INTAKE OF ZINC, COPPER AND MANGANESE BY THE GRAIN OF SELECTED VARIETIES OF BARLEY IN RELATIONSHIPS TO ECOLOGICAL BALANCE OF GROWING ENVIRONMENT

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Abstract

An intake of Zn, Cu a Mn to the grains of selected varieties of the sown barley (spring varieties: Lédi, KM2084, Marthe, Xanadu and winter varieties: Gerlach, Malwinta, Graciosa) was researched depending on three levels of plant nutrition, as well as depending on two kinds of tillage (conventional down to depth of 0,18-0,20m and minimized down to depth of 0,10-0,12m) under small plot conditions; area of one variant presented 14 m^2. The crops were collected when they were fully grown, the plant material was mineralized according to Kopp and content of the micro elements was defined by AAS method using VARIAN 240FS device.

The highest uptake of Cu, Zn and Mn was assessed by spring barley varieties of KM2084 and Marthe, but in winter barley there was not recorded significant influence of variety on cumulating of all monitored microelements. The dependence of uptake of selected microelements on the type of tillage was significant mainly in variants with applied mineral nutrition of plants by nitrogen, phosphorus, and potassium.

Key words: barley, grain, microelements, tillage

INTRODUCTION

Contribution of elements received from soil is influenced by its contamination, physical and chemical features, type of grown plant and specific features of separate elements. Determining factor for receiving of elements by plants is their concentration in soil solution. (Tlustoš et al., 2006). Soil solution consists of several forms of separate elements, mainly of free dissociated ions, as well as from inorganic and organic complexes. Releasing of elements into soil solution can be influenced by their total content in soil, their forms, as well as other factors, such as: soil type, ion exchange capacity, pH, content of organic material, redox potential of soil and also influence of other ions.

Nitrogen fertilization and following availability of nitrogen for plants influence natural level of soil fertility, as well as internal metabolic processes (Janzen et al., 2003). However, available forms of nitrogen for plants are only anions NO_3^- and cations NH_4^+.

Phosphorus is one of 17 elements necessary for growth of plants. However, bigger part of phosphorus occurs in inaccessible form for plants (mainly in inorganic form). In acid soils, there is shortness of available phosphorus accompanied by Mn and Al toxicity, mainly when pH of soil is under the value of 5.4 (Procházka et al., 2003).

Very important macroelement - potassium influences growth of plants, reaction of photosynthesis, it activates enzymes and regulates water regime. About 80-90% of potassium accumulated in plant is in its vegetative part, which is by-product of the plant, such as straw or roots (Birkás et al., 2006). Potassium is received in the form of cation K^+ by plant. Its receiving is realized actively (it prevails in case of lower concentration of K^+ in soil solution – to 0.5 mM), as well as passively. In case of high concentrations of K in soil solution, increased receiving of potassium can emerge, as well as limitation of receiving of Na^+, Mg^{2+}, Ca^{2+}, Zn^{2+} and Mn^{2+} (Tomar and Singh, 1994).

Different tilling of the soil can influence not only incorporating of used industrial fertilizers in soil profiles, but also arrangement of nutrition. In deeper soil profiles, content of inorganic elements decreases more significantly (López-Fando and Pardo, 2009).

MATERIAL AND METHOD

This experiment was realized on experimental base lands of FAPZ SPU in Nitra - Dolná Malanta in 2008-2010. This locality is flat, height above sea level is 177m, coordinates are 48º19' central-west width; 18º09' east-west longitude. Before starting with an experiment, pH of the land was set within the interval 5.72-5.73, humus content was 1.99-2.19 %, percentage of humin acids was 16.30 % and fulvic acids 20.22%. Experiments were based on block method. One variant area was $14m^2$ large. We used small-parcel technique for seeding, treatment and harvesting. Grown grain crop was sorted out and we took three samples from it. We used three species of winter barley, namely: Gerlach, Malwinta, Graciosa and four species of spring barley: Lédi, KM2084, Marthe, Xanadu.

In this experiment, we applied four levels of fertilization: 1) unfertilized (control variant), 2) fertilization by the fertilizer Condit mineral batched $1t.ha^{-1}$ (which added to land 70 kg $N.ha^{-1}$, 4.36 kg $P.ha^{-1}$ and 16.6 kg $K.ha^{-1}$), 3) application of the following fertilizers: Amofos batched in 150 kg , KCl (60 %) 60 $kg.ha^{-1}$, Hakofyt 150 $dm^3.ha^{-1}$ and NH_4NO_3, in total, we added to the land 60 kg $N.ha^{-1}$, 22.7 kg $P.ha^{-1}$, 36 kg $K.ha^{-1}$, 4) same level of fertilization as in the previous case, however, instead of the last applied separate fertilizer NH_4NO_3 we used mixture of $NH_4NO_3 + CaCO_3$ and so we added 60 kg $N.ha^{-1}$ and 5 kg $Ca.ha^{-1}$ to the land.

We realized two types of tillage: conventional tillage (tillage up to the depth of 0.18 - 0.20 m) and minimalization – disc ploughing (up to the depth of 0.10 - 0.12m). In this experiment, three repetitions were executed.

Analytical determination of microelements: Analysis of zinc, copper and manganese in tested material after mineralization was realized in two phases:

- in the first phase, 2 g of milled grain of barley is decomposed in dry way while adding of about 0.5 cm^3 of concentrated HNO_3 oxidizer. It was incinerated in sand bath, then it was annealed in muffle furnace at the temperature of 500 - 550 °C.
- in the second phase, after incineration, this material was mixed up with HNO_3 in the rate of 1:3. Then it was rinsed and added in 50 cm^3 volumetric flask after filtration. Finally we set amount of Zn, Cu and Mn using AAS method by *VARIAN 240FS* device.

Statistical analysis

Statistical processing of the results was carried out in program XL-STAT at levels of significance 95% and 99%.

RESULTS AND DISSCUSIONS

In any of these variants we did not record exceeding of maximum allowed value limit of followed elements according to Foodstuffs code. After averaging of all content values of followed elements in separate species in all four variants we found out that the species of spring barley KM2084 and Marthe had the highest taking of Cu, Zn and Mn, however we did not record more significant influence of the species on accumulation of all followed micro-elements in case of winter barley - increased influence on their content was in the variant of disc ploughing in the following sequence: Graciosa > Malwinta > Gerlach. Application of conventional tillage had influence on increase of manganese and zinc in the following sequence: Malwinta > Graciosa > Gerlach.

Application of minimalization tillage had statistically documented influence (in comparison with unfertilized variant) on the content of Zn and Cu in the grain of spring barley only in the 4th variant of fertilization level (table 1). We recorded the same results also in case of Mn cumulation, besides Marthe species. After application of minimalization tillage, we recorded statistical demonstrativeness in cumulation of Zn and Cu in the 2nd variant and in the content of Cu and Mn in barley grain in 3rd variant (besides Graciosa species, where we did not recorded any statistical dependence of Cu and Mn receiving into the grain of sown barley). By conventional tillage we recorded statistical demonstrative dependence of Zn income into the grain only in fourth variant, namely in species: KM 2084 and Marthe - spring barley and in the following species of winter barley:

Gerlach and Graciosa. In case of application of conventional pillage, we recorded statistical significance on the content of manganese in barley grain in the 4th variant (besides the species Xanadu and Gerlach).

By comparison of both variants (table 2-4) with the similar level of treatment, but in different types of tillage, we found out significance in cumulation of zinc and copper in the 4th variant of winter barley species and in receiving of copper in the 3rd variant of spring barleys - in this variant, we recorded also high significant dependence of manganese receiving in the following species: Lédi, Gerlach and Graciosa depending on type of tillage. We also found out statistically significant cumulation of manganese depending on type of tillage in the 2nd variant of all spring barley species.

Mineral substances such as magnesium, sulphur, sodium, potassium, zinc and calcium are concentrated in external layers of the grain (Gajdošová and Šturdík, 2004). Sekara et al., (2005) states that roots of barley contains 6.5 times more copper than tissues of other aboveground parts of the plant. According to authors, amount of zinc is directly proportional to its amount in roots and grain. Distribution of zinc was similar, however the differences of Zn in tissues were lower. Sekara et al. (2005) states the amount of zinc in dry matters of roots of sown barley is 40.82 $mg.kg^{-1}$, the amount of copper is 15.92 $mg.kg^{-1}$ and content of zinc in the grain is 26.83 $mg.kg^{-1}$, copper - 2.44 $mg.kg^{-1}$ and so in comparison with Sekara et al. (2005), our results of content of zinc are almost the similar with his values of Zn in grains of sown barley (table 1). Also Alvarez et al. (2006) came to similar results in alkaline soil. Influence of soil parameters is one of the most important factors determining receiving of components into the plants (Kabata-Perdias, 2004). Their papers state that contents of Mn in the plant negatively correlate only from pH of the soil and vice versa, content of zinc in the plant positively correlates with the amount of organic components in soil and from total zinc in the soil. For these reasons adjustment of soil by tillage, which caused its internal physical-chemical features, as well as shift of pH had more significant influence on receiving of Cu into the grain of barley in the 4th variant. In this variant, where we applied $CaCO_3$ in combination with phosphate fertilizer we noticed increase of cumulation of Mn in spring barley (conventional tillage) in comparison with other, what is in contrary with statements of Procházka et al. (2003), who states that shortness of phosphorus in acid soils invokes toxicity of plants by Mn and Al, but this statement is in compliance with our experiment only in case of winter species (besides Graciosa species) in both types of applied tillage. Liming in combination with phosphorus nutrition did not have any influence on cumulation of Cu in sown barley grain, in case of Zn it caused its decrease in almost all winter species of barley, as well as in spring species, besides KM 2084, but only after application of minimalization tillage, what is in compliance with statements of Bolan and Duraisamy (2003), who found out limited uptake of risky elements (mainly Zn) after application of phosphates, as well as after liming. On the other hand, phosphates can influence uptake of Zn by creation of stable complexes, mainly in case of higher pH - in our experiment we came into this conclusion in case of species Lédi and KM 2084 after application of conventional tillage

Table 1

Content of zinc, copper, manganese in grain (mg.kg^{-1}) of different varietes of barley in relation to type of tillage (conventional and disk harrowing-minimum tillage) and four levels of fertilization:

		Spring barley varieties				Winter barley varieties		
tillage + level of fertilization		*Lédi*	*KM2084*	*Marthe*	*Xanadu*	*Gerlach*	*Malwinta*	*Graciosa*
				Zn				
1	konven.$_1$	24,09	31,72	30,64	26,78	18,71	23,10	19,68
2	konven.$_2$	27,04 $^{+}$	36,89	29,41 $^{+}$	25,60	21,23	20,55	21,84 $^{++}$
3	konven.$_3$	26,10	36,17 $^{+}$	30,41	28,68	18,74 $^{+}$	20,97	19,02
4	konven.$_4$	27,08	35,90 $^{+}$	30,84 $^{+}$	25,60	17,85 $^{+}$	20,33	19,55 $^{+}$
5	minimal.$_1$	28,10	34,95	28,82	27,16	20,39	19,12	21,03
6	minimal.$_2$	25,07	34,87	29,62	23,89	21,51 $^{+}$	20,07 $^{+}$	20,99
7	minimal.$_3$	27,06	35,15	32,20 $^{+}$	25,94^{+}	20,30	18,70	20,50
8	minimal.$_4$	24,06^{++}	40,32 $^{+}$	28,84 $^{+}$	25,05^{+}	19,40	18,70	20,52 $^{++}$
				Cu				
1	konven.$_1$	5,01	7,23	6,60	5,97	7,15	4,18	3,97
2	konven.$_2$	5,04	6,86	6,28	5,74	3,82 $^{+}$	4,12	3,31
3	konven.$_3$	5,26 $^{+}$	6,93	6,79	6,24	3,66	4,02 $^{+}$	3,32
4	konven.$_4$	5,04 $^{++}$	6,95	6,60 $^{+}$	6,02	3,06 $^{+}$	4,12	2,99
5	minimal.$_1$	5,65	6,86	6,38	6,41	3,61	3,08	3,59
6	minimal.$_2$	5,10 $^{+}$	6,86	6,43	5,22	3,60 $^{++}$	3,47 $^{+}$	4,12
7	minimal.$_3$	5,19	6,76	6,47 $^{+}$	5,47 $^{++}$	3,83 $^{+}$	3,25 $^{+}$	3,86
8	minimal.$_4$	6,72 $^{+}$	7,15 $^{+}$	6,91 $^{+}$	5,59^{+}	3,49	4,80	3,69
				Mn				
1	konven.$_1$	10,57	13,05	13,04	12,54	15,49	20,41	17,25
2	konven.$_2$	11,93	15,67	12,67	11,98 $^{++}$	17,79	18,68	19,64
3	konven.$_3$	11,90 $^{+}$	15,59	12,66 $^{+}$	13,41	16,61	18,27 $^{+}$	17,52
4	konven.$_4$	13,54 $^{+}$	17,16 $^{+}$	14,35 $^{++}$	12,80	16,27	18,19 $^{++}$	17,55 $^{+}$
5	minimal.$_1$	12,57	14,64	11,94	11,34	15,75	17,80	17,00
6	minimal.$_2$	10,53	15,61	12,20	11,37 $^{++}$	16,05	19,24 $^{+}$	17,30
7	minimal.$_3$	13,34 $^{+}$	15,04 $^{++}$	14,10 $^{+}$	12,15	15,43 $^{++}$	16,50 $^{++}$	18,07
8	minimal.$_4$	11,34^{++}	17,13 $^{+}$	14,36	11,90 $^{+}$	15,04	16,55	17,99

1) control variant; 2) N_{70}+ $P_{4..36}$+$K_{16.6}$; 3) N_{60}+$P_{22,7}$+K_{36}; 4) N_{60}+$P_{22,7}$+K_{36}+Ca_5.
($^{+}$ Statistical significance at level 95%; $^{++}$ statistical significance at level 99%)

Table 2

Statistical comparison of two types of tillage: conventional and minimalization (both in the same levels of fertilization) on receiving of zinc into the barley grain.

Zn		**Spring barley varieties**				**Winter barley varieties**		
	level of fertilization	*Lédi*	*KM2084*	*Marthe*	*Xanadu*	*Gerlach*	*Malwinta*	*Graciosa*
1	no fertilized				+	+		++
2	N70+P4.36+K16.6	+						
3	N60+P22,7+K36		+		+	+		
4	N60+P22,7+K36+Ca5	+				+	+	+

Table 3

Statistical comparison of two types of tillage: conventional and minimalization (both in the same levels of fertilization) on receiving of copper into the barley grain.

Cu		**Spring barley varieties**				**Winter barley varieties**		
	level of fertilization	*Lédi*	*KM2084*	*Marthe*	*Xanadu*	*Gerlach*	*Malwinta*	*Graciosa*
1	no fertilized			+		+		
2	N70+P4.36+K16.6							
3	N60+P22,7+K36	+	+	+	++		+	
4	N60+P22,7+K36+Ca5		+	+	+	+	+	+

Table 4

Statistical comparison of two types of tillage: conventional and minimalization (both in the same levels of fertilization) on receiving of manganese into the barley grain.

Mn	**Spring barley varieties**				**Winter barley varieties**		
level of fertilization	*Lédi*	*KM2084*	*Marthe*	*Xanadu*	*Gerlach*	*Malwinta*	*Graciosa*
no fertilized	++	+					
N70+P4.36+K16.6	+	+	++	++		++	
N60+P22,7+K36	++				++		++
N60+P22,7+K36+Ca5	+	+					

CONCLUSIONS

The influence of types of spring barley varieties on the rate of cumulating of Cu, Zn, and Mn into the grain of the spring barley was evaluated. Liming in combination with phosphoric and nitrogen fertilizers had statistically significant affect on the content of Cu and Zn in spring barley only in variants with minimalization tillage system and the same result was evaluated when considering content of Mn, except for variety Marthe. The consequence of agrotechnical amendment of soil by minimalization tillage was manifested as statistically significant dependence of copper and zinc cumulating in varieties of winter barley (except for variety Graciosa) in variants with the highest doses of nitrogen (70 kg.ha^{-1}); in limed and nourished soil with applied conventional tillage the statistical significance was assessed in uptake of Zn into the grain of barley: KM 2084, Marthe (spring barley) and Gerlach, Graciosa (winter barley). There was also statistical significance when evaluating uptake of Mn into the grain of barley (after conventional tillage), with the exception of varieties Xanadu and Gerlach. The type of tillage had statistically significant influence mainly in nourished variants on enter of microelements into the grain of barley.

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