ACCUMULATION OF CADMIUM IN THE GRAIN OF DIFFERENT CULTIVARS OF WHEAT

Ivana Maksimović[1], Marina Putnik-Delić[1], Vojislava Momčilović[2], Srbislav Denčić[2], Imre Kádár[3], Rudolf Kastori[1]

[1]University of Novi Sad, Faculty of Agriculture, Trg Dositeja Obradovića 8, Novi Sad, Serbia
[2]Institute of Field and Vegetable Crops, Maksima Gorkog, 30, Novi Sad, Serbia
[3]Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Herman Ottó ú. 15. Budapest, Hungary
e-mail: ivanam@polj.uns.ac.rs

Abstract
Cadmium (Cd) is in higher concentrations toxic for all living organisms. Therefore, the knowledge on the accumulation of Cd in edible parts of plants is important for health. Genotypes of different crops may differ significantly with respect to accumulation of Cd. Hence, the aim of this research was to assess its accumulation in the grains of genetically diverse wheat genotypes, originating from different parts of the world. In two years, average concentration of Cd ranged from 0.0270 to 0.0403 mg/kg DM and it was significantly below the toxic level. The highest concentration of Cd was recorded in cultivar Bezostaja 1, while the other genotypes differed only slightly in accumulation of Cd in the grain.

Introduction
Many organic and inorganic substances contribute to environmental pollution. Amongst them, heavy metals play important role. The most abundant antropogenic sources of soil pollution by Cd are transport vehicles, mines, ore smelters, metal industry, municipal solid and liquid wastes and others. Significant pollutants of arable land may also be phosphoric fertilizers, application of Cd-laden sludge, and to a lesser extent, manure, compost and atmospheric precipitates.
Cadmium, similarly to the other heavy metals, is in higher concentrations toxic to all living organisms, including plants (Kastori et al., 1997), soil microorganisms, humans and animals (Vapa and Vapa, 1997). Therefore, prevention of pollution by Cd and prevention of its entry into the food chain has a remarkable significance for the environment and health.
The accumulation of mineral substances in plants and their organs depends on genetic background, environmental conditions and the interaction of genotype and environment. Plant species differ in their abilities to uptake, accumulate and transport various mineral elements to different organs, as well as by their sensitivity to deficiency or excess of mineral substances. Differences exist also between genotypes and lines (Clark, 1983). Considering the large global importance of wheat production in the diet of the human population and partly of domesticated animals, as well as the toxicity of Cd, we felt justified to examine the variability of Cd accumulation in the grain of different genotypes of wheat grown in the same environmental conditions.

Material and methods
Eight genotypes of wheat, originating from different parts of the world, were used in the experiment, which was conducted at the experiment field of the Institute of Field and Vegetable Crops in Novi Sad, in 2011 and 2013.

The soil at the experimental field was classified as a calcic, gleyic chernozem (Loamic, Pachic – CH-cc.gl-Ip.ph (IUSS Working Group WRB, 2015)). Concentration of Cd in the soil was significantly lower than the maximally allowed (2 mg/kg) and even lower from the usual concentration of Cd (0.2 to 1 mg/kg) (Tab. 1). Monthly mean air temperature during vegetation in 2010/11 was 8.5 °C, and in 2012/13 it was 9.9 °C. Sum of average day temperatures was slightly higher in 2012/13. Higher amount of precipitation during 2012/2013 than 2010/2011 (591 and 388 mm, respectively), significantly affected average wheat yield at the experimental field and in the entire region of Vojvodina. In 2011 average wheat yield was 4.88 whereas in 2013 it was 5.91 t/ha.

Table 1. Cadmium concentration in different horizons of the soil profile at the experimental site(mg/kg)

Horizon	Depth (cm)	Ekstraction agent [1]EDTA	[2]HNO_3
Ap	0-20	0.206	0.703
A	20-35	0.208	0.753
AC	35-117	0.088	0.773
CG	117-195	0.084	0.777

Form: [1] - soluble; [2] - total

The genotypes were harvested at crop maturity. After digestion of grain wholemeal in a mixture of 10 ml HNO_3 (65%) and 2 ml of H_2O_2 (30%) using the microwave technique, the concentrations of total Cd were determined by inductive coupled plasma emission spectrometer, in Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Budapest. Statistical analyses were done with program XLSTAT- Pro (demo version, Version 03.02.2009).

Results and discussion

Concentration of Cd in examined wheat genotypes in two experimental years ranged from 0.0270 to 0.0403 mg/kg DM (Tab. 2).

Table2. Cadmium concentration in grains of eight wheat cultivars(mg/kgDM)

Wheat cultivars	**Origin**	**Years** 2011	2013	**Average**
Panonnia	SRB	0.0375^{cd}	0.0201^{e}	0.0288^{b}
Bankut 1205	HUN	0.0420^{bcd}	0.0202^{e}	0.0311^{b}
Bezostoja 1	RUS	0.0605^{a}	0.0201^{e}	0.0403^{a}
Siete Cerros	MEX	0.0440^{bc}	0.0180^{e}	0.0310^{b}
Florida	USA	0.0340^{d}	0.0200^{e}	0.0270^{b}
Renan	FRA	0.0332^{d}	0.0225^{e}	0.0278^{b}
Condor	AUT	0.0475^{b}	0.0195^{e}	0.0335^{b}
Bolal	TUR	0.0395^{bcd}	0.0200^{e}	0.0298^{b}
Mean		0.0423^{a}	0.0201^{b}	0.0312
Min		0.0332	0.0180	0.0270
Max		0.0605	0.0225	0.0403
Standard deviation		0.0082	0.0011	0.0039
Variation coefficient (%)		19.51	5.73	12.67
Standard error		0.0031	0.0004	0.0015

Means with a common letter are not significantly different ($p > 0.05$)

In Bezostaja 1 concentration of Cd was significantly the highest, whereas the other genotypes differed insignificantly with respect to Cd (Tab 2, Fig 1). The difference in concentration of Cd in wheat grains was not higher than about 1.5 times within each year. At least in part, this may be explained by the fact that vegetative plant parts of a species (and genotype) in general differ in their chemical composition to a greater extent than generative parts. Measured concentrations of Cd are in line with concentrations of Cd found in wheat grown in different parts of the world (Kabta-Pendias and Pendias, 2000). The difference in Cd concentration in grains between two experimental years was statistically significant. In average, in dry 2011 concentration of Cd was much higher than in humid 2013 (0.0423 and 0.0201 mg/kg DM, respectively). Minimum and maximum concentrations in 2011 were also much higher than in 2013 (Tab. 2).
According to the literature, wheat grain formed in humid years contains less nutritive and other elements than in dry years. Moreover, soil humidity affects differently concentration of nutrients in particular plant parts (Kastori, 1981), which may be the consequence of higher yield and therefore so-called biological "dilution" effect. Indeed, Bogdevitch and Mikulich (2008) explain by dilution effect lower concentration of radionucleides found in wheat grain of high yield.

Table 3. Analysis of variance of Cd concentration in wheat grains

Source	df	SS	MS	F-count	F-table		P-value
					0.05	0.01	
Rep*Y	4	0.050	0.012	0.39^{ns}	2.71	4.07	0.8112
Year (Y)	1	0.006	0.006	476.34^{**}	4.20	7.64	0.0000
Cultivar (C)	7	0.748	0.107	0.82^{**}	2.36	3.36	0.0096
C*Y	7	0.917	0.131	4.15^{**}	2.36	3.36	0.0030
Error	28	0.884	0.032				

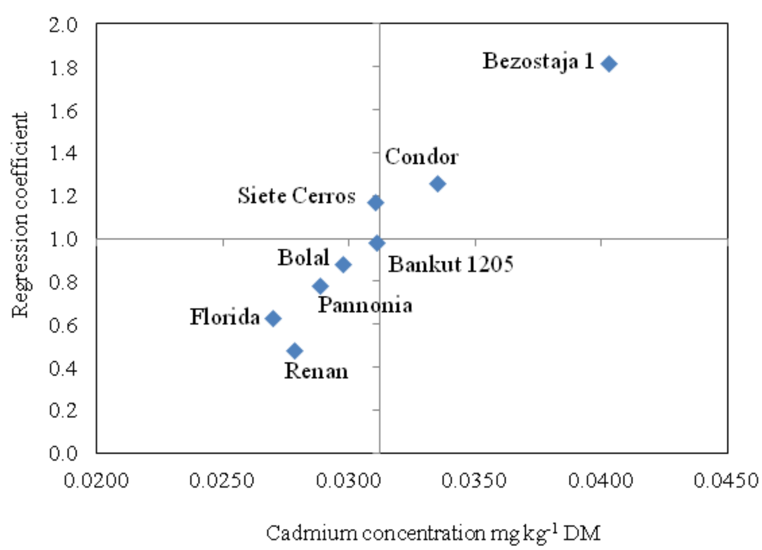

Figure 1. Relation between Cd concentrations in grains of wheat cultivars and the Finlay and Wilkinson's b regression coefficient

There is a close correlation between Cd concentration in the soil and in the grain of wheat (Hornburg and Brümmer, 1986), indicating its good upward mobility in plants (Verkleij and Schat, 1990). The concentrations of Cd in the grain of tested wheat genotypes were significantly below the allowed maximum concentration (0.5 mg/kg DM). This can be explained by a low concentration of soluble Cd with respect to total Cd in the soil (Tab. 1) and low transport rate of Cd from vegetative to generative organs in plants, which was recorded even on soils heavily contaminated with Cd (Leita et al., 1996).

Conclusion

Concentration of Cd in the grain of wheat genotypes of various origin, in temperate continental climate conditions, on calcic, gleyic chernozem soil, that contained low concentration of Cd, in two years, ranged in average from 0.0270 to 0.0403 mg/kg DM. Significantly the highest concentration of Cd was found in the grain of Bezostaja 1. Among the other seven genotypes concentration of Cd in the grain was not statistically different. It can be concluded that genotypes originating from different parts of the world differed only slightly in the accumulation of Cd in the grain and that concentrations of Cd in the grain in all tested genotypes were significantly below toxic levels.

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