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REGULAR ARTICLE

THE EFFECTS OF VARIOUS FERTILIZATION AND TILLAGE ON UPTAKE Cu, Zn TO SOME VARIETIES OF BARLEY GRAIN

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ABSTRACT

A field experiment was conducted to observe the effects of fertilization (with nitrogen, phosphorus and potassium) and application of different tillage: 1) conventional into depth 0.18-0.20 m and 2) minimalization into depth 0.10-0.12 m on micronutrient density (Cu, Zn) in grain of some varieties of barley. In 2009 the following levels were applied in experiment: a) control (not fertilized variant), b) fertilized ($kg.ha^{-1}$: 70 N + 4.36 P + 16.6 K), c) fertilized ($kg.ha^{-1}$: 60 N + 22.7 P + 36 K) and d) the same level of fertilizing as in previous variant, but also with addition of 25 $kg.ha^{-1}$ of Ca.

Harvest was carried out in period of full ripeness and after mineralization of barley grain by dry way method the contents of Cu and Zn were assessed by spectrophotometer Varian DUO 240FS/240Z.

Type of chosen variety had weaker impact on uptake of trace elements in samples of winter barley; there was not any varietal relation to uptake of Zn. Application of fertilizers total reduction of contents of both metals, especially zinc, where significant discrepancies were evaluated with decline of values. Contents of Cu also mostly declined (besides varieties of winter barley). The influence of applied $CaCO_3$ could not be accurately defined - in spring barley it caused an increase in Cu and Zn contents after application of conventional tillage and decline of contents of these elements after application of minimalization tillage, but contrary changes were evaluated in winter barley.

Keywords: barley, fertilization, copper, zinc, tillage

INTRODUCTION

Chemical composition of barley grain is determined not only genetically, but also by ecological factors, such as soil, fertilizing, tillage or also physical and chemical influences during storage and processing. Present tendency forward to increasing of foodstuffs quality requires greater emphasis on quality of products from agricultural first-production (**Fecenko, Ložek, 2000**).

Copper is one of important microelements and its deficit limits the growth of roots of some plants and causes the chlorosis of leaves. It could be absorbed on colloid particles in soil, or it occurs in non-soluble salts as well as in form of water-soluble compounds. Copper forms with organic matter various stable organic complexes, where it could be strongly bound and thus is for plants not available. Soil reaction and also the content of organic matter have the greatest importance on availability of copper in plants from soil traits. Availability of copper influenced by pH is affected less than by Zn. Copper is strongly absorbed in soil and thus excessive concentration in plants is exceptional (**Pueyo, 2003**).

Zinc is an activator and stabilisator of enzymes of regulating the metabolism of plants. It affects saccharides demand, oxidation processes and translocation of amino acids. Its deficit reduces the synthesis of fatty acids, proteins, starch and the formation of chlorophyll is disrupted. Zinc is released by weathering as bivalent cation that is afterwards absorbed on sorption complex. Its availability for plants is in relation to soil reaction. With increased concentration of hydrogen ions also its availability for plants increased. Uptake of zinc by plants is limited by competing cations in acid environment could lead to its easy mobilization. Solubility is strongly affected also by organic ligands in alkali environment which result in greater solubility. Availability of zinc to plants considerably influences also fertilizing by nitrogen and phosphorous fertilizers (**Fecenko, Ložek, 2000**).

Different tilling of the soil can influence not only incorporating of used industrial fertilizers in soil profiles, but also arrangement of nutrients or uptake of heavy metals into plants.

The objective of our study was to determine the relation of Cu and Zn accumulation into barley grain in relation to type of tillage (minimalization and conventional) as well as in relation to three different levels of doses of inorganic nutrients.

MATERIAL AND METHODS

This experiment was established in experimental base lands of FAPZ SPU in Nitra - Dolná Malanta in 2009. Before starting with an experiment, pH of the land was set within the interval 5.72-6.73. Content of Cu in soil profile was as following: in depth 0,0-0,10m 23.8mg.kg^{-1}, in depth 0,20-0,30m 23.7mg.kg^{-1} and content of Zn in depth 0,0-0,10m 44.6mg.kg^{-1} and in 0,20-0,30m depth was 43.5mg.kg^{-1}. Experiments were based on block method. One variant area was 14m^2 large. Small-parcel technique was used for seeding, treatment and harvesting. Grown grain crop was sorted out and we took three samples from it. Three species of winter barley were used, exactly: Malwinta, Graciosa, Wintmalt and four species of spring barley: Kangoo, KM2084, Marthe, Xanadu.

In this experiment, four levels of fertilization were applied: 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 25 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). Three repetitions were carried out in this experiment.

Analytical determination of microelements

Analysis of zinc, copper 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 and Cu using AAS method by Varian DUO 240FS/240Z device.

All data were processed statistically in program Statgraphics.

RESULTS

The highest acceptable amounts of copper and zinc were not exceeded in any of analysed samples of barley grain according to Food Codex SR (tab. 1, 2). By averaging of all values in variant (control with fertilized) of individual varieties in each type of tillage it was found out that relatively high uptake of Cu (tab. 1) was evaluated in variety of spring barley *Marthe* (undependable from type of applied tillage) and in winter barley the order of Cu content was the same in tested varieties in both types of applied tillage: *Malwinta* > *Wintmalt* > *Graciosa*. Variety *Kangoo* was among the highest concentration of Zn accumulation in spring barley and variety *Xanadu* cumulated the lowest concentrations of this element. Final and definite order of varieties in Zn (tab. 2) uptake of winter barley could not be determined.

Application of macroelements (N, P, K) into soil caused decline of Cu (tab. 1) content in grain of most varieties of barley and mostly in all varieties induced decline of Zn (tab. 2) content in barley grain undependable on type of tillage (statistically significant only in varieties *Xanadu, Malwinta and Wintmalt* after application of conventional tillage). Varieties of barley responded very interestingly by cumulating of both tested elements in grain by adding of $CaCO_3$ into soil. Comparison of 3^{rd} and 4^{th} variants that differed only by presence of exact lime showed contrary tendency of changes in access and decline of monitored elements in barley grain in both types of tillage (except for varieties *Xanadu* and *Malwinta*), statistically significant differences were evaluated in varieties *Kangoo* and *Malwinta* after application of both types of tillage. Application of minimalization tillage caused in limed variant the decline in Cu content in grain of spring barley varieties (except for variety *Xanadu*) and its increase in winter barley (except for variety *Wintmalt*). The same decline of Zn in barley grain (except for variety *Marthe*) was induced by minimalization tillage in presence of $CaCO_3$ after application of this tillage an increase of Zn content was assessed in all varieties of winter barley in limed variants.

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

Cu		Spring barley varieties				Winter barley varieties		
	tillage + +level of fertilization	*Kangoo*	*KM2084*	*Marthe*	*Xanadu*	*Malwinta*	*Graciosa*	*Wintmalt*
1	convent. $_1$	4.55 ^{A}	4.54 ^{A}	5.42 ^{A}	5.87 ^{A}	4.66 ^{A}	3.57 ^{A}	3.99 ^{A}
2	convent. $_2$	4.33 ^{A}	5.83 ^{A}	4.47 ^{B}	5.65 ^{A}	4.34 ^{A}	3.78 ^{A}	4.08 ^{A}
3	convent. $_3$	4.23 ^{B}	2.58 ^{B}	4.58 ^{A}	4.79 ^{A}	4.12 ^{B}	3.97 ^{B}	3.74 ^{A}
4	convent. $_4$	4.66 ^{A}	4.97 ^{A}	5.13 ^{C}	4.79 ^{B}	4.03 ^{C}	3.72 ^{B}	3.95 ^{A}
5	minimal. $_1$	5.25 ^{A}	5.38 ^{A}	5.56 ^{A}	4.89 ^{A}	4.00 ^{A}	3.53 ^{A}	3.88 ^{A}
6	minimal. $_2$	4.67 ^{B}	4.30 ^{B}	4.15 ^{A}	5.31 ^{B}	3.98 ^{A}	3.52 ^{A}	3.61 ^{B}
7	minimal. $_3$	4.91 ^{A}	5.51 ^{A}	5.33 ^{A}	4.22 ^{A}	3.66 ^{A}	3.62 ^{A}	3.97 ^{A}
8	minimal. $_4$	4.55 ^{B}	2.80 ^{C}	5.25 ^{A}	4.37 ^{B}	3.79 ^{B}	3.80 ^{A}	3.93 ^{A}

1) control variant; 2) $N_{70}+ P_{4,36}+K_{16.6}$; 3) $N_{60}+P_{22,7}+K_{36}$; 4) $N_{60}+P_{22,7}+K_{36}+Ca_{25}$.

Capital letters in table characterize statistical significance ($P < 0.01$). Their conformity means that the values are statistically non-significant and different letters characterize statistically strong significance.

DISCUSSION

Fertilizing with N, P, and K has also significant consequences on uptake of selected microelements. Decline in Zn content was evaluated in barley grain in our work (undependable from type of tillage), what is opposite to what was reported by **Halil and Turan (2008),** who did not observe any differences in contents of Zn in intercrops from applied nitrogen fertilizing and contrary, content of Cu reported by **Halil and Turan (2008)** in lucerne and smooth brome grass increased with increasing doses of nitrogen in soil, what is again contrary fact in comparison to our analyses (the most significant reduction of Cu was content manifested in spring barley grain after application of minimalization tillage).

The same data were cited by **Rongli *et al.* (2010),** where the concentrations of Zn, and Cu in intact grains were enhanced when the N application was increased from 0 to 130 kg N.ha^{-1}; concentrations were not increased further by increasing the rate from 130 to 300 kg N.ha^{-1}. These results were similar to those of **Hao *et al.* (2007),** who reported that, in a pot experiment, N application rates up to 160 kg N.ha^{-1} increased Cu and Zn concentrations in brown rice.

In our work not so high doses of nitrogen were applied in comparison to published studies of **Rongli *et al.* (2010)** and **Hao *et al.* (2007),** who in their experiments applied even

2--5 fold higher doses of N into soil, that's why we observed contrary, or reducing influence of Cu and Zn uptake to barley grain.

Table 1 Content of zinc in grain ($mg.kg^{-1}$) of different varieties of barley in relation to type of tillage (conventional and disk harrowing-minimum tillage) and four levels of fertilization

Zn		Spring barley varieties				Winter barley varieties		
	tillage + +level of fertilization	*Kangoo*	*KM2084*	*Marthe*	*Xanadu*	*Malwinta*	*Graciosa*	*Wintmalt*
1	convent. 1	25.35 A	26.03 A	25.24 A	24.56 A	23.19 A	22.62 A	24.58 A
2	convent. 2	25.00 A	26.89 A	24.95 B	22.72 B	20.40 B	22.14 A	20.40 B
3	convent. 3	22.80 A	16.42 A	25.19 A	19.15 C	20.29 C	22.99 A	21.56 C
4	convent. 4	22.97 B	24.54 A	23.56 C	20.78 B	20.59 B	22.15 A	19.85 B
5	minimal. 1	26.89 A	31.43 A	24.86 A	21.93 A	23.89 A	20.64 A	21.61 A
6	minimal. 2	26.60 A	25.46 B	21.51 B	21.48 A	21.18 A	20.70 A	20.68 A
7	minimal. 3	24.97 A	27.00 A	23.37 A	21.75 A	19.14 B	18.10 A	19.85 A
8	minimal. 4	24.13 B	11.94 A	23.83 A	21.64 A	19.70 B	19.64 B	20.41 A

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_{25}.

Capital letters in table characterize statistical significance ($P < 0.01$). Their conformity means that the values are statistically non-significant and different letters characterize statistically strong significance.

Halil and Turan (2008) found out that the content of Cu in plants of grass were marginally affected by various doses of phosphorus into soil; the same was reported by other studies when application of P has not any influence on amount of Cu in legumes and in brome grass **(Adjei, 1998)** and contents of Cu in maize **(Komljenovic *et al.*, 2006).** Our recorded decline of contents of both metals in grain of barley could be explained by findings of **Jurkovic *et al.* (2006),** about the influence of P fertilization, where the leaf Zn decreased by 37 % compared to the control. Application of both P and K resulted in decrease of leaf Zn by 30 %. Significant difference the leaf Cu (by 9 % lower) was found under influences of K fertilization only. The leaf Fe was independent on these factors.

Moreover, stronger influence of combination of P and K could be considered responsible for reduction in accumulation of Cu and Zn in barley grain.

Soil analyses suggest that not only Cu is in soil profile more even distributed, while it is generally known, that Cu is more mobile element in soil **(Pueyo *et al.*, 2003),** but also Zn has more even deep distribution in soil. Therefore, theoretically tillage itself has not affect the enter of these elements into plants, but tillage in combination with fertilizing affects the uptake of macronutrients that have a consequence in their uptake and utilization, and thus the ability of accumulation of heavy metals is also changing. In consistency with **Kirchmann and Eskilsson (2010)** decline in Zn content in grain of spring barley with using of liming was evaluated, but only after application of minimalization tillage, while this fact could be influenced in higher rate also by climatic conditions.

CONCLUSION

Weak varietal dependence on Cu uptake in winter spring, in spring barley the highest accumulation of Cu in variety *Marthe* was evaluated. In winter barley it was not able to determine any varietal dependence of Zn uptake, in spring barley Zn was accumulated most by variety *Kangoo* and least by variety *Xanadu*.

Fertilizing with N, P and K caused reduction of enter of Zn into grain of barley, when the decline of its content was also recorded by accumulation of Cu into grain of barley with no regard to type of applied tillage.

Influence of tillage was significant in variants with applied lime: by minimalization tillage was recorded reduction of Cu and Zn content in grain of spring barley and contrary, their increased contents of both elements in grain of winter barleys.

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