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EFFECT OF Cd-Se INTERFERENCE ON CADMIUM AND SELENIUM BIOACCUMULATION IN PEA SEEDLINGS

EFEKT INTERFERENCJI Cd-Se NA AKUMULACJĘ KADMU I SELENU WE WSCHODACH GROCHU

Summary: Effect of three cadmium compounds ($CdSeO_4$, $CdSeO_3$ and $Cd(NCSe)_2(nia)_2$) containing Se in different oxidation states were used for experiments. Pea seedlings (cv. Felix) cultivated in hydroponic solutions under control conditions were treated with the above-mentioned compounds for two weeks ($c = 3 \div 120$ μmol dm^{-3}). Then root and shoot dry mass was estimated and the concentrations of Cd and Se in plant organs were determined using AAS. Bioaccumulation factors related to both investigated elements (Cd, Se) as well as translocation factors were evaluated. Higher compound concentrations were toxic and desiccation of the shoots was observed. Cd concentration in the roots reached higher levels than in the shoots and accumulated Cd amount in plant organs increased with increasing Cd concentration. Whereas treatment with $CdSeO_3$ and $Cd(NCSe)_2(nia)_2$ resulted in expressively higher Se concentration in roots, for $CdSeO_4$ treatment Se concentration in shoots exceeded Se concentration in the roots. Therefore treatment with $CdSeO_4$ resulted in much higher mobility of Cd and Se within the plants than the treatment with $CdSeO_3$ and $Cd(NCSe)_2(nia)_2$.

Keywords: bioaccumulation, cadmium**,** *Pisum sativum* L., selenate, selenite, translocation

Cadmium is toxic metal which is relatively mobile in plants where it can influence mineral nutrition and negatively affects plant growth and development [1, 2]. The main basis of Cd toxicity in biological systems lies in its strong affinity for SH-containing ligands, particularly polythiols. Cd is considered to target zinc metalloenzymes, membrane phospholipids and oxidative phosphorylation [3], so causing impairment of cell respiration, inhibition of enzyme activities and protein denaturation [4]. Cd also causes serious damage of plant photosynthetic apparatus [5]. Cadmium interferes with some essential elements (*eg* Zn, Fe), including Se [6]. It was previously found that in crops Se is mainly taken up in the form of selenate(VI) or selenate(IV) and that Se in form of Se(VI) is more mobile within the plants than Se(IV) [7]. Shanker et al. [8] found that the presence of sodium selenate(VI) and sodium selenate(IV) reduced Cd accumulation in maize shoots. According to Whanger [9], the presumed protective effect of Se against cadmium and mercury toxicity is through the diversion in their binding from low-molecular-mass proteins to higher-molecular-mass ones.

This study is aimed to investigate the effect of some Cd compounds on production characteristics as well as on Cd bioaccumulation in plant organs of *Pisum sativum* L. and to determine the influence of selenium oxidation state on Cd and Se bioaccumulation capacity.

Material and methods

For experiments following compounds were used: $CdSeO_3$, $CdSeO_4$ and $Cd(NCSe)_2(nia)_2$. These compounds were prepared according to Kráľová et al. [10].

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Analytical reagent-grade chemicals purchased from Lachema (Brno, CZ) were employed for the preparation of all solutions. Freshly distilled water was used in all experiments.

For cultivation of experimental plants the seeds of *Pisum sativum* L., cv. Felix were used. The seeds of pea were placed on the surface of filter paper wetted with distilled water and after 72 hours exposure at mean air temperature (25 ±0.5ºC) the seedlings were exposed in hydroponia for 14 days in controlled conditions (mean air temperature: 25 ±0.5°C, relative air humidity: 80% and photosynthetic active radiation: 80 μmol m^{-2} s^{-1}): control variant in Knop solution and metal treated variants in Knop solution containing 3, 6, 12, 24 and 60 μmol dm^{-3} of the studied compounds. Then the dry mass of shoots and roots were estimated. FAAS (Perkins Elmer 110, USA) was used for determination of Cd and Se contents in shoots and roots of studied plant species.

Results and discussion

Dry mass of roots and shoots of pea plants decreased with the increasing concentration of the studied compounds (Fig. 1). However, higher compound concentrations (60 and 120 μmol dm^{-3}) were toxic and desiccation of the shoots was observed.

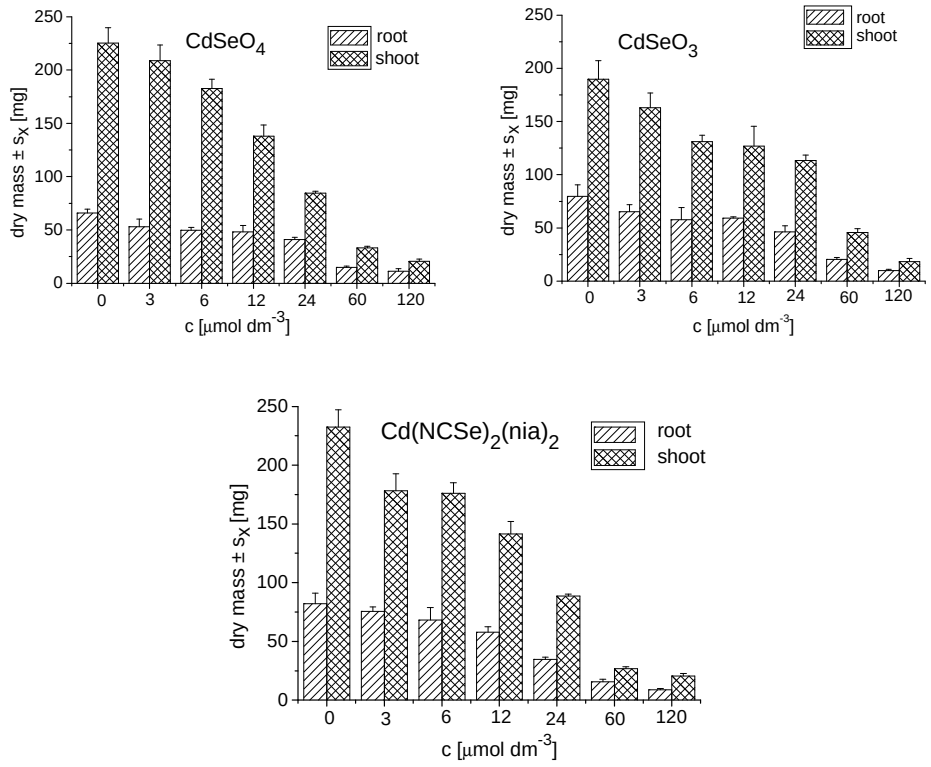

Fig. 1. Dry mass of roots and shoots of pea plants treated with the studied compounds

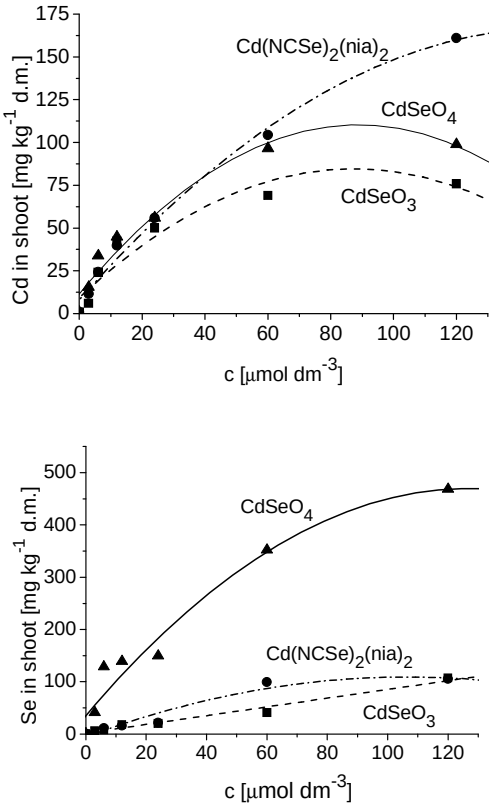

Fig. 2. Cd and Se shoot concentrations after treatment with studied compounds

Cd concentration in the roots reached higher levels than in the shoots and accumulated Cd amount in plant organs increased with increasing Cd concentration. The dependence of bioaccumulated Cd and Se amount in the shoots on the concentration of studied compounds is shown in Figure 2. It is evident that the lowest Cd bioaccumulation in the shoots caused treatment with $CdSeO_3$ whereas the highest Cd concentration was determined after treatment with $Cd(NCSe)_2(nia)_2$. On the other hand, treatment with $CdSeO_4$ resulted in expressively higher Se concentration in shoots than the treatment with $CdSeO_3$ and $Cd(NCSe)_2(nia)_2$ and Se concentration in the shoots exceeded Se concentration in the roots.

The bioaccumulation factors (BAF) related to Cd bioaccumulation in pea roots ranged from 108.6 to 333.0 for $CdSeO_4$, from 170.1 to 726.5 for $CdSeO_3$ and from 327.7 to 705.8 for $Cd(NCSe)_2(nia)_2$ and those related to Se bioaccumulation in pea roots ranged from 34.6 to 158.7 for $CdSeO_4$, from 90.5 to 435.7 for $CdSeO_3$ and from 33.8 to 629 for $Cd(NCSe)_2(nia)_2$.

The corresponding BAF values related to Cd bioaccumulation in pea shoots ranged from 7.3 to 50.0 for $CdSeO_4$, from 5.6 to 35.6 for $CdSeO_3$ and from 11.9 to 35.9 for

$Cd(NCSe)_2(nia)_2$ and those related to Se bioaccumulation in pea shoots ranged from 49.4 to 173.8 for $CdSeO_4$, from 8.7 to 25.9 for $CdSeO_3$ and from 5.6 to 16.9 for $Cd(NCSe)_2(nia)_2$.

In general, BAF values decreased with the increasing Cd (Se) concentration. However, increase of BAF values determined for pea roots at higher $CdSeO_4$ and $Cd(NCSe)_2(nia)_2$ concentrations (60 and 120 μmol dm^{-3}, respectively) indicated damage of root cells by Cd connected with uncontrolled ion uptake. At the lowest applied compound concentration (3 μmol dm^{-3}) values of BAF for shoots confirmed interactive effects of Cd and Se resulting in reduced Cd uptake in case of $CdSeO_3$ treatment and reduced Se uptake in case of $CdSeO_4$ treatment.

It could be concluded that selenium oxidation state in studied compounds significantly affected bioaccumulation of Cd and Se in pea plants and treatment with $CdSeO_4$ resulted in much higher mobility of Cd and Se within the plants than the treatment with $CdSeO_3$ and $Cd(NCSe)_2(nia)_2$. Due to $CdSeO_4$ treatment up to 38% of Cd and 89% of Se from the total accumulated metal amount by the plant was accumulated in the shoots whereas these values for $CdSeO_3$ and $Cd(NCSe)_2(nia)_2$ reached only 18% for both Cd and Se. The obtained results are in accordance with our previous results [10, 11] as well as with the findings of Arvy [7] and Shanker et al. [8, 12].

Acknowledgements

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Streszczenie: W eksperymencie wykorzystano trzy związki kadmu ($CdSeO_4$, $CdSeO_3$, $Cd(NCSe)_2(nia)_2$), zawierające Se w różnych stopniach utlenienia. Wschody grochu uprawiane w wodzie w warunkach laboratoryjnych były traktowane wymienionymi związkami przez dwa tygodnie ($c = 3 \div 120\ \mu mol \cdot dm^{-3}$). Następnie w próbkach korzeni i pędów roślin oznaczano stężenia Cd i Se z pomocą AAS. Dokonano oceny bioakumulacji i czynników wpływających na przemieszczanie się badanych pierwiastków. Większe stężenie związków były toksyczne i powodowały wysuszenie pędów roślin. Stężenia Cd w korzeniach były większe niż w pędach roślin, a stężenie zakumulowanego Cd w organach rośliny zwiększało się wraz ze wzrostem stężenia Cd. Podczas działania $CdSeO_3$, $Cd(NCSe)_2(nia)_2$ wyniki wyraźnie wskazywały, że stężenie Se w korzeniach wzrosło, podczas działania związkiem $CdSeO_4$ stężenie Se w pędach było większe od stężenia Se w korzeniach. Zatem w wyniku działania $CdSeO_4$ ma miejsce większa kumulacja Cd i Se w roślinie niż podczas działania związkami $CdSeO_3$ i $Cd(NCSe)_2(nia)_2$.

Słowa kluczowe: bioakumulacja, kadm, *Pisum sativum L.*, selenian, selenin, przemieszczanie