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VARIABILITY OF LEAF CADMIUM CONTENT IN TETRAPLOID AND HEXAPLOID WHEAT

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Cadmium (Cd) is a toxic trace metal pollutant for humans, animals, and plants. It is a heavy metal present in soils from natural and anthropogenic sources. Much of the Cd taken up by plants is retained in the root, but a portion is translocated to the aerial portions of the plant and into the seed. The objective of this research was to determine the variability and diversity of Cd content in the leaves of 30 wheat cultivars with different ploidy level, during two years. Analyses of Cd content (ppm) in the leaves at heading stage were performed with an atomic absorption spectrometer (AAS). Significant differences between the mean values of the genotypes in Çd content were found. Tetraploid wheat genotypes had higher Cd content than hexaploid genotypes. Cd content was predominantly influenced by the

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year of growing (73%). The influence of genotype on Cd content amounted 16% and the interaction genotype × year 11%. The cluster of the genotypes consists of four groups. In the groups three and four were some of the genotypes (Kalyan Sona, Partizanka and NS Rana 5) with lowest Cd content in the leaves. They could be chosen as parents in the hybridization for lower cadmium concentration.

Key words: Cd content, interaction genotype×year, heading stage, variability, wheat

INTRODUCTION

Cadmium (Cd) belongs to the group of so-called "heavy metals". It is highly toxic to plants, animals and human organisms (ALLOWAY, 1990). A series of determinations of lead and cadmium concentrations in blood of population that lives in environment nearby Kosovo thermo power plants, have shown direct effects in biochemical parameters CRE (Creatinin), DB (Direct Bilirubine), TB (Total Bilirubine), AST (Aspartat Aminotransferaza), CK (Creatin Kinaza) and CHE (Cholenisteraza) in human organism (ZENELI *et al*., 2008). Cadmium in food is a potential health risk as it is accumulated in the kidneys, and if the dietary intake is too high this can lead to kidney damage with time. Exposure to Cd can also cause brittle bones, i.e. osteoporosis (ALFVÉN *et al*., 2000). Effects on human kidney function have already been reported at current exposure levels in areas with moderate pollution (JÄRUP *et al*., 2000, OLSSON *et al.,* 2005).

The main source of contamination of soil and crops with Cd is industrial effluents. Many reports have shown that the use of Cd-containing fertilizers increased Cd uptake by plants (ANDERSON and SIMON, 1991). Atmospheric deposition of Cd on to the leaf surfaces of cereals can be important because cereal based foods are consumed in large amounts, representing 54 % of the food (i.e. dry matter) consumed worldwide (GRAHAM and WELSH, 1996). The emission of toxic substances and ions destroy or damage cell structures, leading to metabolic disturbances, enzyme inhibition and modifications in photosynthesis and plant biomass distribution (DAS *et al*., 1997, STARCK, 1998).

Although unnecessary for the plant growth, Cd is readily taken up by their root system and leaves, with its uptake being usually proportionate to the Cd content present in the environment. High levels of Cd in food crops are a concern in human diets because of possible negative effects on health. Cereal grains represent a large portion of our diet and are therefore a major contributor to Cd intake (WAGNER, 1993). The concentration of Cd in food crops are subject to regulation by national and international agencies. The maximum tolerable intake of Cd for humans, recommended by FAO/WHO is 70 μg/day (VASILEV and YORDANOVA, 1997). CHAUDRI et al., 2001, in wheat genotype Soissons have found that Cd content in the grain was greater than the EU limit (0.24 mg kg^{-1} dry wt). Production of crops not contaminated with Cd requires continuous monitoring of the content of trace elements in fertilizers and systematic reduction of effluents emitted to the atmosphere. Increase in the amount of cadmium in the agricultural environment is primarily the result of use the Cd containing fertilizers, application of Cd-containing sevage sludge and atmospheric deposition of Cd on crop or soil surfaces (RYAN *et al*., 1982, NICKOLSON and JONES, 1994).

As it is known that leaf cadmium content in wheat is highly correlated with grain cadmium content, it would be useful to determine variability of Cd content in the leaves and on the basis of the results to predict cadmium content in wheat grain. This information could be used to facilitate breeding of cultivars with low grain cadmium concentration.

The aim of the study was to get information on the variability and diversity of wheat with different ploidy level, regarding Cd content in the leaves at heading stage.

MATERIALS AND METHODS

The variability of Cd content in the leaves was investigated under field conditions in thirty wheat genotypes with different level of ploidy, belonging to *Triticum* sp., and originating from different parts of the world (Tab. 1). The trial was carried out using RCB design in three replications during two vegetation periods at the experimental station of the Institute of Field and Vegetable Crops, Novi Sad, Serbia. The sample consisted of 10 plants per replication.

Analyses of Cd content (*ppm*) in the leaves at heading stage were performed with an atomic absorption spectrometer (AAS) in the chemical laboratory of the Institute of Field and Vegetable Crops, Novi Sad.

In order to assort genotypes according to Cd content, hierarchical cluster analysis, using “Euclidian distance” was employed. Two-way ANOVA was used to analyze main effects (genotype, year) and interaction genotype x year.

The calculations were made with STATISTICA 7.0 software.

RESULTS AND DISCUSSION

Between the mean values for Cd content in *Triticum* sp. significant differences were found. Cd concentration varied between 0.465 ppm in *Triticum aestivum* ssp *vulgare* var. *nigracolor* to 3.035 ppm in variety Timgalen, originating from Australia, in average for two years (Tab. 1). Differences between wheat cultivars in their ability to accumulate Cd have also been shown by OLIVER *et al*. (1995) and STOLT (2002).

Table 1. Origin, mean values and variability of Cd content in Triticum sp. leaves at heading stage

No.	***Genoype***	***Origin***	***Genome***	***Cd concentration (ppm)***		
				2000	***2001***	***Average***
1.	*Tr. dicoccoides*	LV	*AB*	*0.890*	*1.360*	*1.125*
2.	*Tr. polonicum* var. *gracila*	LV	*AB*	*0.790*	*0.940*	*0.865*
3.	*Tr. turgidum* var. *nigrobarbatum*	LV	*AB*	*0.800*	*1.710*	*1.255*
4.	*Tr. durum* var. *cerulescens*	LV	*AB*	*0.970*	*0.860*	*0.915*
5.	*Tr. durum hordeiformae*	LV	*AB*	*0.985*	*1.295*	*1.140*
6.	*Tr. dicoccum* var. *forrum*	LV	*AB*	*1.110*	*1.490*	*1.300*
7.	*Tr. dicoccum* var. *africanum*	LV	*AB*	*0.890*	*1.015*	*0.953*
8.	NS Rana 5	*YUG*	*ABD*	*0.990*	*0.715*	*0.853*
9.	NSD 1/93	YUG	*AB*	*1.180*	*1.410*	*1.295*
10.	*Triticum macha*	*LV*	*ABD*	*1.345*	*1.585*	*1.465*
11.	*Triticum spelta*	*LV*	*ABD*	*0.900*	*1.290*	*1.095*
12.	Pobeda	*YUG*	*ABD*	*0.950*	*2.430*	*1.690*
13.	*Triticum aestivum* ssp. *vulgare* var. *nigracolor*	*LV*	*ABD*	*0.960*	*0.330*	*0.645*
14.	Chinese Spring	*CHI*	*ABD*	*1.215*	*1.490*	*1.353*
15.	*Tr. paleocolch*. var. *vulpinum*	LV	*AB*	*1.025*	*1.465*	*1.246*
16.	Rodna	*YUG*	*ABD*	*1.305*	*0.780*	*1.043*
17.	Frontana	*BRA*	*ABD*	*1.030*	*1.735*	*1.383*
18.	Renesansa	*YUG*	*ABD*	*1.035*	*1.185*	*1.110*
19.	Libelulla	*ITA*	*ABD*	*1.025*	*1.065*	*1.045*
20.	Trakija	*BGR*	*ABD*	*0.950*	*1.245*	*1.097*
21.	Odeskaya 51	*RUS*	*ABD*	*0.730*	*1.195*	*0.963*
22.	Peking 11	*CHI*	*ABD*	*1.125*	*0.670*	*0.898*
23.	Evropa 90	*YUG*	*ABD*	*0.950*	*1.055*	*1.003*
24.	Timgalen	*AUS*	*ABD*	*1.360*	*4.710*	*3.035*
25.	Bezostaya 1	*RUS*	*ABD*	*0.945*	*0.990*	*0.968*
26.	Partizanka	*YUG*	*ABD*	*0.750*	*0.745*	*0.748*
27.	Kavkaz	*RUS*	*ABD*	*0.800*	*1.440*	*1.120*
28.	Nevesinjka	*YUG*	*ABD*	*0.860*	*1.915*	*1.388*
29.	GK Othalom	*HUN*	*ABD*	*1.055*	*0.985*	*1.020*
30.	Kalyan Sona	*IND*	*ABD*	*0.725*	*0.645*	*0.685*
			Average	*0.997*	*1.325*	

	G	*Y*	*G/Y*
$LSD_{0.05}$	0.194	0.050	0.274
$_{0.01}$	0.258	0.066	0.364

Genotypic variation in grain Cd content has been reported in both common (OLIVER *et al.,* 1995), and *durum* wheat (PENNER *et al.,* 1995). Also, CLARKE *et al*. (1997) have found differences in Cd content in the leaves of *durum* wheat.

In average Cd content was significantly higher in 2001 than in 2000, which could be due to the climatic conditions in these years (Tab. 1).

Table 2. ANOVA for Cd content in the leaves of Triticum sp. at heading stage

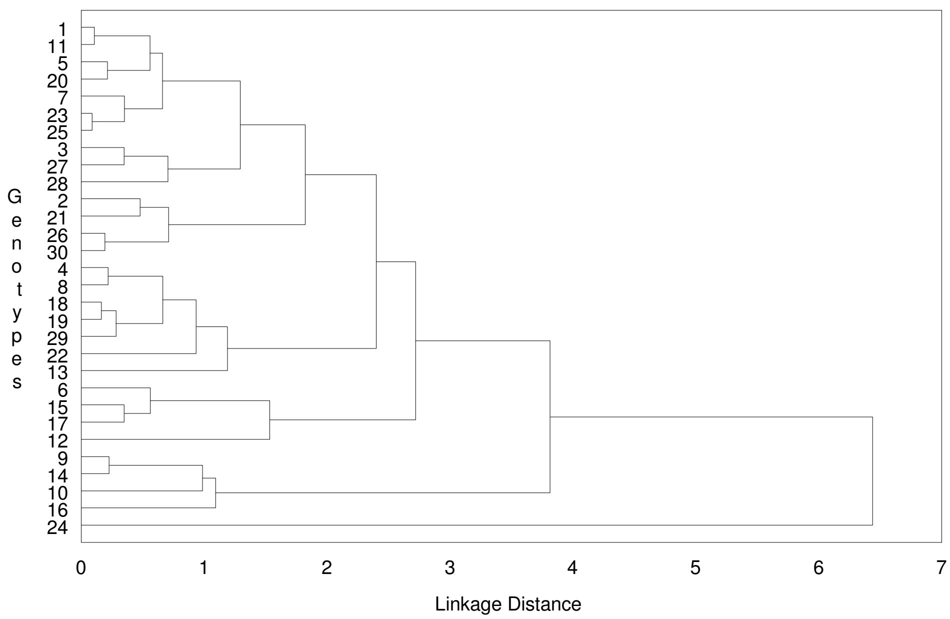
Source of variation	Df	MS		Fe
		Value	%	
Genotype (G)	29	0.721	16	38.4**
Year (Y)	1	3.441	73	182.5**
G/Y	29	0.528	11	28**
E	60	0.019		

Highly significant differences were found for all sources of variation. Cd content was predominantly influenced by the year of growing (73 %). The influence of genotype on Cd content amounted 16 % and the interaction 11 % (Tab. 2). Similar results stated OLIVER *et al*. (1995). They also identified significant cultivar effects for Cd content in wheat grain, but these were less significant than the site effects.

Taking into account that leaf Cd content is highly correlated with grain Cd content ($r = 0.87$-0.89. $P < 0.01$), as reported by CLARKE *et al.* (1997), leaf Cd content could predict the plant phenotype which would be useful on backcrossing to low Cd trait into high Cd cultivar. In durum wheat the heritability for Cd content was high and the inheritance simple. According to CLARKE *et al.* (1997) grain cadmium content is largely controlled by a single gene, with low cadmium dominant. MCLAUGLIN *et al.*, (1999) reported that cadmium accumulation in grain of high- and low-accumulating near-isogenic lines of durum wheat was correlated with Cd accumulation in the leaves of the seedlings under field conditions. This suggests that differences in Cd accumulation in the vegetative phase may be important determinants of Cd accumulation in grain, or at least be indicative of Cd transport to grain during grain filling. This information could be used to facilitate breeding of cultivars with low grain cadmium content. The data from the Swedish soil monitoring programme showed a significant positive correlation between the N and Cd contents in grain of winter wheat, oats and barley (WANGSTRAND *et al*., 2007)

In our experiment Cd content was higher in tetraploid than in hexaploid wheat genotypes (Tab. 1). These results are in agreement with the report of MEYER *et al*. (1982). They have also gotten higher levels of Cd in durum than in common wheat. It is stated that durum wheat used to accumulate more Cd than most other small grains (CHANEY *et al*., 1996, CLARKE *et al.* 1997). Higher Cd accumulation in grains of durum wheat's may be related to their higher sensitivity to Zn deficiency than bread wheats (GRAHAM *et al.* 1992, CACMAK *et al*., 1998). On average diploid wheats (AA) absorbed and translocated more ^{109}Cd than other wheats. The largest variation in ^{109}Cd uptake was found within tetraploid wheats (BBAA). Primitive tetraploid wheats (ssp. *dicoccum*) had a greater uptake capacity for ^{109}Cd than moderm tetraploid wheats (ssp. *durum*), according to CACMAK *et al.* (2000). Content of cadmium in durum wheat grain is influenced by differences in geographic location, soil conditions, cropping season and cultivar (LI *et al*., 1994, CLARKE *et al*., 1997, NORVELL *et al.,* 2000). Compared to bread wheat (*Triticum aestivum* L.), durum wheat (*T. turgidum* L. var *durum*) has a genetic propensity to accumulate Cd in grain (MEYER *et al.,* 1982) to levels often exceeding proposed international limits for Cd in cereal grains (LI *et al*., 1997, CLARKE *et al.,* 2002). Consequently, there is a need to develop low Cd-accumulating durum cultivars and agronomic management practices to minimise soil-to-plant transfer of Cd.

Graph 1. Dendogram for Cd concetration in *Triticum* sp.



The cluster of the genotypes concerning Cd content in the leaves can be divided into five groups. The genotype Timgalen (24), with highest mean value for Cd content, could be considered as independent of the group. The most Cd efficient are Kalyan Sona (30), Partizanka (26) and NS Rana 5 (8) belonging to the group IV or III. They could be used as parents for hybridization as they are genotypes with lowest Cd content in the leaves because they were most Cd efficient in our experiment (Graph. 1).

The results could be useful to simplify breeding of wheat genotypes with low cadmium content.

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VARIJABILNOST SADRŽAJA KADMIJUMA U LISTOVIMA TETRAPLOIDNE I HEKSAPLOIDNE PŠENICE

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I z v o d

Kadmijum (Cd) pripada grupim "teških metala". On je tosičan za biljke, životinje i ljude. Njegovo prisustvo u zemljištu potiče iz prirodnih i intropogenih izvora. Veći deo usvojenog Cd zadržava se u korenu, ali deo se translocira u nadzemne delove biljke i u seme. Cilj ovog istraživanja je bio da se ispita varijabilnost i divergentnost saržaja Cd u listovima kod 30 genotipova pšenice različitog nivoa ploidnosti. Ogled je izveden u toku dve vegetacione sezone. Sadržaj Cd (*ppm*) u listovima pšenice u fazi klasanja određen je primenom AAS. Ustanovljene su značajne razlike u srednjim vrednostima između ispitivanih genotipova. Tetraploidni genotipovi imali su veći sadržaj Cd u odnosu na heksapolidne. Glavni efekti (genotip i godina) i interakcija pokazali su visoko značajne razlike. Sadržaj Cd je najvećim delom bio uslovljen godinom ispitivanja (73%). Uticaj genotipa na sadržaj Cd iznosio je 16%, dok je interakcija genotip×godina iznosila 11%. Klaster genotipova sastojao se od četiri grupe. U grupi tri i četiri nalazili su se genotipovi sa najmanjim sadržajem Cd u listovima tj. najefikasniji u korišćenju Cd (Kalyan Sona, Partizanka i NS Rana 5). Oni bi se mogli koristititi kao roditelji u hibridizaciji na niži sadržaj Cd.

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