ZINC AS A PLANT NUTRITIONAL PROBLEM IN THE EASTERN CROATIA

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ABSTRACT

It has been estimated that zinc deficiency is the most widespread micronutrient deficiency reducing crops production and quality worldwide. Nowadays, Zn deficiency is widely recognized and it is considered as one of the most important micronutrient problem in the world. The major soil factors affecting the Zn availability are neutral to alkaline soil reaction, calcareous soils and acid leached and sandy soils. The Zn deficiency symptoms have been diagnosed on maize plants which were grown on some neutral to slightly alkaline soils in the Eastern Croatia. Maize is a crop species with greater requirements for zinc and more susceptible to Zn deficiency, especially the inbred lines as parental components of hybrids. The objective of this paper was to summarize some previous findings regarding Zn nutritional problems and ways of its alleviations in the area of east Croatia. Response of maize genotypes to different Zn-fertilization treatments, as well as the grain yields and ear-leaf zinc concentration were shown. Results indicated on important role of genotype on Zn content in plant. Also, some results pointed out at complex relations between the Zn content in soil, plant tissue and grain.

Key words: Zn deficiency, Eastern Croatia, maize, inbred lines

INTRODUCTION

Zinc is a micronutrient essential for the growth and development of plants, as well as for animals and humans. As far back as 1926 the findings of Sommer and Lipman (according to Arnon, 1976) for the first time shown that zinc is an essential element for normal plant development, while the extensive use of zinc as a plant nutrient began in the early thirties of last century. It was found that symptoms of zinc deficiency frequently occur in some areas of the world, for example in Australia (Leece, 1976), India (Randhawa et al., 1974) and Turkey (Yilmaz et al., 1995; Cakmak et al., 1999). Today, Zn deficiency is widely recognized and it is considered as one of the most important micronutrient problem in the world, what is well-documented in the recent literature (Alloway,2008). According to Alloway (2009), millions of hectares of arable land are affected by lack of Zn and about one third of the human population suffers from an insufficient intake of this element.

A number of authors pointed out that, regarding the deficiency of available quantities of micronutrient in soils, the most abundant is zinc deficiency. Sillanpää (1990) have found that 49% of 190 soil samples originating from 25 countries have an inadequate zinc supply, while Graham and Welch (1996) reported that approximately 50% of global arable land used for cereal production are of low levels of accessibility of these micronutrient. In addition, Zn deficiency is not related to specific areas, but appears equally in cold and warm climatic zones, in arid and humid areas, and on the alkaline and acidic soil as well as on soils with different texture (Rahman et al., 1993). However, the main reason for the appearance of Zn deficiency symptoms is low solubility of Zn in soils, rather than low total Zn content in soil. Zn availability to plants is mostly reduced in calcareous soil or soils with high pH, on soils with high organic matter contents and high levels of available phosphorus, acid leached and sandy soils with low total Zn content. Also, Zn deficiency is manifested more during cold weather and low soil temperature conditions.

There are two possible ways for overcoming Zn nutritional problems. Plant breeding represents sustainable and cost-effective strategy, but development of new genotypes is a long-term process. On the other hand, application of Zn containing fertilizers is faster solution to the problem.

The Zn deficiency symptoms have been sporadically diagnosed on maize plants which were grown on some neutral to slightly alkaline soils in the Eastern Croatia (Kovacevic et al., 1988). Maize is the first-ranged crop in Croatia and it covers in average more than 30% of arable land. East Croatia has mainly favourable condition for seed-maize growing. It is well known that maize is highly susceptible to Zn deficiency. This is particularly true for seed maize as parents of hybrids are generally more susceptible to nutritional and any other aspect of stress.

The objective of this paper was to summarize some previous findings regarding Zn nutritional problems and ways of its alleviations in the area of east Croatia. Response of maize genotypes to different Zn-fertilization as well as maize ear-leaf Zn status was shown.

MATERIAL AND METHODS

Over the past few decades, several field trials with different Zn-fertilization treatments were conducted on various soil types in the Eastern Croatia. The treatments included presowing incorporation of Zn in the form of $ZnSO_4x7H_2O$ in different doses or foliar application with 0.75% $ZnSO_4x7H_2O$ solution. All trials were set up in a randomized block design with four or three replication. Maize inbred lines and hybrids were tested. Prior to setting up the trials soil analyses were done. They included common procedures for determination of soil pH, plant available phosphorus and potassium (AL-method), Ca, Mg and micronutrients. Zn was extracted by NH4-Acetate+EDTA. Samples of ear-leaf for Zn status were collected at the beginning of the silking stage. Element concentrations were determined by atomic absorption spectrophotometer or by ICP-OES techniques. Methods in details were described in the original papers.

RESULTS AND DISCUSSION

The Zn deficiency symptoms were observed at an early growth stage of maize on certain soils of Eastern Croatia. Growth retardation and pale green appearance of the whole plant was especially expressed during early growth stages of maize and cold weather. Plant (aboveground part) and soil samples were taken from typical places of poor and normal maize status. By chemical analysis it was ascertained that growth retarded maize grew on sites with higher pH values and higher carbonate and calcium contents as well as lower amounts of EDTA-extractable Zn (Kovacevic et al., 1988). The mean values of soil analysis were as follows: 6.17 and 7.09 pH(KCl); 608 and 1008 mg Ca/100 g; 5.8 and 2.4 mg Zn/100 g for the places of normal and chlorotic maize, respectively. The analogous comparison for plant properties were: 69 and 33 cm of plant height; 22.0 and 4.4 g of dry matter/plant, 27 and 18 mg Zn/kg. In the chlorotic plants the P:Zn, Fe:Zn and Mn:Zn ratios were wider (430, 70 and 6.4, respectively) than in plants of normal appearance (226, 16 and 2.6, respectively).

In the period from 1991 to1993 in total 16 field trials on seed-maize were conducted. Application of 13 kg Zn/ha raised yield in seven trials from 10% to 32% compared to control (Kovacevic et al., 1993).

Ten inbred lines, parental compounds of domestic maize hybrids, were grown on calcareous hypogley with pH(H_2O) 8.30, for two years. Folliar spraying by 0.75% $ZnSO_4x7H_2O$ solution at early growth stage significantly affected grain yields, which raised in individual lines from 13% to 34%. However, in two inbreds yield was decreased, confirming the specific reaction of different maize genotypes. (Josipovic et al., 1997).

In another experiment, response of five maize inbred lines to Zn fertilization was tested on neutral calcareous soils belonging to eutric cambisol type. Totally four field trials were conducted during the 1997 and 1998 growing seasons (Rastija, 2002).

Table 1 Impact of fertilization with zinc sulphate on maize inbred lines grain yield and impact of soil (control treatment) and genotype on Zn concentration in maize ear leaves in 1998 growing season

Inbred line	Grain yield (t/ha)			Mean	Zinc ear-leaf concentration (mg/kg)		
	Control	Zinc-soil	Zinc-foliar		Soil 1	Soil 2	Mean
L1	1.98	2.24	2.79	2.34 **d**	12.6	14.4	13.5 **d**
L2	4.74	4.28	5.61	4.88 **b**	20.4	23.2	21.8 **b**
L3	4.90	4.45	5.27	4.87 **b**	17.9	21.9	19.9 **c**
L4	5.10	5.23	5.45	5.26 **a**	17.4	22.2	19.8 **c**
L5	4.19	4.31	4.78	4.43 **c**	23.6	30.1	26.9 **a**
Mean	4.18 **b**	4.10 **b**	4.78 **a**	4.35	18.4 **b**	22.4 **a**	20.4

Mean values followed by different letter are significantly different at $P \leq 0.05$

Besides control (ordinary fertilization) presowing zinc fertilization (20 kg Zn/ha) and foliar application of zinc sulphate (twice at 10-days interval) were used. Very significant differences were found among fertilization treatments and among inbreds. In general, response to foliar Zn application was more efficient, although many studies confirming better results of Zn application into soil, especially from aspect of residual effect (Alloway, 2008). Depending on inbred line, mean ear-leaf Zn concentration on the control treatment ranged from 13.5 to 30.1 mg Zn/kg. Although in some cases Zn levels were lower than 20 mg/kg, what is considering as a critical level (Bergmann, 1992), there were no visual symptoms of Zn deficiency. One inbred line (L1) consistently had the lowest Zn concentration in leaves, and also the lowest yield (Table 1). The results of Zn concentration analysis confirmed the significance of inheritance factors in nutrient elements acquisition at maize inbred lines. Between Zn concentration and grain yield significantly positive correlation were found.

Five inbred lines were grown during 2003 and 2004 on two localities in the east Croatia (Table 2). The both selected plots were below average fertility due to unfavourable soil physical properties and low potassium and micronutrients availability, especially Zn (locality 1) and acid soil with low phosphorus and adequate zinc availability (locality 2). Generally, the concentration of Zn in the leaf was more affected by environments, primarily with soil type and its traits. Hence, considerable differences in Zn concentration among genotypes on two sites are consequence of Zn different availability in soil (Rastija, 2006).

Table 2 Mean values of zinc(mg Zn kg^{-1}) ear-leaf concentrations for five maize genotypes (inbred lines) across the localities and years (2003 and 2004) and results of F-test and t-test with LSD values for genotype (G) and year (Y) effects

Inbred lines (G)	Environment (E)				Mean G
	Locality 1		Locality 2		
	2003	2004	2003	2004	
Os84-44	25,7	17,3	46,4	46,0	33,8 **b**
Os1-44	32,6	28,6	57,0	73,4	47,9 **a**
Os438-95	21,7	19,7	45,3	46,7	33,3 **b**
Os30-8	31,3	26,3	38,4	44,5	35,1 **b**
Os6-2	24,7	22,9	33,0	45,7	31,6 **b**
Mean E	27,2 **b**	23,0 **b**	44,0 **a**	51,3 **a**	36,4
F test	ns	*	*	**	*
LSD $_{0,05}$ (G)		6,32	14,5	9,78	9,16
LSD $_{0,05}$ (E)					8,19

Mean values followed by different letter are significantly different at $P \leq 0.05$

Zinc nutritional problems in plants under practical conditions often can be expected after heavy liming or increased phosphorus fertilization. A number of studies have shown that liming reduces Zn availability in soil and may induce plant Zn deficiency (Brallier et al., 1996). In the experiment which aimed to examine the impact of liming on grain yield and nutritional status of different crops it was found that four years after lime application, soil pH raised from very acid to neutral one, but Zn availability significantly decreased (Rastija et al., 2007). In some other liming trial study in Croatia, Zn concentration in maize ear-leaf decreased for even 60% due to liming, but it still remains in an adequate range (Table 3).

Table 3 Impact of liming with dolomite on Zn status in soil, Zn concentrations in maize grain and ear-leaf at silking stage and on maize grain yield

Lime t/ha	EDTA- Zn in mg/kg	Zn - leaf mg/kg	Zn - grain mg/kg	Grain yield t/ha
0	5.52	71.2	20.1	12.01
5	5.22	44.9	18.0	12.57
10	4.71	33.2	18.4	12.61
15	3.90	26.9	16.5	12.45
$LSD_{0.05}$	ns	13.1	1.9	ns

CONCLUSIONS

Adequate zinc nutrition of major crops is of great significance. Maize is the most susceptible cereal crop to Zn deficiency. As maize is the most widespread crop in Croatia, it is grown on less fertile soils and soils where Zn unavailability could occur. Besides soil properties and environment, genotype is also important factor of grain yields. Results of various Zn fertilization field trials with maize inbred lines and hybrids conducted in the East Croatia, have shown that Zn application on problem soils could improve plant Zn status and grain yield, but that effect is significantly influenced by genotype and environmental factors.

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