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The Structure of Humic Substances in the Agricultural Genetically Modified Soils of the Kansk Forest-Steppe

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***Abstract**: In two long-arable areas that were intended for sowing rapeseed and false flax for oilseeds at LLC «Experimental Industrial Farm Solyanskoye» in the Kansk forest-steppe, the structure and humus substances reserves in agrochernozems were studied. The soil cover of key plot No. 1 with the wide-steeply-sloping terrain with weakly pronounced microrelief, which was intended for rape, was dominated by typical medium and strong clayey-illuvial agrochernozems. Key plot No. 2 intended for false flax was located on a smooth hillside of a wide ridge and was characterized by the complexity of the soil cover represented by a combination of clay-illuvial typical agrochernozems of various kinds, thick podzolized clay-illuvial agrochernozems, and thin cryogenic micellar agrochernozems. It has been shown that agrochernozems featured high content of humus in the layer both 0 – 20 and 0 – 40 cm thick. The content of humus carbon (C_{tot}) and that of carbon of the water-soluble organic matter (C_{H2O}) had little spatial variability (CV = 1.3 – 11.7 %), unlike the carbon content of the alkali-soluble organic matter ($C_{0.1\ n.\ NaOH}$), which in the studied agrochernozems had a very high degree of spatial variability (Cv = 18.7 – 66.1 %). Heterogeneity of the soil cover of the slope part of the plot was the factor that determined the average reduction in the content of the reserves of all fractions of humic substances, except for the water-soluble humus carbon. It has been found that the share of the reserves of stable humus carbon (C_{stab}) was 89 – 95 % of the total carbon reserves of humus, thus the share of C_{H2O} and $C_{0.1\ n.\ NaOH}$ decreased with increasing the complexity of the soil cover from 11 to 5 % of C_{total}. Fields with a pronounced meso- and microrelief and thin kinds of agrochernozems are recommended for sowing false flax, which is a crop that is less demanding to the soil conditions than rapeseed.*

***Keywords**: agrochernozems, soil organic matter, humus carbon, stable humus, water-soluble humus, alkali-soluble humus, spring rapeseed, bigseed false flax.*

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I. INTRODUCTION

Soil organic matter is one of the main parameters of fertility and is characterized by a complex heterogeneous structure and many functions. Part of humic substances is loosely tied to the soil matrix, is not protected chemically and easily accessible for the decomposition; it is, according to the opinion [1, 2], is the active pool of humic substances, which is represented by undecomposed plant and animal residues, microbial biomass, and organic matter of small particle size fractions, non-aggregated and interaggregated organic matter as well as compounds of carbon, extractable water, and salts.

In addition to mortmass, water, and salt-soluble components, the soil organic matter contains substances that can dissolve in alkaline solvents and scale after acidification of the medium, which fact is widely used for determining the fractional-group composition of humus by the method of Tyurin in various modifications [3, 4, 5]. Some authors argue that alkali-soluble components do not reflect the real nature of the organic matter in the soil [6, 7], since, upon the action of alkalis, the organic matter is subjected to adverse chemical reactions, and represents a conglomerate of hardly identified compounds. However, experiments [8] for determining the rate of the native organic matter mineralization in the humus accumulating horizon showed that the highest rate of CO_2 emissions was characteristic for the soil samples without extraction of the labile organic matter (microbial biomass, detritus, small plant remainders), and for the samples with sequential extraction of organic matter using heavy liquids (saturated NaI solution, with the density of 1.8 g/cm^3) and alpha humus (0.1 n. NaOH solution), the rate of decomposition decreases exponentially. Thus, after removing the mortmass from the soil and treating it with a weak alkaline solution, the rate of native organic matter decomposition in the soil decreases sharply to the level comparable to the mineralization rate of the compounds that are hardly soluble or resistant to biodegradation. According to [8], the 0.1 n. solution of NaOH extracts the following from the soil: part of the microbial biomass, pro-humic substances, nonspecific organic substances, newly formed humic substances, and partially humic acids loosely associated with mineral components. Based on these studies, the authors can assume that the alkali-soluble fraction of organic matter is part of the so-called intermediate or "slow" pool of organic matter in the soil, which can be isolated [9] in experiments with continuous bare fallow.

Studies [10, 11, 12] confirm that in the agricultural lands, both water-soluble and alkali-soluble organic matter combine and form a mobile or movable pool of organic matter, performing the structure-forming function and functioning as a high-energy food source for heterotrophic microorganisms, maintaining the biological activity of the soil and mineralization processes, which release nutrition elements for plants, providing effective soil fertility.

However, the greatest part of humic substances is represented by carbon strongly bonded with the solid phase of the soil; this is the so-called stable, or passive, humus, which is chemically inert and poorly undergoes biodegradation, thus ensuring the stable functioning of the soil in time and space, maintaining its properties and conditions even under high agricultural loads [13, 14, 15]. The authors [9] suggest defining the carbon pool of the passive humus as the difference between the total reserves of carbon in the organic matter and the reserves of carbon in the active organic matter in the soil of continuous bare fallow of a specific soil-ecological zone ($C_{pass} = C_{org}$-C_0). In the absence of perennial fallow fields, an alternative to this approach, in the opinion of the authors and according to [10], can be isolation of a pool of passive (stable) humus as the difference between its gross reserves, which is determined by the method of Tyurin without considering the crop residues and the sum of the pools of water-soluble and alkali-soluble carbon humus: $C_{stab.} = C_{tot.}$- (C_{H2O}+$C_{0.1\ NaOH}$).

It is worth emphasizing that following [16], in this study the authors adhere to the principle of designating the fractions of organic matter by the extractant used: water-soluble and alkali-soluble one. In the products that are soluble in decinormal alkali ($C_{0.1\ n\ NaOH}$), mobile (agile) humic and fulvic acids (C_{HA} and C_{FA}) are found.

II. PROPOSED METHODOLOGY

A. General Description

The study was performed on the lands of LLC «Experimental Industrial Farm Solyanskoye» in the **Kansk** forest-steppe of the Kansk-Rybinsk geomorphological district. 360 – 450 mm of precipitation fall annually in this territory. The average annual temperature in the region varies from -0.3 °C to -1.7 °C. The duration of the period of biological activity varies between 84 and 115 days. The sum of active temperatures is 1561 – 1818 °C, the soil freezes to the depth of 1.5 – 3 m.

B. Algorithm

On the two plots of arable land in the grain-fallow crop rotation with the area of five hectares, the humus state of the soil was studied before sowing rapeseed and false flax for oilseeds. The previous crop was peas and oats mixture. The soil cover in the territory was closely related to the conditions of the terrain. Key plot No. 1 (56°006ʾN and 95°052ʾE) was characterized by wide-steeply-sloping terrain with the slightly pronounced microrelief in the form of small depressions and elevations of various shape, which was typical for the most of the Kansk forest-steppe. The structure of the soil cover in this area is dominated by clay-illuvial typical medium and thick agrochernozems. In the barely noticeable microdepressions, various kinds of clay-illuvial podzolized agrochernozems are found. Key plot No. 2 (56°026ʾN and 95°243ʾE) was situated on a smooth hillslope of the wide ridge extending from the West to the East. The experimental plots were laid on the elevated part of the slope, the middle slightly sloping part, and the lower part, where the microdepressions were more pronounced. This area was characterized by the highest complexity of the soil cover and was represented by a combination of clay-illuvial typical agrochernozems of various kinds, clay-illuvial podzolized thick agrochernozems, and cryogenic micellar thin agrochernozems that occured on microelevations. To determine the classificational belonging of the soil, the Classification and Diagnostics of the Soils in Russia was used [17]. Soil samples were taken in ten sample plots from the depth of 0 – 20 cm and 20 – 40 cm. In the samples, the following was determined: bulk density — using the method of Kachinsky [18], humus — using the method of Tyurin, carbon in the water-soluble organic matter (C_{H2O}) — using the method of dichromate oxidation, alkali-soluble carbon in the humus ($C_{0.1\ n.\ NaOH}$), and the content of carbon of humic (C_{HA}) and fulvic acids (C_{FA}) in it — in the decinormal alkaline extract using the method of Tyurin as modified by Ponomareva and Plotnikova [19].

The obtained results were processed by the methods of dispersion analysis and descriptive statistics.

III. RESULTS ANALYSIS

The total content of humus carbon (C_{tot}) in the topsoil was high and ranged from 3.5 to 4.2 %. Statistical parameters show a weak degree of spatial variability in both radial and lateral directions, which does not exceed 10 – 12 % (Table 1). The relative error is 1 % to 5 % of the average value. Thus, despite the combination of various subtypes of agrochernozems in a small area, the studied soils are quite homogeneous in terms of the content of humus carbon. In the 20 – 40 cm soil layer, the content of humus carbon is slightly lower than in the overlying layer, however, it is also considered to be high. This is a positive factor for cultivating crops, and ensures deeper penetration of the roots.

Table 1: Content of humic substances carbon in chernozems, %

Key plot	Depth, cm	Statistical parameters*	C_{tot}	C_{H2O}	$C_{0.1\ n\ NaOH}$	
					C_{HA}	C_{FA}
No. 1 Rapeseed (n = 10)	0 – 20	$\bar{X}$	4.2	0.021	0.201	0.198
		$S_{\bar{x}}$	0.2	0.001	0.019	0.051

		min	4.0	0.018	0.156	0.101
		max	4.7	0.022	0.246	0.300
		C_v, %	8.3	10.0	18.7	51.1
	20 – 40	$\bar{X}$	4.2	0.021	0.18	0.254
		$S_{\bar{x}}$	0.2	0.001	0.049	0.028
		min	3.7	0.017	0.067	0.212
		max	4.7	0.024	0.279	0.335
		C_v, %	10.4	14.0	54.2	21.9
# 2 False flax (n = 10)	0 – 20	$\bar{X}$	3.9	0.019	0.092	0.084
		$S_{\bar{x}}$	0.5	0.001	0.030	0.025
		min	3.3	0.019	0.011	0.028
		max	4.3	0.020	0.156	0.151
		C_v, %	11.7	1.3	65.9	60.4
	20 – 40	$\bar{X}$	3.5	0.019	0.067	0.119
		$S_{\bar{x}}$	0.4	0.004	0.001	0.037
		min	3.2	0.018	0.045	0.039
		max	3.8	0.020	0.100	0.229
		C_v, %	8.9	4.3	36.0	66.1

If * — $\bar{X}$ average, $S_{\bar{x}}$ — standard error of mean; min — minimum; max — maximum; C_v, % — coefficient of variation.

Among the factors that have a significant effect on the content of humus in chernozems, the most important is factor "A" that is associated with the severity of the microrelief and the thickness of the humus horizon; the effect, in this case, exceeds 34 % (Table 2). In the first key plot, where the structure of the soil cover was dominated by the areals of medium and thick types of agrochernozems, the content of humus was significantly higher than that in the second plot with the high complexity of the soil cover, pronounced microrelief, and predominance of thin kinds of agrochernozems.

Table 2: The power of factors influence on the content of humic substances carbon in agrochernozems, %

Factor	C_{tot}	C_{H2O}	$C_{0.1\ n\ NaOH}$	
			C_{HA}	C_{FA}
Key plot (A)	34.1*	23.8	50.9*	45.0*
Depth, cm (B)	4.1	2.9	2.0	6.2
Interaction (A+B)	5.2	6.0	0.03	0.3

* — the effect of the factor is veracious ($p < 0.05$)

The content of the organic matter carbon (C_{H2O}) extracted by the water extract in the studied chernozems was low (0.019 — 0.021 %); this may be explained by the fact that C_{H2O} has a high ability to mineralize and migrate. The value of C_{H2O} spatial variation coefficient is considered low; this is possibly due to the fact that by the moment of taking samples at the beginning of the vegetation season, fresh portions of crop residues that could locally stimulate the decomposition processes and increase the heterogeneity of low molecular weight and soluble organic decay products in the soil were absent [16, 20].

In the alkali-soluble organic matter of chernozems, the content of humic acid carbon ranged from 0.011 to 0.279 %. The coefficient of variation was medium and very high, and amounted to 19 – 67 %. An increased spatial heterogeneity and a veracious decrease in the content of C_{HA} were noted in the second key plot due to the high complexity of the soil cover and reduced thickness of the humic horizon. A similar pattern was observed in the content of fulvic acid carbon in the soils. While in the first plot with flattened terrain and the more uniform soil cover, the contents of C_{FA} ranged between 0.101 and 0.335 %, in the second plot with the strongly expressed micro-relief with small depressions and hills and uneven thickness and transitions of the humus horizon, the content of C_{FA} was significantly lower and amounted to 0.025 – 0.229 %.

No statistically veracious changes were found in the content of C_{HA} and C_{FA} with increasing the depth, due to the high variability of these indicators. Despite the tendency to the higher content of young humic acids in the top layer of the soil, young fulvic acids in the 20 – 40 cm soil layer could be traced in both the first and second key plots, i.e., it was not dependent on the microrelief and the heterogeneity of the soil cover.

The sum of the carbon reserves represented by the water-soluble and alkali-soluble products in the 0 – 40 cm soil layer was 6.6 – 13.3 t/ha (Table 3), their share in C_{tot} ranged from 5 to 11 %. Similar results were obtained on leached heavy loamy chernozems in the variants of crop rotations with bare fallow without fertilizers [9].

The share of stable humus carbon reserves in the studied chernozems was 89 – 95 %. The high share of stable forms of humus in the structure of the organic matter in arable topsoil indicated high agrogenic load and deficiency of plant residues in the soil [15]. Cultivation of high-yielding cabbage oils crops will allow increasing the intake of plant residues into the soil during the vegetation season through partial withering away of the aboveground organs of plants, and after harvesting the seeds through the crop residues and strong root systems of the plants.

Table 3: Reserves of humus and carbon of humic substances in agrochernozems, t/ha

Key plot	Depth, cm	Humus	C_{tot}	$C_{stab.}$	$C_{mobile\ pool}$			$C_{mobile\ pool}$, % of $C_{tot.}$	$C_{stab.}$, % of $C_{tot.}$
					C_{H2O}	$C_{0.1\ n\ NaOH}$			
						C_{HA}	C_{FA}		
No. 1 Rapeseed (n = 10)	0 – 20	110.53	64.11	57.72	0.32	3.05	3.01	9.97	90.03
	20 – 40	111.16	64.48	57.55	0.31	2.76	3.86	10.75	89.25

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	0 – 40	221.69	128.59	115.27	0.64	5.81	6.87	10.36	89.64
No. 2 False flax (n = 10)	0 – 20	111.50	64.67	61.43	0.32	1.53	1.39	5.01	94.99
	20 – 40	99.01	57.43	54.07	0.31	1.10	1.95	5.85	94.15
	0 – 40	210.51	122.11	115.51	0.63	2.63	3.34	5.40	94.60

In addition, it may be noted that, despite the high content of humus in the soil, the reserves of humus in the 0 – 20 cm layer were medium; this was due to the physical state of the soil, which was characterized by low bulk density due to the high humus content, good structuredness, and prolonged frozen state. The density of the 0 – 20 cm layer of cultivated soils in the key plots was estimated on average as 0.76 g/cm^3 with insignificant and negligible variability within the field (Cv = 9 – 15 %). In the subsurface layer, it increased by 0.06 – 0.07 g/cm^3 retaining bulk looseness.

IV. CONCLUSION

The agrochernozems in the Kansk forest-steppe, while having heavy granulometric composition, feature high content and medium reserves of humus due to the bulk looseness. The quantitative assessment of the content and spatial distribution of humus and its mobile compounds in agrochernozems depended on the nature of the fields' relief and the features of the soil cover structure.

A set of typical clay-illuvial, podzolized clay-illuvial, and cryogenic micellar agrochernozems on the back slope, while reducing the content and reserves of humus substances, is determined to increase the heterogeneity of their spatial distribution. Fields with a pronounced meso- and microrelief and thin kinds of agrochernozems should better be used for sowing false flax, which is a crop that is less demanding to the soil conditions than rapeseed.

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REFERENCES

1. V. M. Semenov, B. M. Kogut, *Pochvennoe organicheskoe veshchestvo* [Soil organic matter], Moscow: GEOS, 2015.
2. M. Wander, "Soil organic matter fractions and their relevance to soil function", In: *Soil organic matter in sustainable agriculture*, Eds. F.Magdoff, R.R.Weil, Boca Raton etc.: CRC Press, 2004, pp. 67–102.
3. I. V. Tyurin, *Organicheskoe veshhestvo pochv i ego rol v pochvoobrazovanii i plodorodii. Uchenie o pochvennom gumuse* [Soil organic matter and its role in soil formation and fertility. The theory of soil humus], Moscow: Selkhozgiz, 1937.
4. L. A. Grishina, *Gumusoobrazovanie i gumusnoe sostoyanie pochv* [Humus formation and humus state of soils], Moscow: Publishing house of MSU, 1986.
5. D. S. Orlov, *Gumusovye kisloty pochv i obshhaya teoriya gumifikatsii* [Humic acids in soils and the general theory of humification], Moscow: Publishing house of MSU, 1990.
6. E.G. Gregorich, M.H. Beare, U.F. McKim, J.O. Skjemstad, "Chemical and biological characteristics of physically uncomplexed organic matter", *Soil Sci. Soc. Am. J.*, vol. 70, 2006, pp. 975 – 985.
7. M.H.B. Hayes "Solvent systems for the isolation of organic components from soils", *Soil Sci. Soc. Am. J.*, vol. 70, 2006, pp. 986 – 994.
8. S. Y. Trofimov, A. S. Lazarev, A. D. Fokin, "Mineralizatsiya labilnykh fragmentov organicheskogo veshchestva gumuso-akkumulyativnogo gorizonta dernovo-podzolistoi pochvy" [Mineralization of labile fragments of organic matter in the humus cumulative horizon of sod-podzolic soil], *Soil Science*, vol. 12, 2012, pp. 1259 – 1268.
9. V. M. Semenov, B. M. Kogut, S. M. Lukin, I. N. Sharkov, I. V. Rusakova, A. S. Tulina, V. I. Lazarev, "Otsenka obespechennosti pochv aktivnym organicheskim veshchestvom po rezultatam dlitelnykh polevykh opytov" [Assessing the availability of active organic matter in the soil according to the results of long term field experiments], *Agrochemistry*, vol. 3, 2013, pp. 19 – 31.
10. V. V. Chuprova, "Zapasy, sostav i transformatsiya organicheskogo veshchestva v agropochvakh Srednei Sibiri" [Reserves, composition, and transformation of organic matter in agricultural soils in Middle Siberia], *Bulletin of the Soil Institute n.a. V. V. Dokuchaev*, vol. 90, 2017, pp. 97 – 116.
11. N. L. Kurachenko, "Gumusovye veshchestva morfologicheski raznokachestvennykh pochvennykh agregatov chernozemov Krasnoyarskoi lesostepi" [Humic substances of morphologically heterogeneous soil aggregates of chernozems of the Krasnoyarsk forest steppe], *Soils of Siberia: Features of functioning and use*, Krasnoyarsk, iss. 4, 2012, pp. 102 – 107.
12. A. A. Belousov, E. N. Belousova, "Sezonnaya dinamika vodorastvorimogo organicheskogo veshchestva chernozema vyshchelochennogo v usloviyakh pochvozashchitnykh tekhnologii" [Seasonal dynamics of water-soluble organic matter in leached chernozem in soil-preservation technologies], *News of KrasSAU*, vol. 9, 2017, pp. 134 – 139.
13. V. I. Kiryushin, *Ekologicheskie osnovy zemledeliya* [Ecological fundamentals of agriculture], Moscow: Kolos, 1996.
14. V. V. Chuprova, *Uglerod i azot v agroekosistemakh Srednei Sibiri* [Carbon and nitrogen in agricultural ecosystems of Middle Siberia], Krasnoyarsk: Publishing house of KSU, 1997.
15. A. A. Titlyanova, V. V. Chuprova, "Izmenenie krugovorota ugleroda v svyazi s razlichnym ispolzovaniya zemel (na primere Krasnoyarskogo kraya)" [Changes in the carbon cycle due to various land use (on the example of the Krasnoyarsk Krai)], *Soil Science*, vol. 2, 2003, pp. 211 – 219.
16. V. V. Chuprova, I. V. Zhukova, "Vodorastvorimoe organicheskoe veshchestvo v pochvakh sklonovogo agrolandshafta Krasnoyarskoi lesostepi" [Water-soluble organic matter in the soils of the slope cultivated lands of the Krasnoyarsk forest steppe], *News of krasSAU*, vol. 9, 2017, pp. 140-149.
17. L. L. Shishov, V. D. Tonkonogov, I. I. Lebedeva, M. I. Gerasimova, *Klassifikatsiya i diagnostika pochv Rossii* [Classification and diagnostics of soils of Russia], Smolensk: Oykumena, 2004.
18. A. F. Vadyunina, Z. A, *Korchagina. Metody issledovaniya fizicheskikh svojstv pochv* [Methods of studying physical properties of soils], Moscow: Agropromizdat, 1986.
19. A. V. Sokolov (ed.), *Agrokhimicheskie metody issledovaniya pochv* [Agrochemical methods of studying soil], Moscow: Nauka, 1975.
20. V. M. Semenov, A. K. Khodzhaeva, "Agroekologicheskie funktsii rastitelnykh ostatkov v pochve" [Agro-ecological functions of crop residues in the soil], *Agrochemistry*, vol. 7, 2006, pp. 63 – 81.