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Reserves of Humus Substances in Agrochernozem in Organic Farming Conditions

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Abstract

The results of a field experiment to assess the structure and reserves of humus substances in clay illuvial typical agrochernozem of the forest-steppe of Central Siberia during the transition to an organic farming system are presented. Spring wheat was cultivated on an intensive background with the use of ammonium nitrate and chemical protective agents as per clean fallow as the predecessor with the conditions of an organic farming system - on a treated turf bed of 27 years of age. It was shown that in the spring period, the treatment of the long-fallow ecosystem led to an increase of water-soluble humus by 20% and alkali-hydrolyzable humus substances by 49% in the 0-20 cm layer of agrochernozem. The processes of plant residues' transformation of the long-fallow ecosystem during the growing season significantly replenished the content of humus substances and their alkaline hydrolyzable fraction in the soil. The increase in Chumus compared to the spring period was 283 mgC/100, CNaOH 559 mgC/100g. The structure of humus substances in agrochernozem after wheat cultivation with a long-fallow precursor showed an increase in the mobile humus part by 11%. In the conditions of fallow precursor, stable humus compounds accounted for 86% of the Chums reserves in the 0-20 cm arable layer. For long-fallow, they were reduced to 75%. It was found that during the cultivation of spring wheat on the treated long-fallow, replenishment of humus stocks up to 125 tC/ha, and the mobile part of humus 31 tC/ha was noted.

Disciplinary: Agriculture Science.

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1 Introduction

Organic farming, which provides for the greening of agriculture, rejecting the use of mineral fertilizers and chemical plant protection products, and the recognizing biological factors of the

sustainable agroecosystems' functioning is a global trend (Rigby & Caceres, 2001; Bello, 2008; Nigorev et al., 2018; Zelenev & Seminchenko, 2019; Feklistova, 2020; Haupt et al., 2021, Mistratova et al., 2021). In the conditions of organic agriculture transition, issues of conservation and reproduction of soil fertility are of primary importance. According to M.Yu. Kozyreva (2020), technologies of agricultural crops cultivation without agrochemicals' application will contribute to resource conservation, production of environmentally safe products, and improvement of the soil, which determines the level and quality of agrocenoses' products.

One of the possible ways to preserve and reproduce soil fertility is the transfer of land from arable land to fallow land. Organic matter accumulates in these areas due to the change of various herbaceous phytocenoses; its soil content and reserves serve as the main criterion for assessing its fertility; in recent years, they are being increasingly considered from the point of view of ecological stability of soils as a biosphere component (Kiryushin et al., 1993).

The purpose of the research was to assess the structure and reserves of humus substances in agrochernozem during the transition to an organic farming system.

2 Objects and Methods of Research

The research was conducted in 2021 in a field experiment in the conditions of the Chulym-Yenisei forest-steppe of the Krasnoyarsk Krai located on the southwestern edge of Central Siberia. This area receives 364-456 mm of precipitation per year. The average annual air temperature in the region does not exceed plus 1.3°C. The duration of the biological activity period is 90-100 days. The sum of active temperatures is 1534-1610°C.

The object of the study was clay illuvial typical agrochernozem and agrocenosis of spring wheat of the Svirel variety. In the 0-20 cm layer, the experimental plot soil stood out by high and very high humus content (9.4-10.1%), a high amount of exchange bases (33.2-39.5 mmol/100g), neutral, or slightly acid reaction of the soil solution (pHn2o 6.3-7.0), increased mobile phosphorus availability (210-220 mg/kg), high availability of mobile potassium (196-232 mg/kg).

Spring wheat was cultivated on an intensive background as per clean fallow as the predecessor with the conditions of an organic farming system - on a treated long-fallow of 27 years of age. The following pesticides were used on intensive spring wheat cultivation technology: King Combi, KS – 1.3 l/t; Oven, KE – 0.5 l/ha; Assalyuta, MK - 0.5 l/ha; Tribun, STS - 20 g/ha; Dekster, KS - 0.15 l/ha. Ammonium nitrate was introduced when sowing at a dose of N30.

Soil samples were taken from each field in 10-fold repetition from a depth of 0-20 cm before spring wheat sowing and after harvesting. The following parameters were determined in the samples: moisture by thermal weight method, compaction density according to Kachinsky, humus according to Tyurin; carbon of water-soluble organic matter (Cn2o) - by the method of bichromate oxidability according to I.V. Tyurin (Arinushkina, 1970); carbon of alkali-soluble organic matter (C0.1 nNaOH), in its composition - carbon of humic (Cha) and fulvic (Cfa) acids - in 0.1 n NaOH extract according to I.V. Tyurin in the modification of Ponomareva and Plotnikova (1980).

The obtained results were processed by methods of variance analysis and descriptive statistics (Dmitriev, 1995)

3 Results and Discussion

Depending on the degree of binding to the mineral part, sensitivity to biochemical decomposition and transformation, organic soil compounds are divided into pools of conservative, stable substances and a group of labile compounds (Ganzhara, 1988; Christensen, 2001). The easily mineralized part of organic matter includes plant residues, microbial biomass, and mobile humus. Mobile humus (Cmob) is a complex of humus nature substances, which easily passes into a soluble form. Water-soluble compounds leached from plant residues in decomposition processes are represented by a mixture of organic acids, amino acids, carbohydrates. These compounds make up the peripheral part of humus; they undergo mineralization fairly quickly and serve as the main source for the synthesis of humic substances (Semenov et al., 2004; Kurachenko & Bopp, 2016).

Plant residues are a systematic source of renewal and reproduction of soil organic matter. In the conditions of agrocenoses, this is a by-product of crops entering or placed in the soil (Semenov & Kogut, 2015). The sources of organic matter renewal in the conditions of a long-fallow ecosystem were the plant remains of the turf restoration stage.

Table 1: Statistical characteristics of the spatial carbon content distribution of humus substances in agrochernozem before spring wheat sowing, 0-20 cm (n = 10)

Predecessor	*Xav.*	*Lim*	*Cv, %*
Chumus, mg/100g			
Clean fallow	5519.2	4079.3-6240.3	15
Long-fallow	5979.4	5338.8-6741.9	8
p	0.140		
C_{H2O}, mg/100g			
Clean fallow	19.4	9.1-28.8	26
Long-fallow	23.3	17.6-28.8	15
p	**0.050***		
C_{NaOH}, mg/100g			
Clean fallow	655.8	291.1-1128.6	42
Long-fallow	974.2	635.6-1431.5	24
p	***0.010****		
Cha, mg/100g			
Clean fallow	299.8	108.3-529.9	54
Long-fallow	589.3	315.1-947.5	31
p	***0.001****		
Cfa, mg/100g			
Clean fallow	362.3	182.8-598.7	39
Long-fallow	348.8	320.5-484.0	36
p	0.820		

Determination of the carbon content and its mobile components before spring wheat sowing showed that 27 years of long-fallow ecosystem functioning determined some accumulation of organic matter in the 0-20 cm layer of chernozem (Table 1). After fallow soil processing, the excess of humus content by 460 mg/100 g compared to intensively used arable land was not mathematically reliable. The variation coefficient of Chumus equal to 8-15% indicates its

insignificant and small variability within the fields. During this period, a significant replenishment of the easily mineralized organic matter pool was noted, which significantly affected the concentration of mobile humus compounds. Water-soluble and alkali-hydrolyzable humus compounds are constantly replenished and react to any androgenic effects (Dergacheva, 1984).

In the soil of the treated long-fallow, an increase of 20% of water-soluble humus and 49% of alkali-hydrolyzable humus substances was noted. A noticeable increase (by 96%) of humic acids in the composition of alkali hydrolyzable compounds indicates an improvement in mobile humus quality in fallow soil. The amount of the relative humic acids accumulation in humus composition depends on the biological activity of soils. The higher it is, the relatively less mobile, weakly polymerized components accumulate. Mobile humus substances were characterized by insignificant, medium, and high variability in space (Cv = 15-54 %). Studies have established a decrease in the coefficients' magnitude of spatial variation of chernozems' humus state indicators involved in arable land after long-fallow.

The bulk of the organic matter entering the soil with plant residues quickly mineralized during decomposition and only some was included in the soil organic matter. It was found that while cultivating spring wheat during one growing season, an insignificant accumulation of humus substances occurred against an intense background during the post-harvest period, which was associated with the death of root systems and the entry of plant residues into the aboveground sphere (Table 2). The accumulation value for Chumus amounted to 22 mg/100g, Cn2o 3 mg/100g, and CNaOH 106 mg/100g.

Table 2::Carbon content of humus substances in agrochernozem after spring wheat harvesting, 0-20 cm, mgC/100g

Predecessor	Chumus	Cn_2o	C_{NaOH}	Cha	Cfa	Cha/Cfa
Fallow	5497,3	22,7	761,5	363,6	397,9	0,9
Long-fallow	6262,7	25,3	1533,2	909,0	624,2	1,5
p	0,050*	0,201	0,005*	0,001*	0,030*	0,002*

The transformation processes of the long-fallow ecosystem's plant residues during the growing season led to a significant replenishment of humus substances and their alkali-hydrolyzable fraction in the soil. In the wheat agrocenosis soil by long-fallow, the increase in Chumus compared to the spring period was 283 mgC/100, CNaOH 559 mgC/100g. The amount of water-soluble humus in the soil after wheat cultivation was estimated at a close level (25 mgC/100g) due to the high lability of this component and its accelerated mineralization.

Quantitative estimates of carbon in the humus substances components were determined by the nature of soil use. The results showed that the humus of agrochernozems was dominated by compounds that make up the stable humus fund (Figure 1). Under the conditions of the fallow predecessor, they accounted for 85% of the Chumus reserves in the 0-20 cm layer. A decrease in the stable humus compounds proportion to 80% was noted in the soil of the treated long-fallow. Mobile humic substances passing into the liquid phase had a low proportion - 15-20%. The composition of

the mobile organic matter was dominated by young humic acids extracted by alkaline hydrolysate. The maximum proportion of alkali-soluble humus substances was recorded on the treated long-fallow and amounted to 16% of the Chums reserves. In the structure of chernozems' humus, the proportion of water-soluble compounds is small and was characterized by close quantitative estimates (3-4%).

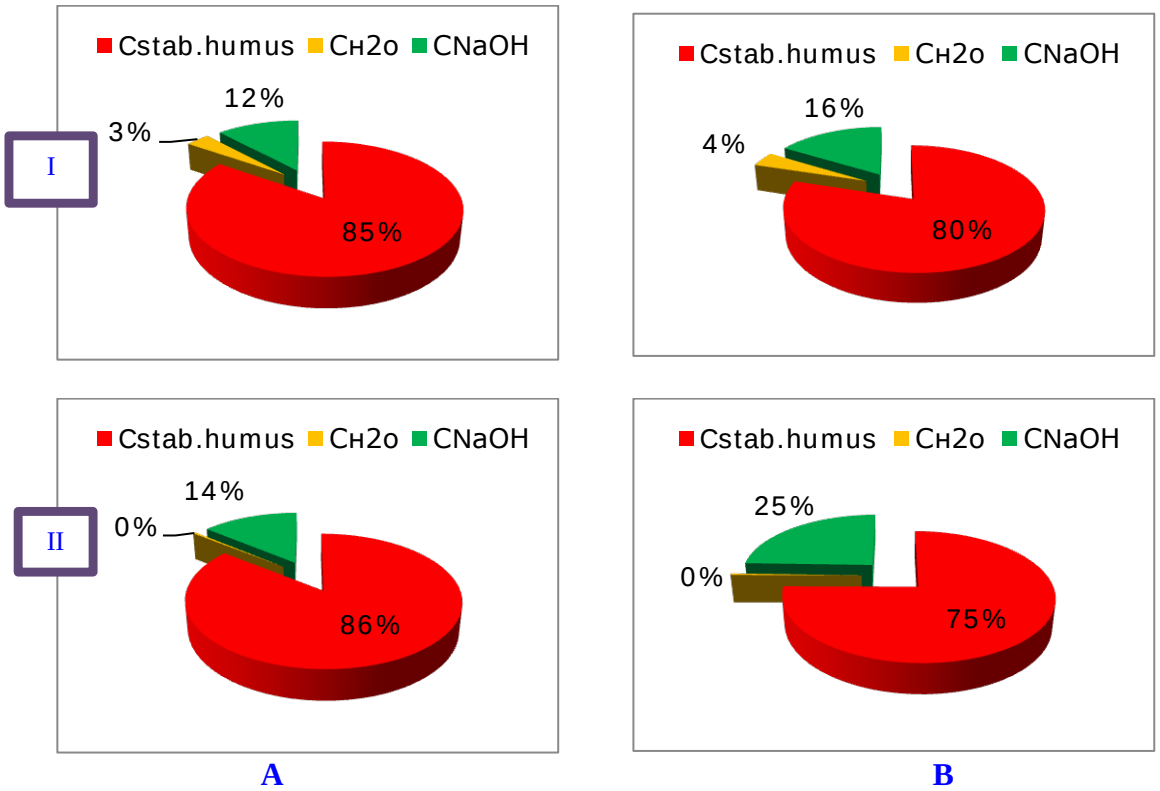

Figure 1: Structure of humus substances in the agrochernozem of wheat agrocenosis by fallow (A) and long-fallow (B) before sowing (I) and after harvesting wheat (II)

The structure of humus substances in agrochernozem after wheat cultivation showed an increase in the mobile part of humus by 11% according to the fallow precursor. In the conditions of fallow precursor, stable humus compounds accounted for 86% of the Chumus reserves in the 0-20 cm arable layer. For long-fallow, they were reduced to 75%.

Table 3: Reserves of humus substances in agrochernozem of wheat agrocenosis, tCha (0-20 cm)

Humus component	Before sowing		After harvest	
	fallow	long-fallow	fallow	long-fallow
Chumus	110.0	120.0	109.9	125.2
Cmob	16.9	24.2	15.7	31.2
Cn_2o	3.8	4.7	0.45	0.51
C_{NaOH}	13.1	19.5	15.2	30.7
Cha	6.0	11.8	7.3	18.2
Cfa	7.1	7.7	7.9	12.5
Cha/Cfa	0.8	1.5	0.9	1.5
Cstab.humus	93.1	95.8	94.2	94.0

A key role in ensuring the stability of humus reserves in arable soils belongs to the easily mineralized fraction of organic matter - mobile humus, detritus, plant residues, those act as a sort

of regulator. This fraction largely determines the intensity of mineralization processes, limiting the reduction or accumulation of carbon with a respective decrease or increase in the intake of fresh organic matter into the soil. The differences between the individual humus components characterize functioning features of the humus substances' system and allow to predict the direction of humus formation processes and humus accumulation in the agricultural use of soils. Studies have found that the reserves of Chumus in the 0-20 cm layer of agrochernozem after long-fallow processing increased by 10 tC/ha (Table 3).

Replenishment of mobile humus substances' reserves was estimated at 7 tC/ha. The reserves' ratio of mobile humic and fulvic acids in agrochernozem indicated that fulvic acids were dominant in the conditions of fallow precursor (0.8). Soil functioning against the background of long-fallow plowing is accompanied by an improvement in the quality of humus up to 1.5. The assessment of humus reserves in agrochernozem allowed to establish that during spring wheat cultivation of the Svirel variety on the treated long-fallow, replenishment of humus reserves was up to 125 tC/ha and the mobile part of humus 31 tC/ha. Thus, replenishment of alkaline hydrolyzable humus compounds reserves by 2 times mainly due to humic acids was revealed in the conditions of spring wheat cultivation according to the organic farming system. This is an important fact that determines the reproduction of the humus state of agricultural soils since, in conditions of agricultural use, losses or accumulation of soil organic matter are mainly associated with easily mineralized components. Thus, the cultivation of spring wheat without the use of protective means and mineral fertilizers against the background of the treated long-fallow determines the preservation of potential and effective soil fertility.

4 Conclusion

The plowing of a 27-year-old long-fallow and its inclusion in agricultural turnover significantly affected the state of soil organic matter of agrochernozem. Compared with the fallow predecessor, replenishment of humus reserves was by 10 tC/ha and 7 tC/ha of mobile humus reserves. The cultivation of spring wheat without the use of protective means and mineral fertilizers against the background of the treated long-fallow determined the preservation of potential and effective soil fertility mainly due to the regulation of the mobile part of the soil organic matter. In the structure of humus substances in agrochernozem after wheat cultivation on a fallow precursor, an increase in the share of Cmob by 11% was revealed.

5 Availability of Data and Material

The data for this study can be available upon a request made to the corresponding author.

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