

POSSIBILITIES OF CADMIUM REDUCING IN ANIMAL FOOD BY SOIL, LIMING AND GENOTYPE

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The harmful elements monitoring, particularly Cd, have become important for environmental protection. Very low concentrations of Cd in dry matter of plant tissues were found under non-polluted environment of the eastern Croatia. With that regard, differences were found in maize leaves as affected by soil type (averages of ten hybrids) from 0.09 and 0.14 ppm Cd, for acid and neutral soil (pH in KCl 4.10 and 6.81), as well as among genotypes from 0.07 to 0.18 ppm Cd. Grain-Cd in maize were considerably lower and below detection limit (<0.02 ppm Cd). Liming is usual recommended management practice for acid soils fertility improvement. Beside effects on crop yields, liming is useful management practice for decreasing Cd transfer into food chain. In the liming experiment on acid soil, we found in maize leaves (2-year averages) 0.17 and 0.09 mg Cd kg⁻¹, for control and averages of four liming treatments, respectively. Differences were found also between two growing seasons (0.10 and 0.07 ppm Cd, respectively). Also, considerably impact of liming on decreases of Cd in alfalfa hay was found (0.113 and 0.047 ppm Cd, for 0 and 20 t·ha⁻¹ of lime).

Key words: cadmium; maize; alfalfa hay; soybean; soil effect; genotype effect; liming effect

МОЖНОСТИ ЗА НАМАЛУВАЊЕ НА КАДМИУМОТ ВО ХРАНАТА ЗА ЖИВОТНИ ПРЕКУ ПОЧВАТА, КАЛЦИФИКАЦИЈАТА И ГЕНОТИПОТ

Мониторингот на штетните елементи, особено Cd (кадмиумот), стана важен за заштитата на животната средина. Многу ниски концентрации на Cd во сувата материја на растителното ткиво беа утврдени во загадена животна средина во источна Хрватска. Во овој поглед има разлики кај листовите на пченка во зависност од типот на почвата (просечно десет хибриди) од 0,09 и 0,14 ppm Cd за кисела и неутрална почва (pH во KCl 4,10 и 6,81), како и меѓу генотиповите од 0,07 до 0,18 ppm Cd. Концентрацијата на кадмиум во пченкарното зрно беше значително пониска и под лимитот на детекција (<0,02 ppm Cd). Калцификацијата е вообичаена практика која се препорачува за подобрување на плодноста на киселите почви. Покрај ефектот врз приносот, калцификацијата е корисна и за намалување на трансферот на Cd во синцирот на исхрана. Во експериментот за калцификација на кисела почва, во пченкарните листови (во просек 2 години) утврдивме 0,17 и 0,09 mg Cd kg⁻¹, за контрола и просечно четири третмани на калцификација, соодветно. Исто така, разлики утврдивме и помеѓу двете развојни сезони (0,10 и 0,07 ppm Cd, соодветно). Покрај ова, калцификацијата има значајно влијание и за намалување на Cd во сеното од луцерка (0,113 и 0,047 ppm Cd за 0 и 20 t·ha⁻¹ вар).

Клучни зборови: кадмиум; пченка; сено од луцерка; соја; ефект на почва; ефект на генотип; ефект на калцификација

INTRODUCTION

The harmful elements monitoring, particularly Cd, have become important for environmental

protection (Pinto et al., 2004; Godt et al., 2006; Stingu et al., 2011; Kadar and Koncz, 2000; Kadar et al., 1998, 2002). Critical concentrations of Cd in plants are between 5 and 10 mg Cd kg⁻¹ and in diet

of animals between 0.5 and 1 mg Cd kg⁻¹ (Bergman 1992; Mengel and Kirkby, 2001). The tolerable daily intake of Cd is 1 µg Cd kg⁻¹/body weight, an equivalent to a daily intake of 70 µg Cd for an adult of 70 kg.

Soil pollutions with Cd in Croatia are mainly low and Cd concentrations in the field crops (Kovačević et al., 2002, 2008; Bukvić et al., 2003) and excessive concentrations of Cd were found mostly in soils of urban areas (Lončarić et al., 2012a, 2012b).

The objective of this study was review of some research of cadmium status in plants as affected by genotype (hereditary effects) and by soil properties including improvement of soil by liming (environmental effects) under non-polluted environment of the eastern Croatia.

MATERIAL AND METHODS

Four field experiments were performed in eastern Croatia with aim of testing adaptability of maize hybrids to different soils and response of field crops to liming. The experiments were conducted in four replicates. Basic plot measured 14 m² and 64 m², for two experiments of hybrids and liming experiment, respectively. Leaves of maize for chemical analysis were taken at silking stage while grain samples were collected at maturity. The uppermost full-developed leaves of soybean and tobacco were taken at the beginning of anthesis (soybean) and at the mid-season (tobacco). The aboveground part of alfalfa were collected during the second cutting in July.

The total amounts of cadmium in plant materials were determined using ICP after their microwave digestion by concentrated HNO₃ + H₂O₂. Determinations were made by Jobin-Yvon Ultrace 238 ICP-OES spectrometer in the Research Institute for Soil Science and Agricultural Chemistry (RISSAC) in Budapest. The data were statistically analyzed by ANOVA and treatment means were compared using *t*-test and LSD at 0.05 probability level.

The experiment A: Ten maize hybrids were grown on two soil types (acid and neutral soil) mutually distanced about 2 km by air-line in Sopje, east Croatia, during the 1997 growing season. Most results of this experiment were shown in previous studies (Antunović et al., 2002, 2003, 2004; Kovačević et al., 2004; Kovačević et al., 2012b).

The experiment B: Ten maize hybrids were grown on two soils of moderate fertility (calcaric fluvisol and pseudogley) at eastern part of Sava valley in Croatia during the 1998 growing season. The experiments were conducted in four replicates and experimental plot was 14 m². Results of this experiment were shown in previous studies (Kovačević et al., 2002; Bukvić et al., 2003; Kovačević et al., 2012b).

The experiment C: Stationary field experiment of liming with Carbocalk (by-product from sugar factory) on acid soil in the east Croatia started in autumn 2000. Carbocalk is very rich in calcium (34.4%) and contain also Mg (1.1%), phosphorus (0.5%), aluminum (0.4%), iron and sulfur (0.3%). Some results of this experiment were shown in the previous studies (Jurkovic et al., 2008; Kovačević et al., 2006, 2010, 2012a, 2012b; Tursić et al., 2008; Rastija et al., 2012c; Kovačević and Lončarić, 2014).

The experiment D: Increasing rates of dolomite powder (0, 10, 20, 30 and 40 t ha⁻¹) were applied in the autumn of 2004 on acid soil (pH in KCl 5.16) in the middle Croatia. Majority results of the experiment were shown in the previous studies (Popović et al., 2007; Rastija et al., 2012a).

RESULTS AND DISCUSSION

Soil properties, mainly pH differences, considerable affected Cd concentrations in maize leaves (means 0.09 and 0.14 mg Cd kg⁻¹, for fluvisol and pseudogley, respectively). However, hereditary effects were stronger factor because under identical environmental conditions, differences among ten maize hybrids were from 0.07 to 0.18 mg Cd kg⁻¹. With that regard, three hybrids (OsSK332, OsSK445 and OsSK382) separated from remaining seven hybrids by the higher Cd concentrations (means 0.16 and 0.09 mg Cd kg⁻¹, respectively). Grain-Cd was considerably lower compared to leaf-Cd and below detection limit of the applied analytical method (Table 1).

Also, under conditions of the experiment B (Table 2), both soil and heredity factors affected Cd status in maize leaves.

Cd concentrations in maize leaves were higher under conditions of pseudogley compared to calcaric fluvisol (means 0.16 and 0.10 mg Cd kg⁻¹, respectively), probably because of acid reaction of pseudogley. Considerable influences of inheritance

on Cd status in maize leaves were found. In four hybrids (OsSK382, OsSK458, OsSK497 and OsSK552) Cd contents were lower than 0.1 mg kg⁻¹ Cd (mean 0.081 mg kg⁻¹ Cd), while in two hybrids (OsSK568exp and OsSK602) they were above 0.2 mg kg⁻¹ Cd (mean 0.263).

In general, amelioration of soil by liming with carbocalk considerably affected Cd concentrations in plants (Table 3). For example, as affected by liming, leaf-Cd were decreased from 0.17 to 0.08

mg Cd kg⁻¹ (maize), from 3.2 to 0.14 mg Cd kg⁻¹ (tobacco) and from 0.50 to 0.5 mg Cd kg⁻¹ (soybean), for the control and averages of four limed treatments, respectively. Regarding this, considerable effect of the growing season (year) were found (Table 3).

Also, liming by dolomite considerably affected Cd status of alfalfa hay as follows: 0.113 and 0.505 mg Cd kg⁻¹, for the control and three limed treatments, respectively (Table 4).

Table 1

Soil and genotype effects on cadmium status in maize leaves
(Bukvić et al., 2003)

The experiment A: Soil and genotype effects on cadmium concentrations in maize											
Soil (A)	Maize hybrid (the factor B)										A effect
	332	373	382	425	426	OsSK 427	445	552	554	622	
Cadmium status in leaves (the ear-leaf at silking stage: mg Cd kg ⁻¹ in dry matter)											
A1	0.14	0.06	0.10	0.06	0.06	0.07	0.15	0.07	0.07	0.07	0.09
A2	0.22	0.10	0.17	0.11	0.09	0.11	0.18	0.14	0.15	0.08	0.14
B effect	0.18	0.08	0.13	0.09	0.08	0.08	0.16	0.10	0.11	0.07	
Statistical analysis (LSD 5%)				A: 0.02			B: 0.04		AB: 0.06		
Cadmium status in grain at maturity:											
Below detection limit of the method (< 0.02 mg Cd kg ⁻¹ on dry matter basis)											

A1: Sopje fluvisol (pH in KCl = 6.81); A2: Sopje pseudogley (pH in KCl = 4.10)

Table 2

Soil and genotype effects on cadmium concentrations in leaves of maize
(Kovačević et al., 2002)

The experiment B: Soil and genotype effects on cadmium concentrations in maize											
Soil (A)	Maize hybrid (the factor B)										A effect
	382	444	458	497	552	OsSK 554	558	568	602	617	
Cadmium status in leaves (the ear-leaf at silking: mg Cd kg ⁻¹ on dry matter basis)											
A1	0.103	0.126	0.099	0.066	0.058	0.093	0.092	0.123	0.148	0.104	0.101
A2	0.092	0.117	0.091	0.065	0.075	0.146	0.146	0.289	0.493	0.126	0.164
B effect	0.097	0.121	0.095	0.065	0.066	0.119	0.119	0.206	0.320	0.115	0.133
Statistical analysis (LSD 5%)				A: 0.017			B: 0.040		AB: 0.060		

A1: Zupanja calcaric fluvisol (pH in KCl = 7.12); A2: Luzani pseudogley (pH in KCl = 5.17)

Table 3

Impact of liming on cadmium status in plants
(Rastija et al., 2012b; Lončarić et al., 2012b; Kovačević and Loncaric, 2014)

The experiment C: Impacts of liming with carbocalk (autumn 2000) on Cd status in plants													
Year*	Carbocalk (t ha ⁻¹)					LSD 5%	Year*	Carbocalk (t ha ⁻¹)					LSD 5%
	0	15	30	45	60			0	15	30	45	60	
Leaf- Cd mg kg ⁻¹ in dry matter							Leaf-Cd mg kg ⁻¹ in dry matter						
2006M	0.15	0.07	0.06	0.05	0.05	0.01	2005T	3.6	2.2	2.1	1.9	1.9	0.4
2010M	0.19	0.10	0.10	0.11	0.09	0.06	2008T	2.7	2.2	2.0	2.7	2.7	ns
Grain-Cd in maize: < 0.02 mg Cd kg ⁻¹							2011S 0.50 0.12 0.08 0.02 0.03 0.07						

* M: maize at silking stage, T: tobacco at the mid-season, S: soybean at beginning of anthesis

Table 4

Influences of liming on cadmium status of alfalfa (Rastija et al., 2012a)

Impact of liming by dolomite on status of alfalfa hay (the second cutting in July 22, 2005)													
	Dolomite (t ha ⁻¹ in autumn 2004)					LSD 5%		Dolomite (t ha ⁻¹ in autumn 2004)					LSD 5%
	0	10	20	30	40			0	10	20	30	40	
Cadmium status (mg Cd kg ⁻¹ in dry matter)						Yield of hay (kg ha ⁻¹ of dry matter)							
0.113	0.065	0.047	0.045	0.045	0.033	4180	3860	4120	4787	4300	448		

CONCLUSIONS

Very low concentrations of Cd, mainly below 0.2 mg Cd kg⁻¹ in dry matter of maize and soybean leaves were found under non-polluted environment of the eastern Croatia. With that regard, differences were found in maize leaves as affected by soil type and under neutral soil conditions Cd concentrations were considerably lower compared to acid environment. Also, Cd concentrations in maize grain were considerably lower (below detection limit: 0.02 mg Cd kg⁻¹) than in leaves. Beside environmental factors, heredity considerably affected Cd status in maize leaves and differences among tested hybrids under identical environmental conditions were higher compared to these differences among soil types.

Soil amelioration by liming had considerably effects on decreases of Cd concentrations in maize and soybean.

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