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Original scientific paper

GENOTYPE AND LIMING EFFECTS ON CADMIUM CONCENTRATION IN MAIZE (*Zea mays* L.)

Vlado KOVAČEVIĆ[1], Domagoj ŠIMIĆ[2], Imre KADAR[3], Desimir KNEŽEVIĆ[4]and Zdenko LONČARIĆ[1]

[1] University J.J. Strossmayer in Osijek, Faculty of Agriculture, Osijek, Croatia
[2] Agricultural Institute, Osijek, Croatia
[3] Research Institute for Soil Science and Agricultural Chemistry, Budapest, Hungary
[4] Faculty of Agriculture, Lesak, Serbia

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Liming experiment with hydrated lime (73% CaO + 2-3% MgO + 21% water) in the amounts 0, 5.0 and 20.0 t ha^{-1} was conducted in spring 2006 on acid soil. Each plot of liming (414m^2) was divided in four sub-plots for receiving four replicates in level of the genotype. Six domestic maize hybrids (Os298P, Tvrtko303, Os499, Os444, Os596 and Os552) originating from Agricultural Institute Osijek was sown at beginning of May (basic plot 24 m^2). The ear-leaf samples of maize were collected at flowering and grain in maturity stages. Mean grain yields of maize in the experiment were 11.63 and 4.83 t ha^{-1}, for the 2006 and the 2007 growing season, respectively. Unfavorable weather characteristics in 2007 were main responsible for

Corresponding author: Vlado Kovačević, Faculty of Agriculture, Trg Sv. Trojstva 3, 31000 Osijek, Croatia; Phone: ++385 31 224 2150, e-mail: vkovacevic@pfos.hr

yield loss. Yield differences between liming treatments and the control were in both years non-significant. Liming effects on decreasing leaf-Cd in maize was found in both years (2-year means: 0.095 and 0.066, for the control and mean of two liming treatments, respectively). Considerable difference of leaf-Cd was found among the maize hybrids and it was in range from 0.040 to 0.160 mg Cd kg^{-1}. Two hybrids (Os298P and Tvrtko 303) separated from remaining four hybrids by the higher leaf-Cd (2-year means 0.141 and 0.043 mg Cd kg^{-1}, respectively). However, these differences are responsible for possible harmful dietary effects only in case of using these hybrids as silage maize because grain-Cd in maize was considerably lower (under detectable range = <0.02 mg Cd kg^{-1}) and without effects on food contamination.

Key words: cadmium, grain, leaf, liming, maize hybrids

INTRODUCTION

Cadmium (Cd) is recognized as an extremely significant pollutant due to its high toxicity and large solubility in water (PINTO *et al*., 2004). Cd may interfere with numerous biochemical and physiological processes and nutrient uptake (STINGU *et al.,* 2011). In general, soil pollutions by Cd in Croatia are low and Cd concentrations in the field crops are in acceptable levels with aspects of food security (KOVAČEVIĆ *et al*., 2002, 2008; BUKVIĆ *et al.,* 2003). Cd uptake by field crops is under influences environmental, mainly soil properties and weather characteristics, and hereditary factors. Regarding soil factors, soil pH has considerable impacts on Cd status in field crops. KADAR *et al.*, (1998, 2002) reported the dynamics of heavy metals, including Cd, based on long-term field trials with toxic metals representing three soil types (calcareous loamy chernozem, calcareous sandy soil and brown forest clay soil) of Hungary. Leaf-tobacco concentrations of Cd differed significantly among the growing regions of Hungary, according to differences in soil pH. Under neutral or slightly alkaline conditions of the central part of Hungary the lowest leaf-Cd values (mean 0.50 mg Cd kg^{-1}) were found. However, these values were extremely high (mean 1.89 mg Cd kg^{-1}) in the North-East part of the country under acid soil (pH about 4.5) conditions (GONDOLA and KADAR, 1995). Aim of this study was testing Cd concentrations in maize as affected by liming and genotype.

MATERIALS AND METHODS

The field experiment

Liming experiment with hydrated lime (73% CaO + 2-3% MgO + 21% water) in the amounts 0, 5 and 20 t ha^{-1} was conducted in term April, 19, 2006 on Rakitovica acid soil (Osijek-Baranya County). Size plot of liming (the factor A) was 414 m^2 (23 x 18 m). Each plot of liming was divided in four sub-plot for receiving four replicates in level of maize genotype. Six domestic maize hybrids originating from Agricultural Institute Osijek (the factor B: B1 = Os298P, B2 = Tvrtko303, B3 = Os499, B4 = Os444, B5 = Os596 and B6 = Os552) was sown at beginning of May (basic plot of the hybrid 24 m^2) by pneumatic sowing machine on planned plant

densities (plants ha^{-1}) 78495 (B1 + B2), 72888 (B3 + B4) and 68029 (B5 + B6). Maize was harvested manually. Mass of cob was weighed by Kern electronic balance (d=100 g). Ten cobs from each treatments were used for determination of grain moisture and grain share in cob weighing by Kern electronic balance, d = 50g). Grain moisture was determined by electronic grain moisture instrument (WILE-55, Agroelectronics, Finland). Grain yields were calculated on realized plant density and 14% grain moisture basis.

Sampling, chemical and statistical analysis

The ear-leaf samples of maize (20 leaves in mean sample) were collected at flowering (beginning of silking) and grain (ten cobs) in maturity stages from each basic plot.

The total amount of cadmium in the leaf and grain samples, after microwave digestion using concentrated HNO_3+H_2O_2, was measured by the ICP-AES technique by Jobin-Yvon Ultrace 238 ICP-OES spectrometer in the laboratory of the Research Institute for Soil Science and Agricultural Chemistry (RISSAC) of Hungarian Academy of Science and Arts in Budapest, Hungary. Detection limit of applied method for Cd was 0.020 mg Cd kg^{-1}. The data were statistically analyzed by ANOVA and treatment means were compared using t-test and LSD at 0.05 and 0.01 probability levels.

Soil and weather characteristics

The experiment was conducted on acid soil and based on the high Hy value liming is recommend. This soil was low in humus and moderate supplied by plant available phosphorus and potassium (Table 1) determined by AL-method.

In general, low yields of maize are in close connection with drought stress and the higher air-temperatures, especially in the summer months (JOSIPOVIĆ *et al*., 2005; JELIĆ *et al*., 2009; MAKLENOVIĆ *et al.,* 2009; MARKULJ *et al*., 2010). The growing season 2007 was unfavorable for maize growing because of drought and high air-temperatures. In the 4-month period May-August 2007 precipitation in Osijek was only 162 mm or 40% lower than 30-year mean, while, air-temperature was for 2.2 ^oC higher, while analogical comparison for 2006 was 319 mm and air-temperature for 0.4 ^oC higher (Table 2). Under these conditions mean grain yield of maize in the experiment was 4.83 t ha^{-1} or 2.4 fold lower than in the favourable 2006 growing season.

Table 1. Soil properties (0-30 cm) at start of the experiment

The experiment Rakitovica (Hy = hydrolitical acidity)					
Soil reaction (pH)		cmol kg^{-1}	%	mg 100 g (AL-method)	
H_2O	KCl	Hy	Humus	P_2O_5	K_2O
5.74	4.34	5.19	1.94	13.0	13.83

Table 2. Weather characteristics

Year	Osijek Weather Bureau: precipitation (mm) and mean air-temperature (°C) in 2006, 2007 and long-term means (1961-1990)													
	April		May		June		July		August		Sept.		∑	X
	mm	°C	mm	°C	mm	°C	mm	°C	mm	°C	mm	°C	mm	°C
2006	87	12.7	79	16.2	91	20.1	15	23.5	134	19.3	11	17.8	415	18.3
2007	3	13.3	56	18.2	33	22.3	27	23.8	45	22.2	65	14.5	230	19.1
LTM	54	11.3	59	16.5	88	19.5	65	21.1	59	20.3	45	16.6	370	17.6

Osijek: 45 kn air-distance from Rakitovica in Eastern-Southeastern-direction

RESULTS AND DISCUSSION

Mean grain yields of maize in the experiment were 11.63 and 4.83 t ha^{-1}, for the 2006 and the 2007 growing season, respectively. As previous mentioned, unfavorable weather characteristics in 2007 were main responsible for yield loss. Yield differences among liming treatments were in both years non-significant in comparison to the control. The possible explanation of this phenomenon could be lime application in spring of 2006 and its incorporation in soil only to maximal 15 cm of depth by pre-sowing cultivation (2006) and drought stress (2007). Differences of yields among the maize hybrids were found in both years and they were in ranges from 10.13 and 12.74 t ha^{-1} (2006) and from 2.48 to 8.20 t ha^{-1}(2007). The OsSK552 and Os499 hybrids had the highest yield in 2006 and (mean 12.70 and 12.74 t ha^{-1}, respectively) and it was for 15% higher than remaining four hybrids. However, in 2007, the Os552 separated by considerably higher yield compared to remaining five hybrids (Table 3).

Mean leaf-Cd concentration in 2007 was for 12% lower than in 2006 (means 0.071 and 0.081 mg Cd kg^{-1}, respectively). Liming effects on decreasing leaf-Cd in maize was found in both years and these effects were considerably higher in 2007 because it was as affected by liming (means of two limed treatments) in comparison with the control decreased for 18% and 40%, respectively (Table 3).

Considerable difference of leaf-Cd was found among the tested maize hybrids and it was in range from 0.040 to 0.160 mg Cd kg^{-1}. Two hybrids (Os298P and Tvrtko 303) separated from remaining four hybrids by the higher leaf-Cd (2-year means 0.141 and 0.043 mg Cd kg^{-1}, respectively). However, these differences are responsible for possible harmful dietary effects only in case of using these hybrids as silage maize because grain-Cd in maize was considerably lower (under detectable range = <0.02 mg Cd kg^{-1}) and without effects on food contamination (Table 3).

In general, low connection between yield and leaf-Cd was found, although two high leaf-Cd hybrids had about 10% lower yield in comparison with the low leaf-Cd hybrids (2-year means: 7.52 and 8.58 t ha^{-1}, respectively)

Importances of soil pH and genotype on Cd uptake by crops were found also by the other studies.Uptake of heavy metals by plants has decreasing trend with the increase of soil pH. The organic matter, clays and hydrous oxides absorb metals and for this reason, soils with higher metal absorption capacity have lower potential for uptake of metals by plants (MENGEL and KIRKBY, 2001). Plant species and varieties vary

widely in tolerance to excess of Cd in the growth medium. Substantial genotypic variation in Cd accumulation in leaf and grain in maize (ZHANG and SONG, 2008), suggesting that genetic factors determine differences in Cd accumulation.

Table 3 . Impacts of liming and genotype on maize yield and cadmium concentrations in leaf and grain

The field experiment Rakitovica: Hydrated lime (the factor A: 0, 5 and 20 t ha^{-1}) and genotype (the factor B) effects on grain yield and cadmium concentrations in maize (the ear-leaf at silking and grain at maturity)

		Grain yield (t ha^{-1})				**Leaf-Cd** in dry matter (mg kg^{-1})			
Maize hybrid		Lime (t ha^{-1})			Mean	Lime (t ha^{-1})			Mean
(the factor B)		A1	A2	A3	B	A1	A2	A3	B
		0	5	20		0	5	20	
		The growing season 2006 (the first year of testing)							
B-1	Os298P	11.44	11.43	11.95	11.61	0.147	0.123	0.113	0.128
B-2	Tvrtko	9.51	10.06	10.81	10.13	0.177	0.140	0.143	0.153
B-3	303	12.81	12.78	12.64	12.74	0.053	0.047	0.043	0.048
B-4	Os499	10.70	10.40	10.71	10.60	0.073	0.067	0.047	0.062
B-5	Os444	11.73	11.57	12.68	11.99	0.043	0.057	0.047	0.049
B-6	Os596	12.33	12.59	13.20	12.70	0.057	0.030	0.043	0.043
	Os552								
Mean A		11.42	11.47	12.00		0.092	0.077	0.073	
		A		B	AB	A	B	AB	
LSD 5%		ns		0.61	1.42	0.010	0.014	ns	
LSD 1%				0.80	ns	0.013	0.018		
		The growing season 2007 (the second year of testing)							
B-1	Os298P	5.84	5.78	5.89	5.83	0.293	0.157	0.130	0.193
B-2	Tvrtko	2.43	2.45	2.56	2.48	0.130	0.073	0.073	0.092
B-3	303	2.83	2.56	2.29	2.56	0.060	0.047	0.033	0.047
B-4	Os499	4.15	4.72	5.02	4.63	0.030	0.023	0.017	0.023
B-5	Os444	5.61	5.84	4.26	5.23	0.033	0.030	0.030	0.031
B-6	Os596	8.45	8.54	7.62	8.20	0.037	0.033	0.043	0.038
	Os552								
Mean A		4.89	4.98	4.61		0.097	0.061	0.054	
		A		B		AB	A	B	AB
LSD 5%		ns		0.61		ns	0.007	0.010	0.017
LSD 1%				0.81			0.009	0.013	0.022
The growing seasons 2006 and 2007						**Grain-Cd** in dry matter (mg kg^{-1})			
B1 – B6 and A1 –A3 treatments						(<0.02 mg Cd kg^{-1})			

KOVAČEVIĆ and VRAGOLOVIĆ (2011) tested 28 maize genotypes (seven parents and their 21 F_1 diallel crosses) two years under field conditions on two soils mutualy air-distanced only 800 m (fluvisol and stagnic albeluvisol) types (pH in KCl = 7.02 and 3.85, respectively). Maize grown on the stagnic albeluvisol contained three-fold more leaf-Cd in comparison with maize on the fluvisol (0.195 and 0.064 mg Cd mg^{-1}, respectively). The Bc707-1 and the Bc706-9 parents had considerably higher leaf-Cd (0.581 and 0.105 mg Cd kg^{-1}, respectively) than remaining five (Bc265-1, Bc779-4, Bc703-19, Bc737-5 and Bc539-1) parents (mean 0.056 mg Cd kg^{-1}). These differences correspondingly reflected on leaf-Cd status of their hybrids. The hybrid Bc707-1 x Bc706-9 had the highest leaf-Cd (0.171 mg Cd kg^{-1}) among 21 hybrids (mean of remaining hybrids: 0.065 mg Cd kg^{-1}). Also, six hybrids of Bc707-1 had the higher leaf-Cd (mean 0.100 mg Cd kg^{-1}) in comparison with remaining 15 hybrids (mean 0.058 mg Cd kg^{1}). Grain-Cd was considerably lower and it was under detectable range (<0.040 mg Cd kg^{-1}) with exception of the Bc707-1 on the stagnic albeluvisol (0.17 mg Cd kg^{-1}).

KOVAČEVIĆ *et al*., (2002b) found considerable differences of leaf-Cd among ten maize hybrids grown on two soil types. Under identical environment, in four hybrids (OsSK382, OsSK458exp, OsSK497exp and OsSK552) leaf-Cd was lower than 0.1 mg kg^{-1} Cd (mean 0.081 mg kg^{-1} Cd), while in two hybrids (OsSK568exp and OsSK602) it was above 0.2 mg kg^{-1} Cd (mean 0.263). Although Cd in maize leaves were in tolerant ranges, similar investigations could useful contribute to improvement of food quality with aspects of their Cd contamination. By the other study, KOVAČEVIĆ *et al*., (2002a) tested 20 maize hybrids and also considerable differences of leaf-Cd in range from 0.07 to 0.21 mg Cd kg^{-1} were found. Especially low Cd concentrations were found in six hybrids (OsSK373, E9917/99, Bc278, OsSK2-191, OsSK382 and Clarica: mean 0.092 mg Cd kg^{-1}), while in three hybrids it was considerably higher, but in amounts acceptable from the aspect of plant and animal health (OsSK395, OsSK378 and Tvrtko 303: mean 0.200 mg Cd kg^{-1}).

CONCLUSION

Both genotype and soil factors, especially soil pH, have considerable role in Cd uptake by plants. For this reason, creation cultivars of main field crops characterizing low-Cd uptake and by correction of soil pH close to neutral by liming is possible contribute to decrease of Cd uptake by main field crops and minimizing contamination of food by Cd.

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UTICAJ GENOTIPA I KALCIZACIJE NA KONCENTRACIJU KADMIJUMAU KUKURUZU (*Zea mays* L.)

Vlado KOVAČEVIĆ[1], Domagoj ŠIMIĆ[2], Imre KADAR[3], Desimir KNEŽEVIĆ[4] i Zdenko LONČARIĆ[1]

[1] Sveučilište J.J. Strossmayera, Poljoprivredni fakultet, Osijek, Hrvatska
[2] Poljoprivredni institute Osijek, Osijek, Hrvatska
[3] Institut za pedologiji agrokemiju, Budapest, Hungary
[4] Univerzitet u Prištini, Poljoprivreni fakulte, Lešak, Srbija

I z v o d

Stacionirani poljski ogled s primenom hidratnog kreča (73% CaO + 2-3% MgO + 21% vezane vode) u količinama 0, 5 i 20 t ha^{-1} postavljen je u proljeće 2006 na kiselom zemljištu. Svaka parcela kalcizacije (površina 414m^2) podijeljena je na četiri jednake podpacele da bi se dobilo 4 ponavljanja. Šest domaćih hibrida kukuruza (Os298P, Tvrtko303, Os499, Os444, Os596 and Os552) porijeklom s Poljoprivrednog instituta Osijek sijana su početkom maja 2006. i 2007 (osnovna parcela 24 m^2). List ispod klipa kukuruza uzet je početkom svilanja, a zrno u zriobi. Prosječni prinosi kukuruza u ogledu iznosili su 11.63 and 4.83 t ha^{-1}, za 2006., odnosno za 2007. godinu. Nepovoljne vremenske prilike bili su glavni razlog za nizak prinos u 2007. Razlike prinosa između tretmana kalcizacije nisu bile statistički značajne. Međutim, u obje godine istraživanja je kalcizacijom smanjena koncentracija Cd u listu (2-god. prosjeci: 0.095 i 0.066 mg Cd kg^{-1}, za kontrolu, odnosno prosjek dva tretmana kalcizacije). Značajne razlike u koncentracijama Cd u listu ustanovljene su između hibrida i one su bile u rasponu od .040 do 0.160 mg Cd kg^{-1}. Dva hibrida (Os298P i Tvrtko 303) izdvojila su se većim koncentracijama Cd (prosjek 0.141 mg Cd kg^{-1}) u odnosu na preostala 4 hibrida (prosjek 0.043 mg Cd kg^{-1}). Međutim, ove razlike su odgovorne za mogući štetni učinak u ishrani samo ako se ovi hibridi koriste kao silažni kukuruz jer je koncentracija Cd u zrnu značajno manja (ispod granice detekcije primijenjene metode = <0.02 mg Cd kg^{-1}) i bez učinka na kontaminaciju hrane.

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