Content of individual micro- and macroelements in different types of soils of the Central Black Soil region

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Abstract. The purpose of fundamental research in agricultural ecology is to solve complex problem of the establishment of patterns of mass transfer in agricultural systems and regulation of these processes in agricultural soil use. The chemical composition of soil is the result of soil-forming processes. The characteristics of the soil-forming material play decisive role. The investigation of the content of macro- and microelements in soils of different types has been quite relevant in recent decades due to their large physiological role in the life of plants and animals and the active transformation of soils during agricultural use. Fertilization is a process of certain soil cultivation and includes a set of measures aimed at the regulation of macro- and microelements, the lack of which can be determined by zonal conditions of soil formation or soil degradation, as a result of irrational agricultural nature management. The paper presents the results of a study of the content of individual macro- and microelements in some types of soils of the Central Black Soil regions. The studies of the aspects of the impact of fertilization existing in the scientific literature are controversial. The consideration of ecologically and economically justified levels of changes in soil properties during cultivation is necessary to control negative transformations of chemical elements in soil and their accumulation in depositing media. A quantitative assessment of the total content of water-soluble salts, their qualitative composition and dynamics under the influence of agrotechnical factors, the study of their spatial differentiation in soil cover allows optimizing the use of fertilizers and increasing the stability of agropedocenoses.

1. Introduction

The most important task of agriculture is to increase fertility and obtain sustainable crop yields. Agricultural production significantly transforms soil properties, soil regimes, affects soil-forming processes and soil genesis. In the context of ecology, the most relevant aspects of the study of the interaction between agriculture and soil are the transformation of the compounds entering the soil, their fixation, migration and, accordingly, the development of the most optimized scenario of soil cultivation.

2. Materials and methods

The soil cover of the Central Black Soil Region is quite diverse. Two types of soils prevail on the territory of the Kursk Region: gray forest and black soil. Soils are intensively used in agriculture, which determines the high importance of the studies of changes in the elemental composition under the influence of natural and anthropogenic factors [1, 2].
The objects of study were soil samples taken at the border of the Kursk region with the Voronezh, Tambov, Lipets, Orel and Belgorod regions: 1) gray forest soils, 2) podzolic black soil, 3) leached black soil, 4) ordinary black soil, 5) ordinary black soil, 6) southern black soil, 7) alkaline soils, 8) sandy soils. In these soils, the following microelements were studied along the genetic horizons, which were of significant importance in agriculture: manganese, zinc, copper, molybdenum, cobalt, nickel, titanium.

3. Results
As a result of the research, it was found that, titanium was in the greatest amount out of all studied microelements. Its content in the arable horizon reached 2000 mg per 1 kg of soil. Then, in descending order, the following were found: manganese (180-800 mg), nickel (20-120 mg), cobalt (30-90 mg), copper (14-70 mg), zinc (20-50 mg) and molybdenum. Molybdenum was found in even smaller quantities. The gross content of individual microelements was not the same for different soils. The maximum amount of microelements was found in ordinary and leached black soils, from where their content decreased to soils of more northern and more southern latitudes. In terms of microelement content sandy soils were the poorest.

A common pattern was observed in the total content of microelements along the genetic horizons: along the vertical profile of soils, the amount of microelements generally decreased, with the exception of gray forest soils and malts, which did not adhere to this pattern. In these soils, the content of microelements in the A horizon decreased towards the A2 horizon, the increase was observed in the B1 horizon and again decreased below it.

Thus, with deepening along the soil profile, the content of microelements in black soils decreased, which indicated their biological accumulation in the upper soil horizons and in gray forest soils, in addition, their migration down the profile was observed [3].

The different contents of microelements in soils and their distribution along the profile of the soil layer were genetically related to the chemical and mechanical composition of soils and soil forming materials. The content of microelements in the soil profile was affected by a number of physical and chemical properties of the soil, including the pH level. Soil acidification, like a highly alkaline reaction, caused a decrease in the content of microelements. The dependence of the assimilation of the main elements on the soil pH level was presented in table 1.

Table 1. Dependence of assimilation of basic elements on pH level of soil

| Level of pH | % content |
|-------------|-----------|
|             | Nitrogen  | Phosphorus | Kalium |
| 4,5         | 30        | 23         | 33     |
| 5,0         | 43        | 34         | 52     |
| 5,5         | 77        | 48         | 63     |
| 6,0         | 89        | 52         | 77     |
| 6,5         | 100       | 95         | 100    |
| 7,0         | 100       | 100        | 100    |
| 7,5         | 100       | 70         | 75     |
| 8,0         | 100       | 30         | 45     |
| 8,5         | 78        | 20         | 30     |
| 9,0         | 50        | 5          | 10     |

Thus, for example, manganese, as a microelement, was studied in the soils of the Central Lane. However, the topic of its research was always relevant. A sufficient number of systematic studies of manganese compounds in the soils of the Central Black Soils were carried out taking into account the need of plants for manganese during the growing season and its biological role in their life, as well as its biochemical role in soil processes in the soils of the Central Black Earth zone. Profile soil samples
were taken at different points of the agronomic soil regions of the Central Black Soil zone and on different lands, where the gross and mobile manganese was determined using the latest methods of analysis.

The distribution of total manganese along the vertical profile of soils was not similar: in light gray and dark gray forest soils, the distribution of manganese was not even, with a maximum in horizon B, which indicated that these soils had a process of migration from top to bottom (along with accumulation); in black soils, the maximum total manganese was found in horizon A, from where, down the profile, its amount usually decreased, which indicated its biological accumulation in the upper horizon (horizon A). At the same time, there was a direct relationship between the content of gross manganese and gross humus. There was also a close relationship between the total manganese and the nature of soil forming material: the richer the soil forming material in calcium, the more manganese was in the soils formed on them.

The content of total manganese in the studied soils (gray forest, black soils) of the Central Black Soil zone was characterized by high rates. Thus, light gray forest soils contained manganese in the arable horizon of 226 mg/kg, podzolic black soil - 575 mg/kg and southern black soil - 800 mg/kg of soil. The total content of manganese naturally increased from north to south, from light gray forest soils to southern black soil.

Thus, in malt a soil, the maximum amount of total manganese was found in the B horizon and the minimum - in the A horizon, from which it followed that these soils had intensive migration of manganese from the upper horizons to the lower.

### Table 2. Manganese content and physical-chemical characteristics of ordinary black soil

| Soil Type                  | Sampling depth, cm | Physical clay fractions, % | Humus, % | pH of aqueous extract | Dry residue, % | E, mg.eq. per 100g of soil | Exchangeable cation, % of E Ca++ | Mg++ | CMB, total |
|----------------------------|--------------------|----------------------------|----------|-----------------------|----------------|---------------------------|---------------------------------|------|------------|
| Ordinary Black Soil        | 0 - 10             | 43,9                       | 3,1      | 7,9                   | 0,08           | 44,3                      | 40                               | 8,1  | 606        |
|thin-humous loamy loess soil| 10 - 20            | 43,4                       | 2,6      | 7,9                   | 0,07           | 43,1                      | 29                               | 7,3  | 591        |
|                           | 60 - 70            | 38,5                       | 1,4      | 8,0                   | 0,06           | 42,9                      | 29                               | 5,6  | 421        |
|                           | 150 - 160          | 37,0                       | 1,2      | 8,0                   | 0,06           | 33,9                      | 23                               | 9,9  | 438        |

The amount of mobile manganese in the soils of the Central Black Soil zone was not the same. Its maximum content was found in gray forest soils and the minimum in black soils. In the distribution of mobile manganese over the soil profile, all soils had a general tendency to decrease from top to bottom.

Mobile manganese in the arable horizon of light gray and gray forest soils was 70% or more of the total: black soil, podzolic leached black soil 13-14% and an ordinary ordinary, southern comprised 11-8%. Therefore, the mobility of manganese decreased from light gray forest soils to southern black soil.

The most important macroelements for plant were nitrogen, phosphorus and kalium. In addition, the content of individual macronutrients had a significant effect on the humus state of soils [3–5]. Despite the fact that the total reserves of phosphorus and kalium in soils significantly exceeded the amount of available nutrients, the degradation of soil fertility in terms of the content of phosphorus and kalium could occur much faster than, for example, nitrogen. In this regard, a comprehensive assessment of the phosphorus and kalium state and its resistance to anthropogenic impact was of particular importance [4].

In soil and agrochemical literature, there was the idea of the rapid retrodation of phosphoric acid fertilizers introduced into soil [5–8]. This was facilitated by a large number of studies that showed the high uptake capacity of various soils in relation to phosphate ions, as well as a small percentage (10-20%) of the use of phosphorus fertilizers by plants. However, for phosphoric acid, being absorbed did not mean being available to plants.
Phosphorus fertilizers introduced into the soil undergo dissolution, enter into reactions with the components of the soil solution and the soil absorbing complex, while transforming into various forms. In addition, the transformation of fertilizers in the soil was largely associated with the vital activity of microorganisms. Striving to get the maximum effect from the applied fertilizers, first of all it is necessary to know the nature of the transformations that the applied phosphates undergo in soil, because the availability of $P_2O_5$ to plants is largely determined by the nature of those compounds into which it passes in different soils. Systematic accounting of the processes of uptake and transformation of phosphate fertilizers and the regulation of these processes will allow forming a system to provide plants with phosphorus nutrition and thereby increase the yield of cultivated plants [9, 10].

In this research the authors studied the processes of uptake and conversion of phosphates in an ordinary black soil with a change in moisture content on various fertilizing backgrounds. The experiment was carried out on an ordinary heavy loamy black soil of the Kursk region. The soil samples were taken from plots fertilized with one superphosphate ($P_{40}$) superphosphate + kalium salt - ($P_{40}K_{40}$) superphosphate + ammonium sulfate - $P_{40}N_{40}$ with full mineral fertilizer - $N_{40}P_{40}K_{40}$ and from control plots with direct effect and aftereffect of fertilizers on green manure fallow and on actual backgrounds. Soil moisture, the amount of $P_2O_5$ uptake of the studied soils and the form of phosphates were determined immediately after taking samples in the field, i.e. in a naturally moist state, then after 7 days and after 6 months in an air-dry state.

Soil moisture at all determination periods on all plots (direct effect and aftereffect) for green manure fallow, as for the manured background, turned out to be slightly higher than for the actual, non-manured background, which indicated the beneficial effect of green manure crops on the physical and physicochemical properties of the soil.

The amount of $P_2O_5$ uptake by the soil on all plots (direct effect and aftereffect) for the manured background was less than for the actual, unfertilized background, due to the formation of active humus, which reduced the uptake of phosphates. On plots fertilized with one superphosphate and superphosphate in combination with other mineral fertilizers (ammonium sulfate and kalium salt), the amount of $P_2O_5$ uptake by the soil was lower than on the control plots for all determination periods.

The uptake of $P_2O_5$ by the soil fertilized with superphosphate in combination with ammonium sulfate, kalium salt and with the introduction of complete mineral fertilization was significantly lower than the uptake of $P_2O_5$ by the soil, which was supplemented with one superphosphate, which was explained by the increased mobilization of soil phosphoric acid.

A significant effect on the uptake of $P_2O_5$ by the soil was exerted by soil moisture, the decrease of which caused the increase in phosphate fixation. Thus, according to green manure fallow, in the first determination period, 67.0 mg of phosphates were uptaken, 82.1 mg - in the second and 95.7 mg per 100 g of soil - in the third. As it is known, in the soil, along with the processes of uptake of phosphates, there were biochemical processes of mobilization of $P_2O_5$, which were most actively carried out during periods of optimal soil moisture, suppressing and thereby reducing the process of absorbing $P_2O_5$.

The uptake of water-soluble phosphates introduced into the soil and their transformation into various forms in ordinary black soil can also be assessed by the content of acid-soluble phosphates in it in a wet and air-dry state.

It was found that the content of phosphates, soluble in carbonic water, in 0.5 N acetic acid and 0.5 N hydrochloric acid, decreased in the soil upon drying and long-term interaction with phosphates.

The content of phosphates in all extracts on fertilized plots, superphosphate alone, superphosphate with ammonium sulfate and superphosphate in combination with kalium salt, as well as with the introduction of complete mineral fertilization, was significantly higher than in the control plots. On a plot fertilized with superphosphate in combination with ammonium sulfate, the amount of phosphates in all extracts was less than on plots without ammonium sulfate, which was obviously associated with the most intense fixation of phosphoric acid by microorganisms under conditions favorable for nitrogen nutrition. The content of phosphates in extracts during the transition from naturally moist to air-dry soil significantly decreased, which indicated the transformation of water-soluble phosphates...
into hardly soluble forms, as a result of which the degree of their mobility and their assimilation by plants decreased.

4. Conclusion
Thus, the study of the content of macro- and microelements, their differentiation in the soil profile has practical importance for rational agricultural land use. The established relationship between the processes of uptake and conversion of phosphates, depending on soil moisture and fertilizing backgrounds, is of great practical importance, since it allows regulating the phosphate regime of soils. Additional study of spatial distribution will allow the design of more efficient farming systems. The consideration of the transformation of macro- and microelements will allow more rational planning of fertilization.

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