Distribution of trace elements in soil and plants under the action of bio-organic and mineral fertilizers

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Abstract. The deficiency of trace elements in the soil is often among the factors limiting the degree of realization of the genetic potential of crops. As a rule, the availability of trace elements to plants from soil is determined by their concentration in it, which is in the easily hydrolyzed phase. At the same time, some trace elements with increasing concentration in soil are considered as one of the most dangerous pollutants. After exceeding the established maximum permissible concentrations (MPC) and approximate permissible concentrations (APC), some trace elements are classified as heavy metals.

1. Introduction

The agents that increase the capacity of saturated bases, as well as the introduction of organic fertilizers are recognized as the methods for reducing the mobility of heavy metals. Due to the fact that the organic matter of soil is the most important indicator of its fertility, the restriction of the use of organic substances should not be accompanied by the decrease in the availability of basic biogenic nutrients of cultivated plants. For this purpose, technologically processed poultry wastes are used as organic fertilizers, characterized by an increased concentration of macrocells and biologically active substances – amino acids, vitamins, etc. The presence of a granular form allows their introduction simultaneously with sowing. Existing scientific and practical data indicate the high efficiency of thermally disinfected and biologically enriched organic fertilizers.

In our work, we evaluate the effect of various fertilizers on the mobility of trace elements (B, Zn, Mn, Fe) in soil and their availability to plants, and derive patterns of their behavior in the soil-plant system.

2. Research relevance

The assessment of the effect of various fertilizers on the mobility of trace elements (B, Zn, Mn, Fe) in the soil and their availability to plants and the patterns of their behavior in the soil-plant system is an urgent task of science and production.
3. Methods and materials
The study of the behavior of trace elements in the soil-plant system was carried out on the experimental field of the Central experimental base of the Tatar Agricultural Research Institute. The experiment was conducted as a part of the International Volga Field Days in 2016 in the Republic of Tatarstan.

Sowing was carried out in the second decade of May.

The experimental field is located in the first agro-climatic region in Bolshie Kabany village of Laishevsky municipal district of the Republic of Tatarstan. The soil of the experimental plot was gray forest, heavy loamy, slightly humus. The humus content in this area was 3.2 %, and the acidity (pH) of the soil in the salt extract was 5.8. [1]. The area of the experimental plots in each variant was 50 m². Soil and plant samples were taken for analysis on July 2, 2016.

Research object:
1. Complex mineral Ammonium nitrate phosphate fertilizer (NPK 16-16-16). Application rate is 200 kg/ha.
2. Bio-organic granular fertilizers are presented on the basis of fermented poultry waste (NPK 4-4-3). The granules are enriched with microorganisms Pseudomonas aspleniiVI 6 at a concentration of 2×10⁷. Application rate is 200 kg/ha.
3. Corn hybrid “FAC – Clifton”, FAO 175.
4. Soybean variety “Milyausha” (L 34/99).
5. Hybrid sunflower “Oxy”.
6. Sugar beet. Variety or hybrid names not established

Research subject:
1. The concentration of trace elements (B, Zn, Mn, Fe) in the root zone of plants.
2. The concentration of trace elements (B, Zn, Mn, Fe) in the leaves of plants.
3. The assessment of changes in the mobility of trace elements in the soil under the influence of bio-organic and mineral fertilizers.
4. The assessment of changes in the intake of trace elements in plants under the influence of bio-organic and mineral fertilizers.
5. The correlation between the content of trace elements in the soil, fertilized with bio-organic and mineral fertilizers.
6. The correlation between the content of trace elements in plants fed with bio-organic and mineral fertilizers.

Analytical work was carried out in the educational and scientific testing laboratory of the Stavropol State Agrarian University in accordance with the contract “On the creation and transfer of scientific and technical products “No. 1291 of 07/22/2016.

The analysis was carried out in accordance with accepted methods:
GOST R 50688-94. Soil types. Determination of mobile boron compounds by the method of Berger and Truog in the modification of Central Research Institute of Agrochemical Services (CRIAS).
GOST R 50686-94. Soil types. Determination of mobile zinc compounds by the method of Krupsky and Alexandrova in the modification of CRIAS.
GOST R 50685-94. Soil types. Determination of mobile manganese compounds by the method of Krupsky and Alexandrova in the modification of CRIAS.
GOST 27395. Soil types. Method for determination of mobile compounds of ferrous and ferric iron according to Verigina-Arinushkina.

4. Results
The methods to determine mobile compounds are used during the assessment of the soil reserves of trace elements. As a rule, the degree of mobility of the elements is graded depending on the solvents used to extract the elements from the soil and is classified in increasing order – water-soluble, readily soluble, acid-soluble and fixed or hardly soluble. The total number of trace elements that have passed into all extracts is called the gross stock, and it determines the potential supply of soil to them.
In this work, the authors aimed to determine the dependence of the intake of trace elements into plants from soil fertilized with heterogeneous materials. The analysis revealed that a direct relationship between the content in soil of mobile compounds of trace elements and their amount in plants was not found. To a greater extent, a close relationship is traced depending on the types of fertilizers used. The use of bio-organic fertilizers leads to the decrease in the content of mobile forms of trace elements in the soil while increasing their concentration in plants.

The work of F.G. Azanova-Vafina and Z.S. Ismagilov, who experienced the influence of complex fertilizers of biological nature (CFBN) on chernozem typical of the Republic of Bashkortostan, provides data confirming the patterns identified in the conditions of the Republic of Tatarstan on gray forest heavy loamy soils. The content of mobile compounds in the first year of application in the middle of the growing season decreases in boron – by 26 %, manganese – 16 %, zinc – 24 %. [2].

Figure 1. Boron content in the root zone of plants under the influence of various fertilizers, mg/kg

Figure 1 indicates the absence of a close relationship between the type of used fertilizer and the concentration of mobile boron compounds in plants. If in the root zone of sunflower and corn the increase occurs under the influence of bio-organic fertilizer, then under soybeans and sugar beets, the growth of mobile boron compounds increases under the influence of mineral fertilizers. The correlation coefficient shows an average level, \( r = 0.56 \).

Figure 2. Content in plants under the influence of various fertilizers, mg/kg

Figure 2, in its turn, demonstrates the unambiguous effect of the fertilizers used on the flow of boron into plants, regardless of crops. It is necessary to note the nature of the behavior of boron in soil-plant system in the case of soybeans and sugar beets. If the boron content under these crops is lower by 5.3 and 13.8 %, respectively, from the use of bio-organic fertilizer, then in plants their content is higher than from the use of mineral fertilizer by 12.3 % in soybean and 20.3 in sugar beet. The correlation coefficient is \( r = 0.95 \).

Zinc shows similar behavior to boron in soil and plants. The dependence of the effect of the fertilizers on the change in mobility in soil under various crops is \( r = -0.12 \) (Fig. 3). At the same time, the influence of the chosen fertilizer system on the intake of zinc into plants of the studied cultures characterizes a high dependence, \( r = 0.97 \) (Fig. 4).
The mobility of manganese in soil depends both on the type of fertilizer and on crops. The growth of this indicator from the introduction of bio-organic fertilizer is traced under corn and sugar beets. There is no single pattern, as well as in the case with a change in the mobility of boron and zinc. The correlation coefficient is $r = 0.58$ (Fig. 5).

Analyzing the intake of manganese in plants, it is necessary to note that, despite the general high correlation between the type of fertilizer and the intake of manganese in plants of various crops ($r = 0.97$), a change in trends is observed. In particular, the manganese content in soybean plants under the influence of mineral fertilizers increases by 15.4 %, and sugar beet plants – by 7.6 % (Fig. 6). Despite this, the changes in the mobility of manganese in the soil caused by mineral fertilizers affect its supply not proportionally. With the increase in the mobility of this element in the soil by 103 %, its content in the plant changes by only 7.6 %.

Iron is the only object that stands out from the general pattern of behavior in the soil-plant system as a part of the objects of study of this work – four trace elements, four crops and two types of fertilizers. Figure 7 clearly shows the effect of mineral fertilizers in the form of ammonium nitrate phosphate fertilizer commercial product on increasing the mobility of iron in soil. Depending on the culture, mobility increases in the range of 8.1–21.9 %. The correlation coefficient is $r = 0.78$.

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**Figure 3.** Zinc content in the root zone of plants under the influence of various fertilizers, mg/kg

**Figure 4.** Zinc content in plants under the influence of various fertilizers, mg/kg

**Figure 5.** Manganese content in the root zone of plants under the influence of various fertilizers, mg/kg

**Figure 6.** Manganese content in plants under the influence of various fertilizers, mg/kg
At the same time, a significant increase in the concentration of iron in plants caused by the type of fertilizer does not occur and is in the range of 0.29–6.7 %. (Fig. 8). The correlation coefficient is \( r = 0.84 \).

![Figure 7. Iron content in the root zone of plants under the influence of various fertilizers, mg/kg](image1)

![Figure 8. Iron content in plants under the influence of various fertilizers, mg/kg](image2)

The action of bio-organic fertilizers can be associated with the increase in the microbiological activity of soil [3, 4], resulting in the formation of compounds, on the one hand easily accessible to plants, and on the other hand, poorly extracted with solvents used in traditional methods. Previous analyzes of soil samples taken from the same sites revealed the increase in the number of different groups of microorganisms with the addition of bio-organic fertilizer by 20–45 % [5].

5. Conclusion
The change in the mobility of trace elements in the soil is closely dependent on the direction of the bio-geochemical processes in it. In this regard, the selection of a fertilizer system through the influence on the microbiological activity of soil can control the transformation processes. Organic fertilizers act not only as a direct source of plant nutrients, including mineral, but also as the most important energy material for beneficial soil microorganisms. [6].

The role of trace elements as a complete and integral element of plant nutrition was identified by the French scientist Rolen back in the 19th century. He was the founder of research in this area. [7]. Nevertheless, the problem of the predicted supply of crops with microelements has not been solved yet. We can name the fragmentation of ongoing research on the theme of trace elements as the main reasons. According to the results of the research, it can be stated that the existing methods for the assessment of the availability of soil with trace elements available for plants are subject to modernization, including through the search for new extracting substances. As an indicator of soil fertility, both effective and potential, it is recommended to use an expanded list of criteria for its assessment due to soil and biological parameters.

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