of cadmium in plant is present as the free ions [5]. Cadmium has in higher concentrations carcinogenic, mutagenic and teratogenic effects.

Many authors had focused on the interaction of Cd – Zn and with regard on their chemical relationship and their conclusion was that the addition of zinc into the environment lowers the cadmium uptake by plants.

Our work is focused on the effects of bivalent cations of cadmium and zinc in soil. The solo effects of cadmium on plant growing, yield and cummulation ability of soya bean (*Glycine max*) and faba bean (*Faba equine*) have been compared and the influence of the bivalent zinc cations addition to cadmium cations effect has been evaluated.

Material and methods

Biological material. Soya bean (*Glycine max*, *variety KORADA*) – used in this study is characterized by big seed of yellow to green-yellow color with yellow or brown navel. Soya bean is used mainly for its content of qualite proteins.

Faba bean (*Faba vulgaris subsp. Equina*, *variety Stabil C 1*) belongs to legumes as feed. It is grown mainly for beans. It is valuable for high content of nitrogenous compounds. It contains 32–34 % of crude proteins.

The experiment was realized as a pot trial. The plastic pots were bowl shaped with an average of 20 cm and height of 25 cm with perforated bottom. Into pots 6 kg of soil was weighted and the basic nutrients were applicated in form of NPK fertilizer.

In B variant 10 mg Cd in form of bivalent solution $CdCl_2 \cdot 2^1/_2$ (Merci, Bratislava, Slovak Republic) and in C variant 10 mg cadmium and 80 mg zinc in form bivalent solution $ZnSO_4 \cdot 7H_2O$ (Merci, Bratislava, Slovak Republic) per kg of soil was added.

Table 1

Agrochemical characteristic of the used soil [mg · kg^{-1}], the value of exchangeable pH and of active pH

Locality	K	Ca	Mg	P	N	pH_{KCl}	pH_{H_2O}
Vycapy	212.5	1459.5	265.0	19.86	2975.0	4.36	5.98

Table 2

Heavy metals contents of tested soil in extract of HNO_3 [mg · kg^{-1}]

Locality	Zn	Cu	Cd	Pb	Co	Cr	Ni
Vycapy	5.34	9.12	0.22	8.88	1.84	1.92	6.38

Table 3

Characteristics of pot experiment variants

Variants	
A	NPK – control
B	NPK – 10 mg Cd per kg of soil
C	NPK – 10 mg Cd + 80 mg Zn per kg of soil

We evaluated the weight of the overground biomass and the qualitative composition of soya bean and faba bean from the standpoint of the content of risky elements.

The content of cadmium and zinc was determinated after mineralization by dry way by AAS method on apparaturs PYE UNICAM SP 9.

Results and discussion

The results of pot experiments showed the ability of bivalent cations zinc to decrease the cadmium uptake by plants and simultaneously to eliminate its negative influence oi the soya and the faba beans yield. The single cadmium and also the combination of cadmium with zinc were studied.

The weights of yield of soya bean as well as the content of cadmium and zinc in soya and faba beans from qualitative parameters in mg · kg^{-1} on dry matter were determined. The obtained results show that the addition of solo cadmium application (B variant – 10 mg Cd) had the negative effect on the yield and also on the qualitative parameters in both crops. The yield of soya was 12.95 ± 0.37, while in C variant after the application of cadmium and zinc (10 mg Cd + 80 mg Zn) the yield was mildly increased by 18.02 ± 0.49. The similar situation was in faba bean, where in B variant the yield was 12.07 ± 0.32 and after the application of cadmium and zinc ions the yield was 15.06 ± 0.42 (Figs. 1, 2).

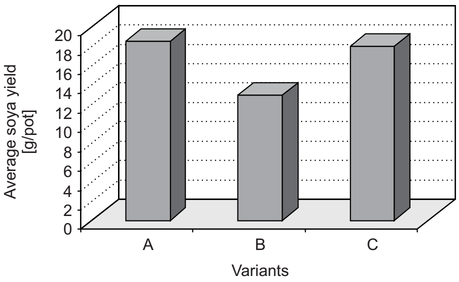

Fig. 1. Soya beans yield after application of Cd and Zn cations

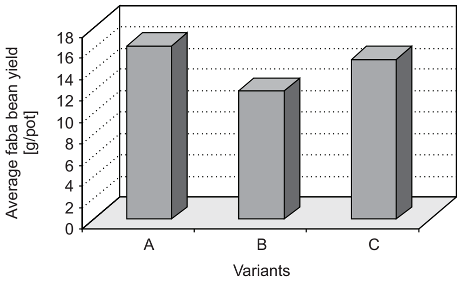

Fig. 2. Faba beans yield after application of Cd and Zn cations

The cadmium content in soya bean and also in faba bean after the application of both ions (C variant) the required effect of cadmium content lowering was observed. While cadmium alone applied had increased its content in soya beans on the value 3.41 ± 0.45, the application of cadmium and zinc ions this value was 0.2 ± 0.045. In Faba bean there was in B variant the value 2.45 ± 0.37 mg Cd $\cdot$ kg^{-1} and in C variant 1.33 ± 0.32 mg Cd $\cdot$ kg^{-1} (Figs. 3, 4).

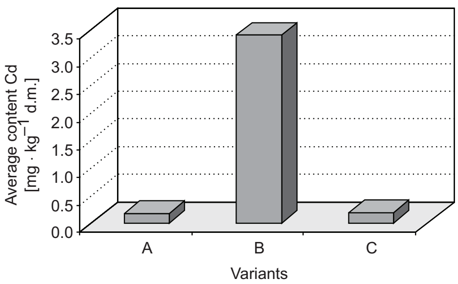

Fig. 3. Content of Cd [mg $\cdot$ kg^{-1} d.m.] in soya bean

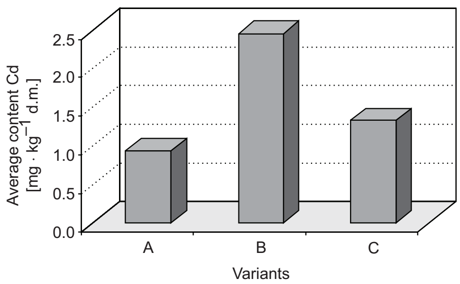

Fig. 4. Content of Cd [mg $\cdot$ kg^{-1} d.m.] in faba bean

Applying zinc ions into the soil to eliminate negative effects we naturally focused on its content in dry matter of plants. The assessed values of zinc present 50.09 ± 1.23 mg Zn $\cdot$ kg^{-1} by application of cadmium alone in soya, in faba bean 39.94 ± 0.9 mg Zn $\cdot$ kg^{-1} and in C variant these values were in soya 79.16 ± 1.88 mg Zn $\cdot$ kg^{-1} and 85.91 ± 2.01 mg Zn $\cdot$ kg^{-1} in faba bean (Figs. 5, 6).

Our results can not be uniformly assigned to the effect of zinc cations, because the plant reaction on zinc presence widely vary and depends on plant species and variety, cadmium content in soil, doses and mutual combination of cadmium and added zinc cations, as well as on many other factors but can indicate cadmium accumulation as well as preventive effect of zinc.

The content of risk elements with high biotoxicity level belong to the most important monitored soil parameters [6]. Monitoring is focused on risk elements mentioned in legislative hygienic directives [7]. Total content includes all forms, in which certain

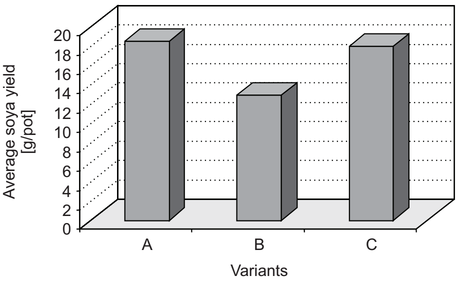

Fig. 5. Content of Zn [mg · kg^{-1} d.m.] in soya bean

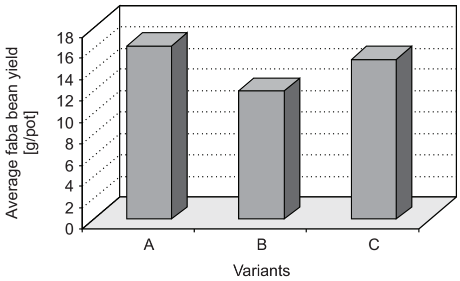

Fig. 6. Content of Zn [mg · kg^{-1} d.m.] in faba bean

element in soil is occurring. It is basic information about natural element content in soil enriched in content aroused from immissions. For evaluating of soil hygienic state it has low importance, because the prevailed part of total risk elements content is formed by other non-soluble and/or less soluble forms [8]. High importance has the determination of total risk elements content only in the case of strongly contaminated or devastated soils, where the highest rate of correlation between their content in plant and in soil takes place.

Many works [9, 10] have been written about the study of interaction of heavy metals, especially the one of Cd – Zn mainly to their chemical relationship. The conclusions of these works are not at all uniform. By [11] the addition of zinc into the environment lowers the Cd uptake by plants, by others [3, 12] the mechanisms of the uptake of zinc and cadmium by plants are depending on each other and it comes to equal uptake of both elements in conditions of their high accumulation in soil [13].

It is believed that the interaction of Cd – Zn is based on competitive inhibition when Cd and Zn compete in active centres of carriers.

Our research has been focused on the interaction of Cd – Zn. While in C variant we increased in both cases the content of potentially available zinc from value 51.5 mg · kg^{-1} (A variant) on the value 131.5 mg · kg^{-1}. This increase was observed for soya as well as for faba bean. It presented 50 % in the soya beans and even 150 % in the horse beans when compared with the control variant.

Zinc uptake by plants is realized in the form of Zn^{2+} and it depends on soil pH reaction. When hydrogens ions concentration increases the zinc availability increases.

In most of plants the zinc content is in range 25–100 mg · kg^{-1}.

Zinc in plants is accumulated mainly in roots, in higher concentrations is phytotoxic. Its mobility mainly in older plant overground biomass is inhibited. Zinc is the activator and stabilizator of many enzymes. Zinc has also an effect on biological active substances forming.

Conclusion

The soil contamination reflects the content of risky elements in vegetation including agricultural soils. It is necessary to find solution which will in some way minimalize the enter of dangerous heavy metals from agricultural soils into the food chain. Our work was focused on the effects of influence of bivalent cations cadmium and zinc as one of the many ways of elimination of negative effects of cadmium. We found out that the dose 80 mg Zn · kg^{-1} had the positive influence on qualitative and quantitative parameters of soya and faba beans.

Acknowledgement

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MOŻLIWOŚĆ OBNIŻENIA POBRANIA KADMU PRZEZ NASIONA ROŚLIN STRĄKOWYCH DZIĘKI APLIKACJI JONÓW Zn^{2+} DO GLEBY

Abstrakt: Kadm jest toksycznym i rakotwórczym pierwiastkiem występującym w glebie w stężeniu wynoszącym około 1 mg · kg^{-1}. Kadm jest łatwo wychwytywany przez rośliny, co prowadzi do obniżenia plonów. Jednym ze sposobów zmniejszenia wychwytu kadmu przez rośliny może być wykorzystanie antagonizmu między jonami Cd^{2+} a jonami Zn^{2+}, Ni^{2+} i Mn^{2+}. W prezentowanych badaniach obserwowaliśmy zdolność jonów Zn^{2+} do obniżenia kumulacji jonów Cd^{2+} przez rośliny strączkowe oraz zmniejszenia szkodliwego wpływu Cd^{2+} na odżywianie badanych roślin. Uzyskane wyniki wykazują, że dodanie jonów kadmu do gleby (wariant B) miało negatywny wpływ na ilość plonów oraz badane parametry jakościowe soi oraz bobu. Dodanie do gleby jonów Zn^{2+} oraz Cd^{2+} (wariant C) spowodowało niewielki wzrost plonów w obu obserwowanych uprawach. Dodanie jonów Zn^{2+} do gleby spowodowało zmniejszenie zawartości Cd^{2+} u obydwóch badanych gatunków roślin. Ziarna soi rosnące w glebie z dodatkiem kadmu zawierały w suchej masie kadm w stężeniu 3,41 $mg \cdot kg^{-1}$. Obecność w glebie jonów Zn^{2+} spowodowało obniżenie zawartości Cd w suchej masie nasion soi do 0.2 $mg \cdot kg^{-1}$. W przypadku bobu rosnącego w glebie zawierającej kadm (wariant B) zawartość Cd^{2+} w suchej masie nasion wynosiła 2,45 $mg \cdot kg^{-1}$. Jony Zn^{2+} dodane do gleby zmniejszały zawartość Cd^{2+} w suchej masie nasion bobu do 1,33 $mg \cdot kg^{-1}$.

Słowa kluczowe: nasiona soi, nasiona bobu, kadm, cynk, kumulacja