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MICROELEMENTS CONCENTRATIONS IN MAIZE INBRED LINES GROWN ON ACID SOIL

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Abstract

Maize genotypes show great variability in nutrients content, depending on growing conditions. The objective of present study was to determine effects of genotype and environment on grain yield and Fe, Mn, Zn and Cu concentrations in leaf and grain of maize inbred lines grown on acid soil. Five inbred lines were grown in a field trial during 2003 and 2004 in the east Croatia on the very acid soil with pH (KCl) 3.9. Growing season of 2003 was very dry and warm, while in 2004 above average rainfall was recorded. Highly significant effect of genotype and year was observed for the grain yield. Average yield across the years was 3.08 t ha^{-1}, and it was significantly lower in 2003, due to severe drought. Higher influence of genotype was found for microelements in leaf, while for microelements concentrations in grain effect of year was also significant. Average microelements concentrations (in mg kg^{-1}) were 143 Fe, 185 Mn, 47.7 Zn and 15.0 Cu for the leaf, and 30.7 Fe, 5.4 Mn, 24.5 Zn and 7.02 Cu for the grain.

Key words: *maize inbred lines, microelements, acid soil, leaf, grain*

Introduction

Adequate microelements concentrations in agricultural plants, grain or seed, is very important for both, crops productivity and nutritive value of agricultural products. Maize genotypes show great variability in nutrients content, depending on environmental and growing conditions. Nutrients availability is associated with soil pH. The most microelements essential for plants are more available in acid soils, but this could lead to some other nutrient imbalances in plants. Important role of genotype on nutritional status of maize genotypes grown on acid soil has been reported (Kovacevic et al., 1997; Kovacevic et al., 2004; Antunović et al. 2003, Rastija et al., 2010). Heckman et al. (2003) reported that nutrient concentration in the same maize hybrid can vary considerably depending on the environment and microelements in grain shows much higher variability than macroelements. The microelements content in grain is a complex trait affected by a number of factors, including genotype, soil properties, environmental conditions and nutrient interactions (House, 1999).

Significant genetic variation in grain mineral concentration has been reported among maize inbred lines in Croatia (Brkić et al., 2003; Brkić et al., 2004; Šimić et al., 2004). The objective of present study was to determine effects of genotype and environment on grain yield and Fe, Mn, Zn and Cu concentrations in leaf and grain of maize inbred lines grown on acid soil.

Materials and methods

Five genetically divergent maize inbred lines, parental components of hybrids, were grown at the location in the east Croatia during 2003 and 2004. The lines Os 84-44 (L1), Os 438-95 (L2) and Os 30-8 (L3) which are used as female parents of hybrids belong to BSSS pool, while Os 1-44 (L4) and Os 6-2 (L5), used as male parents, are of Lancaster origin. The field trial was conducted on a very acid distric luvisol with very low phosphorus and low potassium, but high manganese and iron availability, whilst zinc and copper were in a moderate range (Table 1).

Table 1 Soil chemical properties

Year	pH		Organic matter	$mg(100\ g)^{-1}$		$mg\ kg^{-1}$			
	H_2O	KCl	%	P_2O_5	K_2O	Fe	Mn	Zn	Cu
2003	5.23	3.87	1.55	7.50	18.46	40.12	65.72	1.60	2.30
2004	4.83	3.90	2.00	9.57	17.85	98.70	56.81	2.51	3.69

The trial was set up in a randomized complete block design in three replications. The size of experimental plot was 8.4 m^2 in two rows. Usual crop management practice for maize growing was used. Maize was sown and harvested in the optimal agrotechnical terms.

Soil samples for chemical analysis were taken before each harvest. Soil pH was determined according to ISO (1994), organic matter by sulfocromic oxidation (ISO, 1998), plant available phosphorus and potassium by ammonium-lactate extraction (Egner et al., 1960), and concentrations of microelements (Fe, Mn, Zn and Cu) by absorption technique after extraction with EDTA. The samples of ear-leaves were taken at the siliking stage. Grain samples were made of the five randomly picked ears per plot. The concentrations of Fe, Mn, Zn and Cu in leaf and grain were measured by inductively coupled plasma (ICP) technique after microwave digestion with HNO_3+H_2O_2.

The obtained data were statistically analysed using ANOVA firstly separately for each year. Afterwards, combined analysis of variance was performed, considering genotype (inbred line) and year as main factors.

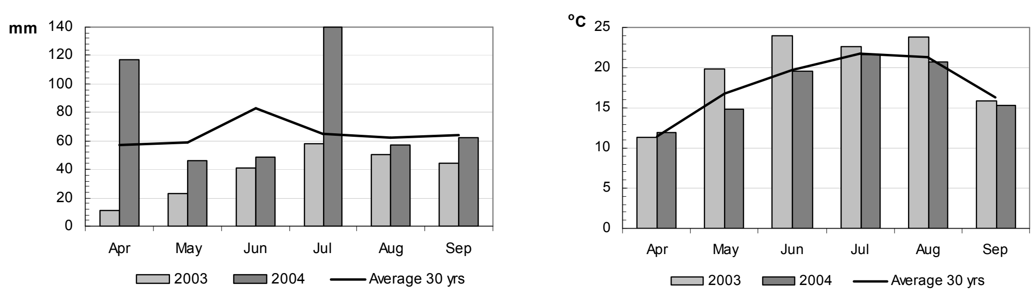

Figure 1. Monthly amount of rainfall (mm) and average air temperatures (°C) for maize growing season 2003 and 2004 and 30-year mean values for field trial location

Weather conditions during maize growing season considerably differed in two experimental years (Picture 1). The 2003 was exceptionally dry and warm and total rainfall in the growing period achieved only 50% of the long term mean value. The main feature of 2004 was rainy April and July, but generally it was more favourable year for maize growing.

Results and discussion

The analysis of variance showed very significant ($P \leq 0.01$) effect of genotype (inbred line) on all traits, except for grain Fe concentration ($P \leq 0.05$). The effect of year was also statistically proven for grain yield, concentration of Zn in leaf as well as for concentrations of all microelements in the grain. On the other hand, interaction line x year was no significant in most cases, except for Fe, Zn and Cu concentrations in grain.

Table 2. Grain yields ($t\ ha^{-1}$) of inbred lines over the years and significance levels for line (L) and year (Y) effects with LSD at the 0.05 probability level

Inbred line (L)	Year (Y)		Mean (L)
	2003	2004	
L1	2.93	4.79	3.86 a[#]
L2	2.39	3.68	3.03 b
L3	2.65	5.06	3.86 a
L4	2.02	3.05	2.54 b
L5	1.81	2.49	2.15 b
Mean (Y)	2.36 b	3.81 a	3.08
F-test	**	**	**
$LSD_{0.05}$ (L)	0.48	1.25	0.66
$LSD_{0.05}$ (Y)			0.42

[#] Mean values followed by the same letter within each column are not significantly different at P≤0.05
** - significant at P≤0.01 level

The grain yield averaged over years was 3.08 t ha^{-1} and great differences among years were found (Table 2). Much lower yield in 2003 is a consequence of severe drought and high air temperatures during maize growing season. It is well known that inbred lines are more susceptible to stress and that lower maize grain yield is in connection with dry and hot summer (Kovačević et al., 2009). Expectedly, female parental lines achieved higher yield. The lowest yield in the both years had L5, which is used as a male component and characteristic of high yield is not primarily important.

Table 3. Concentrations of Fe, Mn, Zn and Cu (mg kg^{-1}) in leaf and grain of five maize inbred lines averaged over two years and significance levels with LSD at the 0.05 probability level

Inbred line	Leaf (mg kg^{-1})				Grain (mg kg^{-1})			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
L1	143 b[#]	157 c	46.2 b	16.7 b	29.5 a	5.36 b	22.2 c	10.7 a
L2	138 b	161 c	46.0 b	13.9 c	33.8 a	4.22 c	25.1 b	7.12 b
L3	123 b	122 c	41.5 b	9.2 d	23.8 b	5.10 b	21.6 c	3.70 c
L4	131 b	269 a	65.2 a	16.4 bc	32.1 a	5.45 b	25.0 b	7.36 b
L5	180 a	218 b	39.4 b	20.0 a	34.4 a	6.86 a	28.7 a	6.25 b
Mean	143	185	47.7	15.2	30.7	5.40	24.5	7.02
F-test	**	**	**	**	*	**	**	**
$LSD_{0.05}$	22	47	7.57	2.67	6.3	0.77	2.76	2.03

[#] Mean values followed by the same letter within each column are not significantly different at P≤0.05
*,** - significant at P≤0.05 and P≤ 0.01 level

Regarding microelements concentrations in ear-leaf, great variability among inbred lines was found, but even greater for concentrations in grain (Table 3). The highest Fe and Cu concentration in leaf had L5, while the highest values for Zn and Mn in leaf was observed for the L4. Generally, in the both years quite high Mn leaf status was determined, what is a consequence of low pH and high Mn availability in soil (Table 1). According to Godo and Reisenauer (1980) manganese content in the leaves abruptly increases when soil pH drops below 5.5. Mengel and Kirkby (2001) reported that the value of 200 mg Mn kg^{-1} may reduce dry matter yield, while values of 35 to 100 mg Mn kg^{-1} in maize ear leaves consider as optimal (Bergmann, 1992). The both male parental lines had leaf Mn above 200 mg kg^{-1}. However, although two years differed regarding growing conditions, year effect wasn't significant for microelements in leaves, except for the Zn. In the more favourable 2004 growing season, higher Zn concentration was found (Table 4) and it was in the optimal range. The greatest variability among lines was determined for the Cu concentration, as it was in the wide range from 9.2 to 20.0 mg kg^{-1}.

Table 4. Mean values for concentrations of Fe, Mn, Zn and Cu in leaf and grain of five maize inbred lines across the years and significance levels with LSD at the 0.05 probability level

Year	Leaf (mg kg^{-1})				Grain (mg kg^{-1})			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
2003	146	194	44,0 b[#]	15,2	37,2 a	5,80 a	25,5 a	10,3 a
2004	140	176	51,3 a	15,2	24,2 b	5,00 b	23,6 b	3,7 b
Mean	143	185	47,7	15,2	30,7	5,40	24,5	7,0
F-test	ns	ns	**	ns	**	**	*	**
$LSD_{0.05}$			4,79		3,4	0,49	1,74	1,29

[#] Mean values followed by the same letter within each column are not significantly different at p<0.05
*,** - significant at 0.05 and 0.01 level respectively, ns - not significant

Unlike the leaves concentrations, growing year considerable affected micronutrient grain status, especially copper, whose concentrations was almost three times higher in the first year (Table 4). Overall, higher values for all tested microelements was recorded in 2003, what can be attributed to concentration effect i.e. reverse dilution effect due to lower grain yield and lower carbohydrates accumulation in dry growing season. Microelements concentrations in grain are often in the negative correlation with grain yield (Bänziger and Long, 2000) and depend on the content in a vegetative tissue and on the efficiency of translocation, both of which may be under genetic control (Bouis et al., 1999).

Inbred lines were clearly differentiated by concentrations of micronutrients in the grain. The highest grain Mn and Zn content again were determined in L5, male component of hybrid. Brkić et al. (2003) also found the highest Zn concentration in grain of genotypes that included this line as a parent, indicated importance of inheritance for grain nutrient contents. Commonly, maize grain contains small amount of manganese and the average value of 5.40 mg Mn kg^{-1} is in the normal range, although quite high concentration in leaves were observed. On the contrary, between Zn concentration in leaf and grain is much smaller difference than in Mn (Table 3), due to more efficient translocation of Zn into the grain (Pearson and Rengel, 1994). Unlike other microelements, whose concentration in the grain was highest in L5, the highest Cu value in the grain was determined in L1, female parent, suggesting the specificity of this genotype for Cu accumulation.

Conclusion

The study showed that the both, year and genotype significantly affected maize grain yield and grain Fe, Mn, Zn and Cu concentrations, while on leaf microelements concentration higher influence had genotype. In hot and dry growing season the microelements grain content was higher due to lower yield. Considerable variability for micronutrient status in leaf and grain of maize inbred lines was determined, although only five genotypes were included. It seems that independently on higher Mn availability in acid soil and its greater accumulation in leaf, Mn content in the grain remains relatively low. Generally, male inbred lines had higher microelements concentrations in leaf and grain. However, the highest Cu concentration in grain had one female parental line, suggesting on some genetic specificity for higher Cu accumulation.

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