Influence of replacing bare fallow with a disused land on the content of macro- and microelements in typical chernozem of Kursk Region

Mamontov Vladimir Grigorievich
Doctor of Biological Sciences, Full Professor
Russian State Agrarian University - Moscow Timiryazev Agricultural Academy
Rogova Olga Borisovna
Candidate of Biological Sciences
Dokuchaev Soil Science Institute
Lazarev Vladimir Ivanovich
Doctor of Agricultural Sciences
Kursk Scientific Research Institute of Agro-Industrial Production
Belyaeva Svetlana Alekseevna
Postgraduate
Russian State Agrarian University - Moscow Timiryazev Agricultural Academy

Abstract. 20 years after the replacement of permanent steam with a deposit in typical chernozem, the content of the main organogenic elements increased: carbon by 43%, hydrogen by 31%, nitrogen by 25%. At the same time, the recovery of the organic carbon content occurs very slowly, at a rate of about 0.05% per year, which must be taken into account when regulating the humus state of arable soils. The content of the main macronutrients - silicon, aluminum, iron, potassium, sodium, which form the basis of the mineral part of the soil, did not change significantly during this period. At the same time, in the upper part of the profile of the typical fallow chernozem, the content of some mineral elements, actively involved in the biological circulation of substances, increased. This primarily concerns such elements as phosphorus, chromium, lead, sulfur and zinc, to a lesser extent manganese, calcium and magnesium.

Keywords: typical chernozem, permanent fallow, fallow, macroelements, microelements.

Introduction

At the end of the last century, significant areas of agricultural land in Russia were abandoned and turned into a fallow land. This phenomenon was observed in all natural zones, including the chernozem one. The total area of former agricultural lands that have passed into the category of fallow lands in Russia is more than 4.9 million hectares [1]. The overgrowth of former croplands with natural herbaceous vegetation is accompanied by a change in the biogeochemical cycle of substances underlying soil formation. This entails a change in the intensity and direction of elementary soil processes, which is reflected in the properties and regimes of soils. The study of the features of the functioning of soils withdrawn from active agricultural use is of scientific importance associated with the forecast of their development [2, 3]. Also, the study of fallow soils is promising for the development of certain aspects of practical measures to increase the fertility of soils of old arable lands, in particular, improve their humus state.

To date, a certain amount of information has been obtained regarding the peculiarities of changing soil properties during the transformation of arable land into fallow land. In most cases, there is an improvement in the physical properties of fallow soils in comparison with old arable soils, largely due to their better aggregation [4, 5, 6]. In the soils of the fallow, the content of humus increases [2, 3, 5, 6], while the proportion of non-humified organic residues in the composition of organic matter significantly increases [6]. Along with this, relatively dynamic physicochemical characteristics of soils change noticeably in the soils of fallow lands: the reaction of the environment, the sum of exchange bases, the content of water-soluble humus and mobile phosphorus, migratory forms of free carbonates, the activity of a number of enzymes [7-11].

In general, as the researchers note, the transfer of arable soils to a fallow state contributes to the restoration of their main features and properties to the level inherent in virgin zonal soils [3, 8].

The speed and completeness of the restoration of the characteristics and properties of agricultural soils left in the fallow to the indicators characteristic of their natural analogues will, apparently, largely depend on the initial state of the soils withdrawn from agricultural use.

The direction and depth of changes in soil properties under the influence of agricultural use are largely determined by the level of correspondence between the nature of land use and the natural conditions of soil formation.

In areas occupied by crops of continuous sowing, especially perennial grasses, to some extent the natural process of soil formation is imitated. A much stronger anthropogenic impact on the soil is inherent in areas occupied by row crops. The strongest anthropogenic impact on the soil is observed in areas with pure fallow [12], under the influence of which there is a significant change in soil properties and regimes up to the transformation of the mineralogical composition [13].

The least favorable situation for the restoration of the lost characteristics with the involvement of arable soils in the fallow will be inherent in soils of agricultural landscapes subjected to severe degradation, especially considering the fact that certain types of degradation can be irreversible [14].

The chemical composition is one of the fundamental properties of the soil and is its most important characteristic [15]. It was found that in the chernozem zone there are very significant changes in the chemical composition of soils under the influence of agrogenesis due to the transition of chemical elements from one compound to another [16]. At the same time, certain types of chemical degradation are noted in chernozems that have been subjected to extensive agricultural use for a long time [17].

Therefore, the identification of the features of changes in the chemical properties of typical chernozem, which is the most important representative of soils in the chernozem zone as a result of the transformation of permanent steam into a fallow, is of scientific and practical importance.

Objects and Methods

Samples of typical chernozem were selected on the stationary field experiment of the Petrinsky support point of the Kursk SRI APP, which was laid in 1964. The following variants of the experiment were studied: permanent fallow (54 years). Plot size 296 m^2. In 1998, 2/3 of the area of steam was left for permanent fallow, and 1/3 of the area was set aside for a deposit, whose age at the time of sampling was 20 years. Samples were taken from a layer with a thickness of 0-20 cm. The content of C, H and N was determined on an automatic CHNS analyzer vario Micro cube in individual samples in 3 replicates and the average values were found. The elemental composition was determined in mixed samples by an X-ray fluorescence method using a ReSPEKT substance composition analyzer.

Research results

According to previously obtained data [5], under the influence of fallow deposits in the upper layer of chernozem with a typical thickness of 0-20 cm, the pH value decreased from 6.42 to 6.22 and the content of mobile phosphorus from 177.8 to 97.0 mg/100 g of soil. At the same time, the content of exchangeable calcium increased by 1.9, and hydrolytic acidity by 1.03 meq/100 g of soil, the content of organophosphates increased by 50.9 mg/100 g of soil. The number of waterproof units increased from 7.60 to 60.5%. Aggregation of the soil mass contributed to a decrease in the content of water-peptized sludge from 3.81 to 1.82%.

As a result of overgrowing of the fallow area with natural herbaceous vegetation, the scale of the biological cycle of substances and the amount of plant residues entering the soil changed, which was reflected in the content of organophilic elements (tab. 1).

Table 1

Influence of replacement of permanent steam with a deposit on the content of organophilic elements in typical chernozem of Kursk Region, $M \pm m \cdot t_{05}$, %

Option	C	H	N
Permanent steam	2.43±0.17	0.81±0.13	0.24±0.04
Deposit	3.48±0.22	1.06±0.07	0.30±0.01

Under the influence of deposits in typical chernozem, the content of the main elements of organophiles increased: carbon from 2.43 to 3.48%, hydrogen from 0.81 to 1.06%, nitrogen from 0.24 to 0.30%. Of the organophilic elements, the greatest increase was observed in the content of organic carbon, the amount of which increased 1.4 times, while the amount of hydrogen and

nitrogen increased 1.3 times. This is consistent with the increase in the humus content in the soils of the fallow, which has been repeatedly noted by many researchers [3, 4, 6, 9]. At the same time, mineralization processes are actively proceeding in the chernozem of the deposit, which can be judged by the less noticeable increase in the content of hydrogen and nitrogen in comparison with carbon. Hydrogen and nitrogen, predominantly included in the composition of aliphatic compounds of newly formed humic substances, are actively utilized by microorganisms, while carbon, to a greater extent localized in the composition of stable cyclic compounds, accumulates in the soil. This is also evidenced by some narrowing of the H:C and N:C ratios during the transition from steam to reservoir from 0.33 to 0.31 and 0.10 to 0.09, respectively.

Apparently, at first, the enrichment of old arable soils with humus after their transfer to fallow occurs mainly due to stable cyclic compounds forming molecules of humic acids.

Some changes also occurred with the content of the main chemical elements composing the mineral part of chernozem (tab. 2).

Table 2.

The effect of replacing permanent steam with a deposit on the content of the main constitutional elements in the typical chernozem of Kursk Region, %

Option	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	R_2O_3	Na_2O	SiO_2/R_2O_3
Permanent steam	68.36	12.62	4.14	0.76	17.52	0.84	7.81
Deposit	67.03	12.55	4.21	0.77	17.53	0.87	7.67

In the chernozem of permanent steam, silicon oxide predominates, the content of which was 68.36%. In fallow chernozem, its amount tends to decrease and amounted to 67.03%, which may be due to the intensive consumption of silicon by perennial herbaceous vegetation and active involvement in the biological cycle of substances [18].

The content of other chemical elements that make up the basis of the mineral part of chernozem is noticeably lower and is within the following limits: Al_2O_3 – 12.62-12.55%, Fe_2O_3 – 4.14-4.21%, Na_2O – 0.84-0.87 %, TiO_2 – 0.76-0.77, the R_2O_3 value is 17.52-17.53. In general, as a result of the transformation of permanent steam into a deposit, the content of these chemical elements in typical chernozem practically did not change over 20 years, which may indicate the stability of its mineral part. This can be evidenced by the practically unchanged value of the molecular ratio SiO_2/R_2O_3.

The content of some biophilic elements in the chernozem of permanent steam and deposits is shown in table 3.

Table 3. Influence of the transfer of permanent steam to the deposit on the content of biophilic elements in the typical chernozem of Kursk Region, %

Option	CaO	MgO	K_2O	P_2O_5	SO_3	$\frac{P_2O_5}{SO_3}$
Permanent steam	1.09	1.30	1.89	0.19	0.28	0.68
Deposit	1.17	1.34	1.83	0.24	0.32	0.75

The transfer of permanent steam to the deposit has an ambiguous effect on the total content of the most important biophilic elements in the chernozem. The content of CaO is in the range of 1.09-1.17%, MgO – 1.30-1.34%, and K_2O – 1.89-1.83. The content of these elements during the period when typical chernozem was in the state of the deposit practically did not change. At the same time, under the influence of the fallow in typical chernozem, the content of SO_3 increased from 0.28 to 0.32%, and P_2O_5 from 0.19 to 0.24%, which, apparently, is due to the accumulation of these elements in the organic matter of the soil. At the same time, the accumulation of P_2O_5 in chernozem proceeds more intensively in comparison with SO_3. This can be judged by the value of the P_2O_5/ SO_3 ratio, which changed from 0.68 in the chernozem of permanent steam to 0.75 in the chernozem of the deposit.

The content of trace elements in the chernozem of permanent steam and deposits is shown in table 4.

Table 4. Influence of the transfer of permanent steam to the deposit on the content of trace elements in the typical chernozem of Kursk Region, mg/kg

Option	Mn	Cr	Rb	Zn	Y	Ga	Pb
steam	6115	55	90	58	36	24	15
deposit	6656	123	94	66	36	25	21

Among the microelements in typical chernozem, Mn predominates, the content of which in vapor chernozem was 6115 mg/kg of soil, and in chernozem of fallow lands it increased to 6656 mg/kg of soil. The Cr content changed from 55 mg/kg of soil in the chernozem of permanent fallow to 123 mg/kg of soil in fallow chernozem. A weakly pronounced tendency to an increase in the content in fallow chernozem is found in Rb, Zn and Pb, while the amount of Y and Ga remained unchanged.

Conclusions

1. As a result of the transfer of permanent steam to the fallow, the level of humus content of typical chernozem increased, which can be judged by the increase in the content of organic carbon, hydrogen and nitrogen, the amount of which in the soil of the fallow increased by 1.05, 0.25 and 0.06%, respectively.

2.The change in the biological cycle of substances contributed to the accumulation in the upper part of the profile of chernozem and a number of mineral elements, of whichCr, P_2O_5, Pb, SO_3 and Zn are most actively accumulated, to a lesser extent – Mn, Ca Mg

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