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GENETIC VARIABILITY OF CONCENTRATION OF MICROELEMENTS IN WILD SUNFLOWER SPECIES AND HYBRIDS*

ABSTRACT: The aim of this work was to investigate genetic specificity of sunflower nutrition with microelements. Therefore, concentrations of essential (Zn, B, Mn, Cu, Fe and Ni) and non-essential (Cr, Al, Cd, As, Pb and Ba) micronutrients were analyzed. Five sunflower hybrids the most grown in Serbia and different populations of wild sunflower species originating from North America: *Helianthus neglectus Heiser* (3), *Helianthus agrophyllus T&G* (3), *Helianthus petiolaris Nutt.* (2), *Helianthus annuus* L. (4) were included in the experiment.

Populations of wild sunflower species and hybrids differed significantly with respect to the concentration of analyzed elements. Manganese concentration was significantly higher in hybrids than in wild species. In all genotypes Fe, B and Mn had the highest concentration. Coefficient of variation of microelement concentration depended on genotype and particular element. In wild populations, for essential microelements, it was between 3.7 and 59.5, whereas in hybrids it varied from 10.0 to 48.8.

Coefficient of variation of concentration of non-essential microelements in wild populations varied from 7.7 to 73.8, and in hybrids from 15.1 to 48.8.

Average coefficient of variation in both wild species and hybrids was the lowest for Mn and Pb. It was the highest for Cr, Ni, and Zn in hybrids and for Cd, Ni, and Cr in wild species.

The results suggest that genetic specificity with respect to uptake of microelements in wild species and hybrids is highly expressed. Broad genetic variability of concentrations of microelements in wild species and hybrids indicate that their reactions to deficiency and/or excess of those elements probably are not the same either. This finding may be used in breeding process aimed specifically at improvement of tolerance and capacity to accumulate microelements in sunflower. Phytoremediation technology designed to reduce the amount of microelements in the soil could thus be advanced by utilization of such plants.

KEY WORDS: wild sunflower species, populations, hybrids, essential, non-essential, microelement concentration

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INTRODUCTION

Plants belonging to the genus *Helianthus* are widely present all over our planet. Various climatic and edaphic conditions resulted in appearance of species that are variable in their morphology and biological characteristics, one of which is mineral nutrition. Breeding process imposed by human activities stimulated an increase in genetic variability of mineral nutrition of some species and genotypes of sunflower. The first reports about varietal differences in plant nutrition were published in the middle of last century (Vose, 1963). Since then, in many studies the existence of genetic variability in mineral nutrition between species and genotypes was confirmed (Epstein, 1972; Klimaševski, 1974; Sarić, 1981). This specificity refers to the temporal dynamics of nutrient uptake and accumulation, plant sensitivity to nutrient shortage or excess, nutrient distribution in plants, etc. (Kastori, 1983).

In sunflower, genetic specificity of mineral nutrition was examined prevalently in different lines and hybrids (Foy et al., 1974; Sfredo et al., 1985; Kastori and Stanković, 1985; Vrebalov, 1987; Krstić and Sarić, 1991; Kastori et al., 2008), and to a much lesser extent in wild sunflower species (Krstić and Sarić, 1987; Seiler and Campbell, 2004; Seiler and Campbell, 2006). The knowledge of specific nutrient requirements of a crop is important both theoretically and practically. It allows farmers to optimize plant mineral nutrition, which in turn makes room for maximum utilization of genetic potential for yield and quality of various crops and particular genotypes.

Environmental pollution with heavy metals and radionuclides, which results from human activities, has serious implications on the production of safe agricultural products. It was found that sunflower could be successfully employed for decontamination of soils polluted with heavy metals and radionuclides (Adler, 1996). In Ukraine, 30 km from Chernobyl, rhizofiltration was used together with phytoextraction for decontamination, and the best result was obtained with sunflower (Sorochinsky, 1998). Dushenkov et al. (1995) found in the laboratory that within 24 h roots of sunflower plants were able to substantially reduce the levels of Cd, Cr (VI), Cu, Mn, Ni, Pb, Sr, U (VI), and Zn in water, bringing metal content close to or below the discharge limits. Sunflower is also able to accumulate ^{137}Cs and ^{90}Sr. Roots of sunflower accumulated up to eight times more ^{137}Cs than the roots of timothy (*Phleum pratense* L.) or foxtail (*Alopecurus pratense* L.). The ability of sunflower to accumulate uranium (U) was reported by Salt et al. (1998) and Jovanović et al. (2001). Apart from the fact that sunflower intensely takes up some heavy metals and radionuclides, it also has high biomass, enabling it to accumulate and extract significant amounts of pollutants from the rhizosphere.

Cited results suggest that sunflower may be suitable for remediation of soils and waters polluted with heavy metals and radionuclides. Therefore, the aim of this study was to assess the capacity of some populations of wild sunflower species and hybrids to take up microelements important from agronomical point of view, i.e. B, Zn, Mn, Cu, Fe, and Ni, but also of the other, potentially toxic elements: Pb, Cd, As, Cr, Al, and Ba.

MATERIAL AND METHODS

Plants were grown on weakly calcareous chernozem of good physical and chemical properties (Tab. 1). At flowering, completely developed upper leaves, which are physiologically the most active (Ć u p i n a and S a k a č, 1989), were taken for the analyses. Micronutrient concentration was analyzed in different populations of wild sunflower species from Northern America (number of populations per species is given in parenthesis): *Helianthus neglectus* Heiser (3), *Helianthus petiolaris* Nutt. (2), *Helianthus agrophyllus* T&G (3), *Helianthus annuus* L. (4) as well as in five sunflower hybrids the most grown in Serbia. Micronutrient content was determined by ICP. The data were statistically processed by analysis of variance, calculation of the least significant difference (LSD), standard deviation, and coefficient of variation using Statistica 8 computer program.

Table 1. Basic soil properties

Depth (cm)	pH		$CaCO_3$ %	Humus %	Total N (%)	AL-P_2O_5	AL-K_2O
	In KCl	In H_2O				mg/100 g	
0—30	7.19	8.22	2.76	1.96	0.154	15.0	24.1
30—60	7.37	8.26	4.56	1.95	0.142	6.6	20

RESULTS AND DISCUSSION

Concentration of analyzed essential microelements varied between populations of wild sunflower species as well as hybrids, suggesting that there is significant genetic specificity with respect to uptake and accumulation of microelements in analyzed genotypes (Tab. 2). Average values of microelement concentrations in wild species and hybrids were the most variable with respect to Mn concentration, which was significantly higher in hybrids. Comparison between the results obtained in hybrids with corresponding values for microelements available in the literature, significant discrepancies are noticed. Concentrations of Fe, B and Mn were significantly higher in hybrids while Zn concentration was lower that was found by R o b i n s o n (1970, 1973), P a i s (1980), and B e r g m a n (1986). Concentrations of essential microelements shown here correspond to the results that in similar agroecological conditions obtained K o v a č e v i ć (1986). Higher concentration of essential microelements in hybrids suggests that the soil on which plants were grown was, in spite of weak alkaline reaction, well supplied with microelements in the forms available to plants (U b a v i ć et al., 1993). Especially high was B concentration, which in hybrids was 165 mg/kg DW in average. Sunflower indeed has high requirements for B (B l a m e y et al., 1978), which is in accordance with our results. In hybrids, the highest variation from the average was found in hybrid NS-H-45, in which concentration of nearly all analyzed elements was significantly lower as compared to the other hybrids. To the best of our knowledge, concentration of microelements in different populations of wild sunflower species has not been studied thus far. In some populations of *Helianthus agrophylus* high Fe concentrations were recorded.

Concentration of a microelement in plant tissues signifies the need of a plant for such an element and therefore such data are of primary biotechnical significance. The knowledge about the accumulation of non-essential microelements may help to choose the species and genotypes for phytoremediation of soils polluted with heavy metals. In Tab. 3 are shown concentrations of non-essential microelements in wild sunflower species and hybrids. In all populations of wild species and in hybrids Al had higher concentration than Ba, Cr, Pb, and As whereas concentration of Cd was the least. There was especially high concentration of Al, Pb, and As in some populations of *Helianthus agrophyllus*. Of tested hybrids, the highest concentration of all analyzed elements was found in NS-H-111, and especially high were concentrations of Cr and Al. Relatively high As concentration in analyzed genotypes may be explained by high As concentration in underground waters of South Bačka, where the plants were grown. Accumulation of Pb in plants was most probably enhanced by the vicinity of highway. Concentration of non-essential microelements in sunflower was studied extensively in the past. Simon (1998) and Simon et al. (1999) studied the accumulation and distribution of Cd in sunflower. In leaves of sunflower, grown on calcareous Chernozem, they found the following concentrations of non-essential microelements (mg/kg): As 0.03, Ba 5.4, Cd 0.2, Cr 0.1, and Pb 0.0. These values were much lower than values found in hybrids tested in our experiment. Kádár and Pálvölgyi (2003) found that sunflower accumulated low amounts of tested elements even when high doses were applied to the soil (810 kg/ha). They concluded that, in spite of high biomass production, sunflower is not suitable for phytoremediation of heavy metal-contaminated soils. At the same time, it is necessary to note that cited authors included only one genotype in their study. The data on the concentration of non-essential microelements in wild sunflower species are not known so far.

Results presented here suggest that there is high genetic variability between populations of wild sunflower species and hybrids in the uptake and tissue concentration of essential and non-essential microelements. This is supported by high coefficient of variation of concentration of some microelements in wild species and in hybrids. Coefficient of variation between populations of some wild species was element-depended and for essential elements varied between 3.7 and 59.5. For hybrids it varied from 10.0 to 48.8. Coefficient of variation depended both on genotype and on the element. Average coefficient of variation between populations of wild species had the following order: Cd>Ni>Cr>As>Al>B>Fe>Zn>Cu>Ba>Pb>Mn, and when hybrids were compared: Cr>Ni>Zn>Al>Fe>As>Cu>B>Ba>Cd>Pb>Mn (Tab. 2, Tab. 3). Although analyzed populations of wild sunflower species are quite distant as compared to hybrids, they all have low coefficient of variation for Mn and Pb concentration, and high for Ni and Cr. Based on presented data, one can speculate that analyzed genotypes also differ in their tolerance to the deficiency and excess of microelements. This feature of wild species can be used in breeding process. However, genotypes in which concentration of microelement(s) was above the average may be suitable for phytoremediation, especially hybrids, because they produce more biomass.

Tab. 2 — Content of essential microelements in populations of wild sunflower species and hybrids (mg/kg DM)

Genotypes		Zn	B	Mn	Cu	Fe	Ni
Species	Population						
Helianthus agrophylus	1575	27.56	109.0	74.70	14.26	978.2	1.31
	1677	16.27	138.8	78.50	12.13	443.7	2.36
	1317	22.58	165.7	81.75	17.49	852.8	3.52
	Average	**22.13**	**137.8**	**78.31**	**14.62**	**751.6**	**2.93**
	SD	4.94	24.7	2.93	2.44	239.7	1.78
	CV	22.30	17.9	3.75	16.69	31.9	43.85
Helianthus petiolaris	722	20.82	223.1	68.30	8.88	515.0	1.35
	2167	22.58	111.3	59.60	8.10	452.3	0.40
	Average	**21.70**	**167.2**	**63.95**	**8.49**	**483.6**	**0.87**
	SD	1.32	61.3	4.79	0.77	34.5	0.52
	CV	6.11	36.6	7.50	9.04	7.13	59.51
Helianthus neglectus	457	24.63	164.5	77.80	12.79	515.0	1.50
	1363	25.53	91.5	87.55	12.65	426.3	1.20
	1183	17.53	133.9	73.45	8.16	589.4	3.33
	Average	**22.56**	**131.0**	**79.50**	**11.20**	**510.3**	**2.01**
	SD	3.83	30.5	6.85	2.37	73.2	0.98
	CV	16.97	23.3	8.60	21.12	14.3	48.31
Helianthus annuus	2144	15.19	100.8	126.20	6.60	379.8	1.10
	2156	33.15	90.0	82.80	10.72	413.9	1.61
	2038	20.75	144.3	60.75	9.08	415.2	1.13
	2162	22.03	102.4	108.25	8.13	654.7	2.28
	Average	**22.78**	**109.4**	**94.50**	**8.63**	**465.9**	**1.53**
	SD	6.84	21.9	26.01	1.61	115.7	0.51
	CV	30.04	9.9	27.53	18.61	24.8	33.60
LSD	0.05	1.30	5.32	3.23	1.12	22.5	0.35
	0.01	1.74	7.14	4.34	1.50	36.9	0.47
Hybrids							
NS-H-45		8.28	135.0	129.55	9.55	284.6	1.27
NS-H-111		20.99	153.2	152.50	12.72	706.2	3.52
NS-H-Bačvanin		27.55	159.2	127.55	13.98	377.3	1.70
NS-H-Krajišnik		16.42	163.6	162.30	9.59	385.9	1.00
NS-H-Velja		14.06	218.3	135.95	7.10	397.1	1.87
Average		**17.46**	**165.3**	**141.57**	**10.59**	**430.2**	**1.87**
SD		6.74	29.3	14.15	2.56	150.1	0.91
CV		38.61	17.7	10.00	24.21	34.9	48.80
LSD	0.05	1.05	9.63	3.59	0.64	44.2	0.09
	0.01	1.46	13.36	4.98	0.88	61.3	0.13
LSD for species and hybrids							
	0.05	1.21	6.44	3.30	0.96	31.1	0.29
	0.01	1.61	8.58	4.41	1.28	41.4	0.39

Tab. 3 — Content of non-essential microelements in populations of wild sunflower species and hybrids (mg/kg DM)

Genotypes		Cr	Al	Cd	As	Pb	Ba
Species	Population						
	1575	0.43	135.80	0.43	1.22	2.84	21.50
	1677	0.10	59.25	0.09	1.07	2.27	15.50
Helianthus agrophylus	1317	0.13	117.70	0.13	1.50	2.33	19.99
	Average	**0.22**	**104.25**	**0.22**	**1.26**	**2.48**	**18.99**
	SD	0.16	34.72	0.16	0.23	0.36	2.72
	CV	69.06	33.30	73.86	18.54	14.45	14.29
	722	1.07	48.25	0.32	1.26	1.08	18.70
	2167	1.57	31.35	0.08	0.98	1.09	15.49
Helianthus petiolaris	**Average**	**1.32**	**39.80**	**0.20**	**1.12**	**1.09**	**17.09**
	SD	0.28	9.31	0.13	0.16	0.08	1.78
	CV	20.99	23.39	65.59	14.19	7.70	10.39
	457	1.75	65.65	0.64	1.04	1.47	21.00
	1363	1.55	60.35	0.21	0.44	1.40	14.01
Helianthus neglectus	1183	1.37	79.20	0.17	1.18	1.68	21.00
	Average	**1.89**	**68.40**	**0.34**	**0.88**	**1.52**	**18.67**
	SD	0.37	8.95	0.23	0.35	0.14	3.51
	CV	19.67	13.08	66.00	39.61	9.32	18.78
	2144	1.16	48.95	0.27	1.02	1.47	17.03
	2156	3.17	55.70	0.35	1.16	1.17	19.36
	2038	1.87	56.45	0.14	1.06	1.74	12.73
Helianthus annuus	2162	3.40	92.80	0.11	0.37	2.07	16.77
	Average	**2.40**	**63.47**	**0.22**	**0.90**	**1.61**	**16.47**
	SD	1.00	18.05	0.10	0.33	0.37	2.54
	CV	41.48	28.44	46.91	36.22	23.24	15.42
LSD	0.05	0.26	4.42	0.01	0.16	0.29	0.67
	0.01	0.34	5.93	0.02	0.22	0.39	0.90
Hybrids							
NS-H-45		2.30	46.30	0.28	0.50	1.54	24.52
NS-H-111		6.86	105.05	0.34	0.59	1.89	28.14
NS-H-Bačvanin		3.11	53.25	0.26	0.43	1.35	17.17
NS-H-Krajišnik		2.68	47.35	0.34	0.82	1.56	20.34
NS-H-Velja		2.83	60.05	0.28	0.53	1.97	23.04
Average		**3.55**	**62.40**	**0.30**	**0.57**	**1.60**	**22.64**
SD		1.74	22.63	0.05	0.14	0.25	3.81
CV		48.80	36.24	15.54	25.20	15.17	16.82
LSD	0.05	0.26	2.53	0.05	0.05	0.17	0.50
	0.01	0.37	3.51	0.08	0.08	0.24	0.70
LSD for species and hybrids							
	0.05	0.25	3.81	0.05	0.14	0.25	0.60
	0.01	0.33	5.09	0.07	0.18	0.34	0.80

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САДРЖАЈ МИКРОЕЛЕМЕНАТА У ПОПУЛАЦИЈАМА ДИВЉИХ ВРСТА СУНЦОКРЕТА И ХИБРИДА

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Резиме

У циљу проучавања генетске специфичности исхране сунцокрета микроелементима испитан је садржај неопходних (Zn, B, Mn, Cu, Fe и Ni) и не неопходних микроелемената (Cr, Al, Cd, As Pb и Ba) у пет најраспрострањенијих хибрида сунцокрета у Србији као и у различитим популацијама дивљих врста сунцокрета пореклом из Северне Америке: *Helianthus neglectus* Heiser (3), *Helianthus agrophyllus* T&G (3), *Helianthus petiolaris* Nutt. (2), *Helianthus annuus* L. (4).

Испитиване популације дивљих врста сунцокрета и хибрида значајно су се међусобно разликовале у погледу садржаја испитиваних микроелемената. Највећа разлика између популација дивљих врста сунцокрета и хибрида утврђена је у садржају Mn који је код хибрида био значајно већи. Код свих испитиваних генотипова највећи је био садржај Fe, B и Mn. Коефицијент варијације садржаја микроелемената зависио је од генотипа и елемента. Код популација дивљих врста сунцокрета кретао се од 3.7 до 59.5, а код хибрида од 10.0 до 48.8. За неесенцијалне микроелементе код дивљих популација коефицијент је био између 7.7, и 73.8, док је код хибрида варирао од 15.1 до 48.8. Коефицијент варијације био је најмањи код Mn и Pb код дивљих врста и хибрида. Код хибрида највећи коефицијент варијације имали су Cr, Ni и Zn, а код дивљих врста Cd, Ni и Cr.

На основу добијених резултата може се закључити да је генетичка специфичност у погледу усвајања неопходних и других микроелемената код популација дивљих врста сунцокрета и хибрида веома изражена. Широка генетска варијабилност испитиваних генотипова у погледу садржаја појединих микроелемената упућује на претпоставку о различитој реакцији према њиховом недостатку и сувишку, што може да буде од значаја у оплемењивачком раду, посебно при стварању генотипова подесних за фиторемедијацију земљишта загађених микроелементима.