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Genotypic variation for leaf cadmium concentration in *Triticum* sp.

M. Kraljevic-Balalic, S. Petrovic, M. Dimitrijevic and N. Mladenov
Faculty of Agriculture, Institute of Field and Vegetable Crops, Novi Sad, Serbia

Introduction

Cadmium (Cd) belongs to the group of "heavy metals". It is highly toxic to plants and animals (Alloway, 1990). The main source of contamination of soil and crops with cadmium is industrial effluents. Although unnecessary for the plant growth, Cd is readily taken up by their root system and leaves, with its uptake being usually proportional to the Cd concentration 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 maximum tolerable intake of Cd for humans, recommended by FAO/WHO is 70 µg/day (Vasilev and Yordanova, 1997). Chaudri *et al*. (2001) showed that the Cd concentration in the grain of the wheat genotype Soissons was greater than the EU limit (0.24 mg kg^{-1} dry wt). The production of crops which do not contain high levels of Cd requires continuous monitoring of the content of trace elements in fertilizers and systematic reduction of effluents emitted to the atmosphere.

The aim of the study was therefore to obtain information on genetic variation in the Cd concentration in the leaves of various *Triticum* sp.

Material and methods

Variation in the Cd concentration of leaves was investigated under field conditions in thirty genotypes and species of *Triticum*, originating from different parts of the world (Table 1). The trial was carried out using a randomized complete block design with three replicates during two growing seasons at the experimental station of the Institute of Field and Vegetable Crops, Novi Sad, Serbia. Samples consisted of 10 plants per replicate. The Cd concentration (ppm) in the leaves at heading stage was determined using atomic absorption spectroscopy.

Hierarchical cluster analysis, using "Euclidian distance" was employed to order genotypes according to Cd concentration. Calculations were made with STATISTICA 7.0 software.

Results and discussion

Significant differences were found between the mean values for Cd concentration in the various lines of *Triticum*. Cd concentration varied between 0.465 ppm in *Triticum aestivum* ssp *vulgare* var. *nigracolor* to 3.035 ppm in the cultivar Timgalen, originating from Australia, averaged over two years (Table 1).

Genotypic variation in grain Cd concentration has been reported in both bread (Oliver *et al.,* 1995), and durum wheats (Penner *et al.,* 1995). Also, Clarke *et al.* (1997) showed differences in Cd concentration in the leaves of durum wheat.

The average Cd concentration was higher in 2001 than in 2000 (Table 1), which could be due to the climatic conditions in these years.

Table 1. The *Triticum* genotypes and their leaf Cd concentrations measured at heading stage

No.	*Genotype*	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
			$LSD_{0.01}$	0.258	0.066	0.364

Highly significant differences were found for all sources of variation. The Cd concentration was predominantly influenced by the year of growth (73%). The genotype accounted for 16% of the variation in Cd concentration and the genotype x year interaction for 11% (Table 2).

Leaf Cd concentration is highly correlated with grain Cd concentration, as reported by Clarke *et al*. (1997). The leaf Cd concentration could therefore be used to identify lines with low levels of grain Cd accumulation for exploitation in plant breeding. In durum wheat the heritability for Cd concentration was high and the inheritance simple.

In our experiment the leaf Cd concentration was higher in tetraploid than in hexaploid wheat genotypes (Table 1) which is in agreement with the report of Meyer *et al*. (1982). These authors also reported higher levels of Cd in durum than in bread wheat.

Table 2. ANOVA for Cd concentration in the leaves of *Triticum* sp. (heading stage)

Source of variation	Df	MS Value	%	Fe
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		

Cluster analysis divides the genotypes into five groups based on the Cd concentrations in their leaves. The genotype Timgalen (24), with highest mean value for Cd concentration, could be considered to form an independant group. The genotypes which contained the least Cd are Kalyan Sona (30), Partizanka (26) and NS Rana 5 (8) belonging to groups IV or III. They could therefore be used as parents for hybridization to transfer the low Cd trait to other genotypes (Fig. 1).

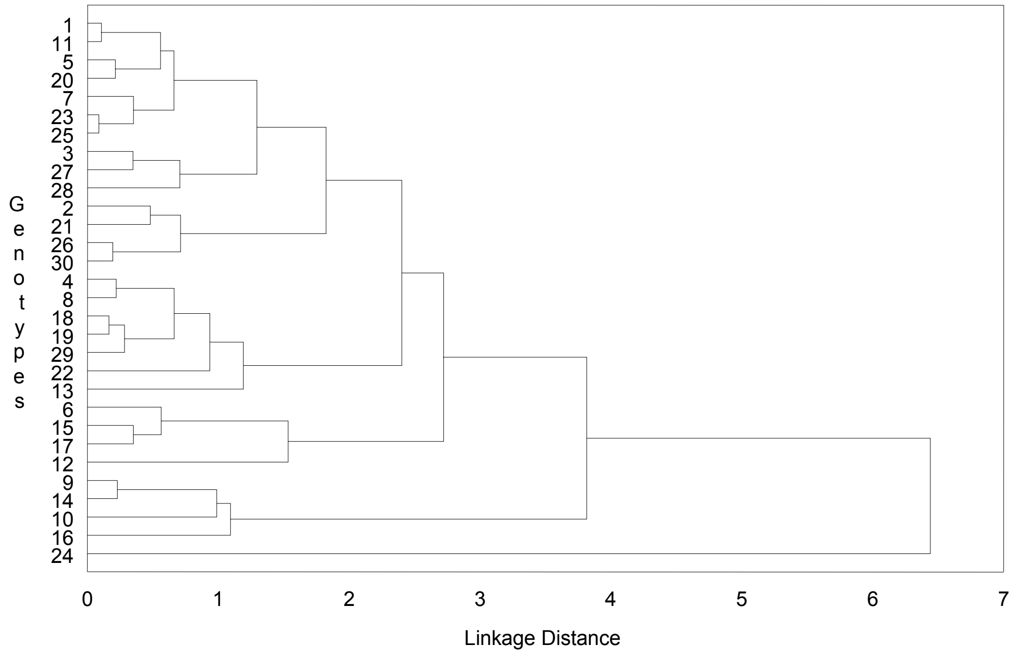

Fig. 1. Dendrogram of Cd concentration in *Triticum* sp.

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