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Effects of Heavy Metals on Chemical Composition of *Camelina sativa* L.

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Abstract

Camelina (*Camelina sativa* L.) is studied mostly as oil plant that can replace oilseed rape in the extensive agriculture. It is a good source of oil (40% oil in seeds) similar to sunflower, soybeans, canola, castor been and other oil crops. Oil of camelina is rich in essential omega 3 fatty acids. In addition, seed protein content is relatively high. Camelina has modest requirements for agro-ecological conditions and it is highly resistant to pathogens. Those features make camelina suitable for human nutrition and animal feed. Its use is related to sustainable agriculture, bio-diesel industry, cold-pressed oils and the use of so-called marginal land. Examination of its ability to uptake and accumulate heavy metals (HM) is interesting from the standpoint of 1) food safety and 2) potential for phytoremediation. Hence, the aim of this study was to investigate the effect of HM on uptake and accumulation of some essential macro- and micronutrients and unwanted HM. Experiments were done with *Camelina sativa* L., cultivar Stepski 1. The seeds were exposed to 1 µM Cd or Cu and 10 µM Ni or Zn since the beginning of germination. Plants were grown in water cultures, in semi-controlled conditions of a greenhouse, on ½ strength Hoagland solution to which were added HM in the same concentrations as during germination. Concentrations and distribution of Ca, Mg, P, K, Fe and Mn in roots and shoots were altered in the presence of increased concentration of Cd, Cu, Ni and Zn.

Key words: camelina, Cd, Ni, Cu, Zn, essential macronutrients, micronutrients

Introduction

Cruciferous species *Camelina sativa* L. (also known as false flax, Gold of Pleasure, camelina or German sesame) was a quite common crop in Europe and North America until the middle of the last century, but since then has been continually losing in importance so that it is now virtually unknown in Europe (Gehringer, 2010). As the interest in renewable energy has increased greatly, this summer annual oil plant has become topical again. Camelina is studied mostly as oil plant that can replace oilseed rape in the extensive agriculture. It is a good source of oils; it contains about 41.41% of oil depending on conditions, location and N nutrition (Müller, 2001). Camelina is similar to sunflower, soybeans, canola, castor been and other oil crops. Oil of camelina is rich in essential omega 3 fatty acids (Müller et al., 1999). In addition, seed protein content is relatively high. Camelina has modest requirements for agro-ecological conditions (Makowski, 2003). An important feature of camelina is its high level of resistance against insect pests and plant pathogens and low doses of nutrients (Volmann et al., 1996, 2005; Ceccarelli, 1996). Camelina is suitable for human nutrition and animal feed. Its use is related to sustainable agriculture, bio-diesel industry, cold-pressed oils and the use of so-called marginal land. The comparatively short vegetation period of approximately 120 days makes it particularly suitable as an alternative annual crop for production of renewable energy within tight crop rotations (Agegnehu & Honermeier 1997; Müller & Friedt 1998; Müller et al., 1999). Examination of camelina ability to uptake and accumulate heavy metals (HM) is interesting from the standpoint of 1) food safety and 2) potential for phytoremediation. Hence, the aim of this study was to investigate the effect of HM on chemical composition of camelina.

Materials and methods

Plant growth

Before sowing, seeds were kept for 24 h in deionized water (control), 1 μM Cd (as $CdCl_2$) or Cu (as $CuSO_4x5H_2O$) and 10 μM Ni (as $NiSO_4$) or Zn (as $ZnSO_4x7H_2O$) dissolved in deionized water. Seeds were germinated in the quartz sand, in an incubator, at 26°C. Seedlings were planted in pots containing ½ strength Hoagland nutrient solution (Hoagland & Arnon, 1950) (control) to which were added Cd or Cu to final concentration of 1 μM and Ni or Zn to final concentration of 10 μM, respectively. Each treatment was set in 5 replications with 8 plants per replication. Nutrient solution was changed every other day and aerated regularly. Plants were grown for 30 days.

Plant analyses

Concentrations of K, Ca, Mg, Fe, Cu, Zn, Mn, Ni and Cd were determined by atomic absorption spectrophotometry (AAS SHIMADZU AA-6300), after ashing plant material at t = 500° C and dissolving in deionized hot water in the presence of 0.25 M HCl. P concentration was determined spectrophotometrically, by the ammonium vanadate-molybdate method.

Results and discussion

A certain number of plants belonging to the family Brassicaceae have hyperaccumulative properties (Lagercrantz et al., 1998; Paterson et al., 2001). For this reason a large number of studies focused on the possibility of using plants from this family for phytoremediation (Zeremski, 2011). Rapeseed belongs to the same family as *Arabidopsis thaliana* and *Thlaspi caerulescens,* plants that are known as hyperaccumulators of Zn and Cd (Lagercrantz et al., 1998; Paterson et al., 2001; Lombi et al., 2001; Roosens et al., 2003). The ability of this species to accumulate in shoots high concentrations of Zn and Cd was confirmed by experiments of Grispen et al. (2006), while Angelova et al. (2008) experimentally found potential of *Brassica napus* for phytoremediation of soils contaminated by Pb and Cd. The ability of *Brassica juncea* to accumulate in shoot high concentration of Cd was the research subject of many scientists in the last ten years (Banuelos et al., 2005; Ghosh & Singh, 2005). Because of that, analyzes of effects of excess essential (Cu and Zn) and non-essential (Cd and Ni) elements on chemical composition of *Camelina sativa* contributes to advance knowledge on species belong to the family *Brassicaceae*.

Heavy metals in camelina had great influence on concentration of essential macronutrients (Figure 1). Largest changes were in the presence of Cd compared with control plants. Minor changes were observed in presence of Cu. Uptake of Ca in rice was decreased by Zn treatment (Fageria, 2002). In common bean, uptake of Mg was increased by Zn application, whereas, uptake of P was decreased. The same results were obtained in camelina.

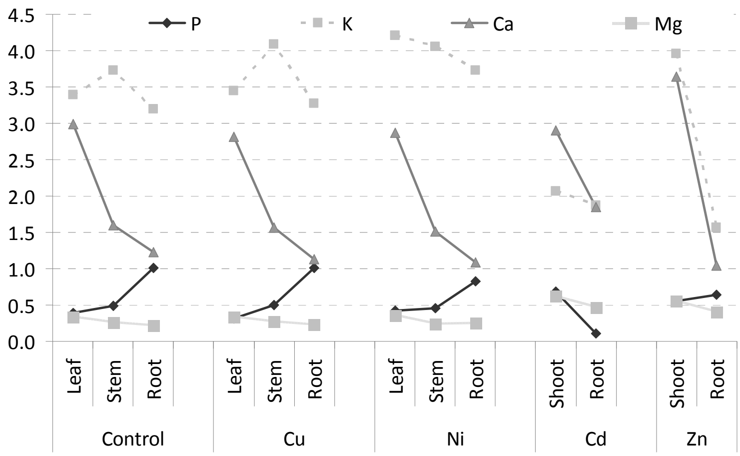

Fig. 1. Concentration (in % in DW) of P, K, Ca and Mg in above-ground parts and roots of camelina grown in the presence of Cu, Ni, Cd or Zn
Koncentracija (u % u DW) P, K, Ca i Mg kod nadzemnih delova i korenova lanika gajenog u prisustvu Cu, Ni, Cd ili Zn

In presence of Ni concentration of Zn was higher in the stem than in the leaf, whereas in the presence of Cu and in the control Zn concentrations in leaves and stems were almost equal (Fig. 2 (A)). Concentration of Mn in leaves declined in the presence of Ni and especially Cu with respect to the control. Those differences were smaller in stems (Fig. 2 (A)). As expected, significant increase in concentration of Ni, Cu, Zn and Cd in shoot, was observed plants treated with those metals.

The very high levels of accumulated metals is often result growth on metal-enriched soils. Genetically, metal accumulation is independent of metal tolerance (Assun *et al.* 2006), and under regulation of a small number of other genes (Macnair et al., 1999). Therefore, it is not possible to conclude that a plant with an increased metal concentration in leaves is also tolerant to that metal. Metal concentration in leaves *per se* can only be taken as an indication of a plant's potential tolerance to that metal, but not as evidence of tolerance itself, (Ernst, 2006).

Concentration of Fe increased in root by Cu treatment, while concentration of Mn decreased in presence of Ni (Fig. 2 (B)). Cu toxicity to plants is relatively low, because they have a number of protective mechanisms that protect excessive Cu uptake and Cu translocation (Merian et al., 2004). In this experiment, the presence of Cu concentration of Fe, Mn and Zn was altered less than in the presence of Zn, Ni and Cd in both shoots and roots.

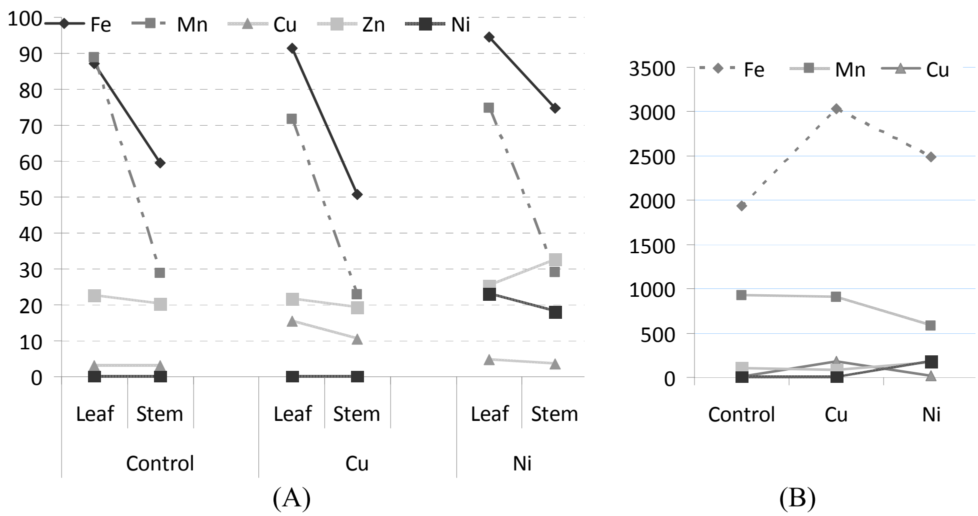

Fig. 2. Concentration (in mg kg^{-1} DW) of Fe, Mn, Cu, Zn and Ni in leaves and stems (A) and roots (B) of camelina grown in the presence of Cu or Ni

Koncentracija (u mg kg^{-1} DW) Fe, Mn, Cu, Zn i Ni u lišću i stabljikama (A) i korenovima (B) kod lanika gajenog u prisustvu Cu ili Ni

Poor translocation of Cu from roots to shoots found in many plant species (Chaignon et al., 2002; Liu et al., 2001) is also found in camelina (Fig. 2). The highest concentration of Cu in shoot is a feature of intensive growth phase (Kabata-Pendias & Pendias, 2003).

Tab. 1. Concentration (in mg kg^{-1} DW) of Fe, Mn, Cu, Zn and Cd in camelina grown in the presence of Zn or Cd
Koncentracija (u mg kg^{-1} DW) Fe, Mn, Cu, Zn i Cd kod lanika gajenog u prisustvu Zn ili Cd

Treatment *Tretman*		Fe	Mn	Cu	Zn	Cd
Control *Kontrola*	Shoot *Izdanak*	73.26	58.83	3.11	21.38	1.17
	Root *Koren*	1939.88	920.83	11.80	103.10	3.56
Zn	Shoot *Izdanak*	75.48	142.91	12.60	833.33	-
	Root *Koren*	3733.33	90.96	67.63	9633.33	-
Cd	Shoot *Izdanak*	257.22	62.29	11.12	78.21	181.80
	Root *Koren*	9685.90	116.45	51.07	319.02	1929.49

In the presence of Zn and Cd concentration of Cu increased four to six times, while in the presence of Cd concentration of Fe and Zn increased more than threefold (Tab. 1). Increase in concentrations of essential elements (not added as a tretament) may be explained by severe reduction in fresh and dry weight in the plants treated with Cu and Ni and especially Cd and Zn.

Matthaus and Zubr (2000) concluded that generally even very low content of Cd and a low content of Zn and Ni, could make adverse effects on biological value of camelina and may make it unsiutable for animal feed. The specific role of Zn in metabolism and its presence in camelina oil seed cakes (CSOC) can be considered as an advantage supporting the acceptance of CSOC as a component of fodder mixtures.

Conclusion

Apart from applied HM, concentrations and distribution of Ca, Mg, P, K, Fe and Mn in roots and shoots were also altered. Concentrations of Fe, Cu, Zn and Ni increased in presence of Cd and Zn. Cu and Ni did not provoke large changes in concentrations of macroelements. Concentrations of Ni, Zn and Cd increased substancially after their application, suggesting that *Camelina sativa* can be considered for phytoremediation.

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Uticaj teških metala na hemijski sastav *Camelina sativa* L.

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Sažetak

Lanik (*Camelina sativa* L.) je vrsta koja je interesantna prvenstveno kao uljana kultura, koja može da zameni uljanu repicu u ekstenzivnoj poljoprivrednoj proizvodnji. Seme lanika sadrži 40% ulja i po tome je lanik sličan suncokretu, soji, uljanoj repici, ricinusu i drugim uljanim kulturama. Ulje lanika je bogato esencijalnim omega 3 masnim kiselinama. Osim uljem, seme je bogato i proteinima. Lanik ima umerene zahteve za agroekološkim uslovima i veoma je otporan na bolesti. Ove osobine ga čine pogodnim za ishranu ljudi i životinja. Upotreba lanika je uglavnom vezana za održivu poljoprivredu, industriju biodizela, hladno ceđenih ulja i korišćenje tzv. marginalnih zemljišta. Ispitivnje svojstava lanika vezanih za intenzitet usvajanja i nakupljanja teških metala (TM) je interesantan sa dva stanovišta: 1) zdravstvene bezbednosti hrane i 2) mogućnosti za korišćenje lanika u fitoremedijaciji. Zbog toga je cilj ovog rada bio da se ispita uticaj TM na usvajanje i akumulaciju nekih neophodnih makro- i mikroelemenata, kao i nepoželjnih teških metala. Ogledi su izvedeni na *Camelina sativa* L., sorta Stepski 1. Seme je naklijavano u prisustvu 1 μM Cd ili Cu i 10 μM Ni ili Zn. Biljke su gajene metodom vodenih kultura, u polukontrolisanim uslovima staklenika, na ½ koncentrovanom hranljivom rastvoru po Hoagland-u, kome su dodavani TM u istim koncentracijama kao i tokom naklijavanja semena. Koncentracija i distribucija Ca, Mg, P, K, Fe i Mn u nadzemnom delu i korenu je takođe promenjena pod uticajem primenjenih koncentracija Cd, Cu, Ni i Zn.

Key words: lanik, Cd, Ni, Cu, Zn, neophodni makroelement, mikroelementi

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