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MICROELEMENTS (Cu, Mo, Zn, Mn, Fe) IN CORN GRAIN ACCORDING TO THEIR AVAILABILITY IN THE FALLOW SOD-PODZOLIC SOIL PROFILE

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Abstract

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It is necessary to use micro-fertilizers in growing crops due to several reasons: use of high-yielding hybrids, whose increased yield may decrease the content of microelements in the productive mass; improved grain quality; increased resistance to disease and adverse factors; balanced nutrition of plants and enrichment of crop production with microelements. When growing plants in sod-podzolic soils, it is necessary to take into account the specific chemical composition of these soils: increased acidity, lack of calcium, phosphorus, potassium, sodium, cobalt, copper, iodine, boron; sufficient amount and, sometimes, excess of manganese and zinc; relatively high content of strontium. In these soils, many cultivated plants lack calcium, potassium, phosphorus, copper, boron. In addition, sod-podzolic soils may differ in the content of certain trace elements and their combination. The number of nutrients also varies within the same soil profile. The standard method of agrochemical soil survey, based on averaged samples for large areas, does not take into account the differences in the number of microelements in different soil layers or their availability to plants. Taking into account the peculiarities of the distribution of microelement forms available to plants in the soil profile, it is possible to adjust the combinations of macro and micronutrients in such a way so as to obtain crops rich in microelements contributing at the same time to soil fertility conservation.

Key words: microelements; grain; enrichment; sod-podzolic soil; micro-fertilizers; zinc; copper; molybdenum; iron; manganese

Introduction

The use of micro-fertilizers in agriculture is due to the need to obtain a better-quality and high yield (Federal State Unitary Enterprise Goszemkadastrsjemka, 2003). At the same time, the choice of necessary micro-fertilizers depends on their availability on the market and on the responsiveness of the plant to fertilization (yield increase, improvement of biochemical quality indicators). Most often, seeds are treated with microelements prior to sowing. The introduction of micro-fertilizers into the soil is not cost-effective and is technically difficult due to small doses of fertilizers and the need for uniform distribution over the surface of the field. The need for micro-fertilizers should be calculated on the basis of the concentration of forms available in the soil (Shemnyakov, 2015). However, the analysis of the content of micro elements in soil, especially under conditions of strong soil heterogeneity within both the field and the soil profile is limited as the selection of soil samples and their analysis is costly (Ohrimenko, 1962; Pejve, 1962).

There are general recommendations concerning the application of micro-fertilizers on different types of soils. Thus, for example, it is recommended to apply manganese and zinc fertilizers, if the content of mobile forms of these

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trace elements does not exceed 236-296 mg/kg of dry soil for manganese and 0.25-0.30 mg/kg of dry soil for zinc, when growing maize for grain in gray podzolized, soddy medium podzolized, meadow-chernozem podzolized, podzolized or low humus chernozem in order to increase the yield and the quality of grain (Kidin and Bakhitova, 2016; Saet et al., 1990; Shabalin, 1962; Sujkovskij, 1962).

In this field study, the content of microelements (Cu, Mo, Zn, Mn, Fe) in the soil was established by analysing the soil, layer by layer.

The aim of this investigation is to determine the optimal application depth of micro-fertilizers to obtain high-quality corn grain (Samykin, 2012).

Research Methodology

Corn was grown in the experimental field of Timiryazev Academy in the fallow area by means of traditional technology using moderate doses of macro-and micro-fertilizers. Macro-fertilizers containing nitrogen, phosphorus and potassium were introduced in the form of granules and micro-fertilizers were used in the form of chemical salts in a point-wise manner at the depth that ensured optimal assimilation of nutrition components taking into account the features of the root system of maize and the chemical composition of the fallow sod-podzolic soil.

No organic fertilizers, chemical means of protection or ameliorants were used on the test plots. Weeding was carried out manually twice during the growing season.

The layer-wise soil analysis establishing the presence of mobile forms of microelements was carried out before sowing and after harvesting by means of a Quant-Z.ETA atomic absorption spectrometer in compliance with M-MVI-80-2008 “Methodology of performing measurements of the element mass fraction in samples of soil, surface and bottom sediments applying atomic emission and atomic absorption spectrometry methods, St. Petersburg, 2008”. The extraction of soil samples included the following steps: heating the soil sample (2 g) with 10 ml of 0.5 mol/l nitric acid in water bath and stirring it (90°C) for 3 hours; filtering through a paper filter into a volumetric flask and bringing it to the bidistilled water mark.

Analysis of trace element content in corn grain was carried out using the Quant-Z.ETA atomic absorption spectrometer after preliminary dry mineralization (in compliance with “GOST 26929-94 Raw materials and food products.

Sample preparation

Mineralization for determining the content of toxic elements in a SNOL muffle furnace, gradually raising the temperature up to 450°C: 250°C – 30 minutes; 300°C – 30 minutes; 350°C – 30 minutes; 400°C – 30 minutes; 450 °C – 1-3 hours until obtaining white ash. The resulting ash was dissolved in nitric acid, for which 1 cm^3 of solution of nitric acid diluted with water (1:1) was added to the cup with the ash and heated in water bath until the ash dissolved. The solution was then evaporated to wet salt, 5 cm3 0.03 mol/l nitric acid solution, heated in water bath until the salts were completely dissolved, cooled and quantitatively transferred to a 25 cm^3 volumetric flask. The volume was brought to the mark by means of nitric acid background solution.

The results were processed using Excel. To analyse the close relationship between yield and microelements content (Cu, Mo, Zn, Mn, Fe) in corn grain, a correlation analysis was carried out.

Results and Discussions

The agrochemical analysis of the soil from the experimental plots before sowing showed that soil acidity decreased throughout the soil profile from medium to strong acid, the humus content also sharply decreased with the increase of the depth, the soil was well-supplied with phosphorus and potassium, whereas the content of copper, zinc and molybdenum was lowered (Table 1).

The corn grain mass obtained during the experiment varied greatly in the variants. The greater the grain mass, the lower the content of microelements (Cu, Mo, Zn, Mn, Fe). When the grain mass increased significantly, the content of microelements was lower than the control value (without fertilizers), Table 2.

Table 1
Agrochemical analysis of the soil from the experimental plots prior to sowing

Soil layer cm	Humus %	pH_{KCl}	Hydrolytic acidity mg eq/g	N_{NO_3} mg/kg	N_{NH_4} mg/kg	P_2O_5 mg/kg	K_2O mg/kg	Zn mg/kg	Cu mg/kg	Mo mg/kg
0-20	2.0	4.6	1.7	15.0	57.7	148	150	0.14	1.48	0.015
20-40	0.6	4.5	1.0	12.5	44.5	120	85	0.12	1.38	0.012
40-60	0.2	3.2	4.4	11.8	108.2	80	75	0.12	1.30	0.008
60-80	0.1	3.2	5.3	7.0	114.1	8	61	0.03	0.26	0.004

Table 2
The content of microelements in corn grain, mg/kg of dry weight

№	Nutrition components and application depth	Cu	Zn	Mo	Mn	Fe
1	Control, without fertilizers	1.2	28.3	0.11	2.3	51.1
2	N 0-20 cm	1.8	29.2	0.08	2.0	33.3
3	PK 0-20 cm	1.1	77.8	0.37	1.0	26.7
4	PK 20-40 cm	1.0	17.4	0.07	1.5	36.7
5	PK 40-60 cm	1.0	21.9	0.09	1.0	48.9
6	PK 60-80 cm	0.8	17.4	0.08	0.9	36.7
7	N 20 cm + PK 20-40 cm	1.0	23.9	0.09	1.3	40.0
8	N 20 cm + PK 40-60 cm	1.3	27.9	0.07	15.9	60.0
9	N 20 cm + PK 60-80 cm	0.6	31.9	0.09	1.0	46.7
10	N 0-20 cm + PK, Cu, Zn, Mo 20-40 cm	1.0	27.2	0.09	4.0	46.7
11	N 0-20 cm + PK, Cu, Zn, Mo 40-60 cm	1.1	29.0	0.14	8.0	26.7
12	N 0-20 cm + PK, Cu, Zn, Mo 60-80 cm	1.5	20.6	0.16	1.0	40.0
13	NPK 0-20 cm	1.2	29.6	0.07	9.9	33.3
14	NPK 20-40 cm	1.3	16.2	0.07	3.5	33.3
15	NPK 40-60 cm	1.2	22.3	0.07	1.0	24.4
16	NPK 60-80 cm	0.8	25.1	0.08	1.1	25.9
17	NPK, Cu, Zn, Mo 0-20 cm	1.5	26.1	0.11	2.0	30.0
18	NPK, Cu, Zn, Mo 20-40 cm	0.7	37.7	0.12	9.9	20.0
19	NPK, Cu, Zn, Mo 40-60 cm	0.8	17.4	0.11	1.0	33.3
20	NPK, Cu, Zn, Mo 60-80 cm	0.5	21.4	0.09	2.0	36.7

With the application of micro-fertilizers together with macro-fertilizers, the content of microelements in the corn grain increased insignificantly, but only when applied to soil layers of 20-40 cm and 40-60 cm. It should be noted that the agrochemical conditions of each layer of soil analyzed in the experiment were heterogeneous, which could affect the availability of the analysed microelements to plants.

Earlier it was shown in the works of various authors that the application of increased doses of nitrogen fertilizers increased the mobility of some microelements that polluted the soil during the agrotechnical process (Azarenko and Ermohin, 2012). Gaponyuk et al. (1982) showed that the application of phosphorus fertilizers into sod-podzolic medium loamy soil resulted in a sharp increase in the mobility of Zn (from 83 to 220-330 mg/kg element extracted with 0.1 N hydrochloric acid), Mn (from 300 to 670 mg/kg), As (from 1.5 to 3-4 mg/kg) and water-soluble organic matter (from 1.62 to 2.3-3.3%).

With regard to this experiment, despite the high content of iron and manganese, as well as high acidity (pH 3.2) and light granulometric composition of the subsurface soil, the content of these microelements in the corn grain did not exceed the MPC (maximum permissible concentration).

With respect to the microelements Cu, Mo, Zn, which were introduced into the soil as micro-fertilizers, since their content in the soil was low, it should be noted that the content of these trace elements in the corn grain varied as the grain mass increased. So, for example, despite the strong correlation (0.72) between the mass of the obtained grain and the content of copper in the grain, a significant increase in copper content was obtained only in the variant with a surface application of nitrogen fertilizer to the soil (Figure 1).

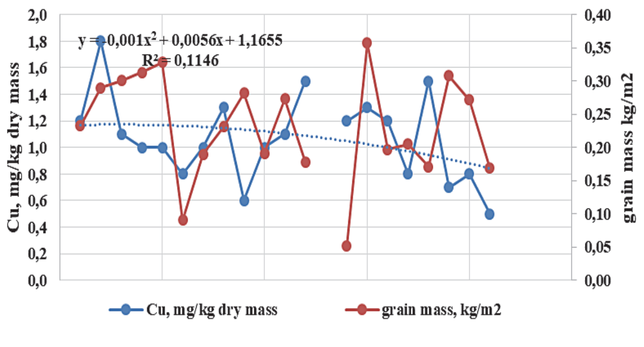

Fig. 1. Correlation between Cu content and grain mass

When only phosphorus-potassium fertilizers were introduced, the content of copper in the grain decreased both with the depth of application and with the increase in the grain mass.

The superficial application of nitrogen fertilizer with the simultaneous introduction of phosphate-potassium fertilizers into the soil layer of 20-40 or 40-60 cm made it possible to increase slightly the copper content in the grain.

In addition, the introduction of a nitrogen-phosphorus-potassium fertilizer at a depth of 60 cm had virtually no effect on the content of this microelement in the grain.

Adding micro-fertilizers – Cu, Mo, Zn to nitrogen-phosphorus-potassium fertilizers allowed to increase copper content in grain only when these were applied to the surface soil layer at 0-20 cm. –see Figure 2 and Figure 3. The grain mass was lower than in the control sample (without fertilizers). With an increase in the mass of the grain, the copper content decreased.

The correlation between the yield and the content of zinc and molybdenum in the grain is modetrate – 0.56 and 0.47, respectively.

When applying phosphorus-potassium fertilizers in the surface soil layer at 0-20 cm, it was possible to obtain grain with a significant increase in the content of zinc and molybdenum, but with a slight increase in yield compared to the control sample (without fertilizers). In the other variants, the content of zinc and molybdenum in the grain decreased with the increase of yield and application depth.

The analysis of manganese and iron content in grain was carried out in connection with the large number of mobile forms of these microelements in the soil. The correlation between the yield and the content of manganese in the grain is weak, and the average iron content in the grain is 0.08 and 0.63, respectively. The largest amount of manganese in corn grain was found only in the variant with surface application of nitrogen fertilizer into the 0-20 cm layer with the simultaneous introduction of phosphate-potassium fertilizer into the soil at 40-60 cm (Figure 4 and Figure 5).

After adding microelements (Cu, Zn, Mo) to phosphorus-potassium fertilizers in this variant, manganese content somewhat decreased, but the grain mass remained the same. The content of iron in the grain increased only in the version where the grain mass was lower than or close to the control sample (without fertilizers).

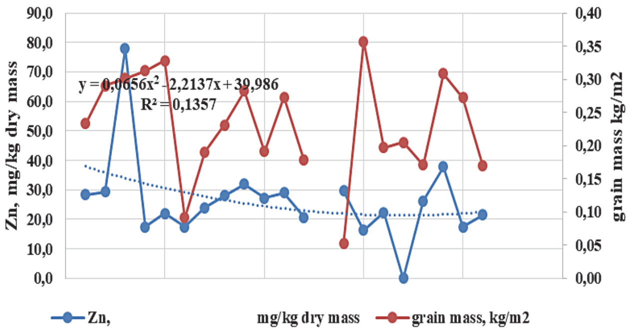

Fig. 2. Correlation between Zn content and grain mass

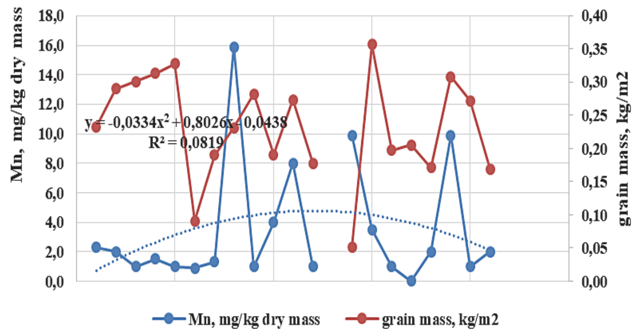

Fig. 4. Correlation between Mn content and grain mass

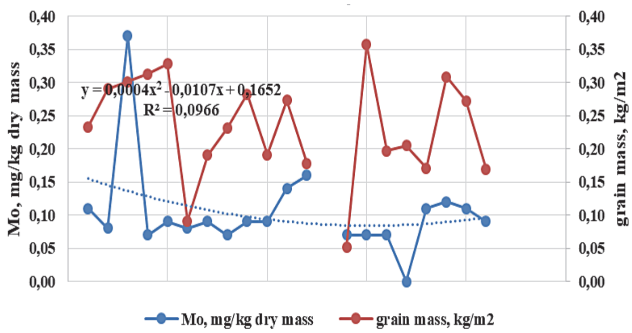

Fig. 3. Correlation between Mo content and grain mass

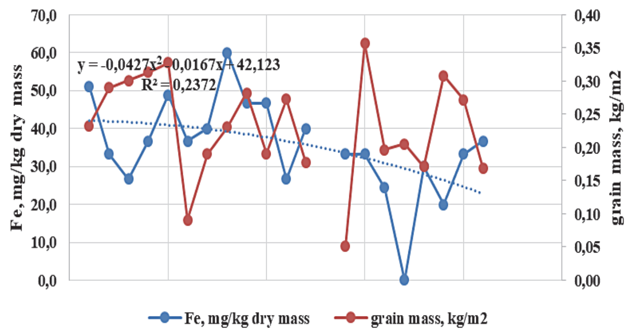

Fig. 5. Correlation between Fe content and grain mass

Conclusions

With a significant increase in the corn grain mass, a decrease in the amount of micro elements is most often observed. This effect can be explained by the "growth dilution", due to increase in a harvest the quantity of microelements in biomass unit decreases.

The increased zinc removal in corn grain in the variant with the application of phosphorus-potassium fertilizer in the surface layer of the soil (0-20 cm) can be explained by the largest content of humus and zinc in this soil layer (2.0% and 0.14 mg/kg dry soil, respectively), as well as the maximum availability of microelements from organic soil compounds.

In general, it can be said that the addition of trace elements, Cu, Mo, Zn, to the 60-80 cm soil layer is ineffective, both with respect to the increase in the grain mass and its enrichment with microelements. However, the use of microelements Cu, Mo, Zn together with nitrogen-phosphorus-potassium fertilizers allows reducing the amount of manganese and iron in the grain. This feature should be taken into account when growing corn on soil with a high content of iron and manganese.

References

Azarenko, Y.A. and Y.A. Ermohin, 2012. Assessment of potential of absorption of microelements by plants depending on their concentration in the soil. The Omsk Scientific Bulletin, **2** (114) 150-154.

Federal State Unitary Enterprise Goszemkadastrsjemka - VISHAGI the Rosniizemproyekt Center, 2003. The methodical recommendations about assessment of quality and classification of lands by their suitability for use in agriculture, Moscow, 170 p.

Kidin, V.V. and A.R. Bakhitova, 2016. The content of microelements in barley seed at application of fertilizers in different layers of the sod-podsolic soil. *Fertility*, **6** (91) 27-30.

Ohrimenko, M.F., 1962. Influence of manganese and zinc on a corn grain yield depending on contents in soils. Materials of the IV All-Union meeting on microelements. Microelements in Agriculture and Medicine. *Publishing house: Kiev, "Gosselkhozizdat"* USSR printing house, Kiev, pp. 261-264.

Pejve, Y.A.V., 1962. Biochemistry and agrochemistry of molybdenum. Materials of the IV All-Union Meeting on Microelements. Microelements in Agriculture and Medicine. *Publishing house: Kiev, "Gosselkhozizdat"* USSR printing house, Kiev, 133-137 p.

Saet, Y.E., B.A. Revich and E.P. Yanin, 1990. Geohimiya okruzhayushchej sredy. *Nedra*, Moskow, 335 p.

Samykin, V.N., E.L. Solovichenko and I. Logvinov, 2012. In Effect of fertilizers and the main processing of the soil on productivity and quality of green material and grain of corn. *Achievements of Science and Technology of Agrarian and Industrial Complex*, 9.

Shabalin, I.N., 1962. Value of minerals in improvement of quality of a harvest at irrigation of corn, sugar beet and spring-sown field. Materials of the IV All-Union Meeting on Microelements. Microelements in Agriculture and Medicine. *Publishing house: Kiev, "Gosselkhozizdat",* USSR printing house, Kiev, pp. 298-302.

Shemnyakov, D.V., 2015. Studying of interfield variability of agrochemical indicators of arable soils and definition of need for fertilizers and meliorants in technologies of exact agriculture. *The Molochnokhozyaystvenny Messenger*, **2** (18), II of quarter 2015.

Sujkovskij, Z., 1962. Influence of minerals on pigmentary system and photosynthesis and their topography in plants. Materials of the IV All-Union Meeting on Microelements. Microelements in Agriculture and Medicine. *Publishing house: Kiev, "Gosselkhozizdat"*, USSR printing house, Kiev, pp. 202-207.

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