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CHANGES IN THE HUMUS STATE OF TYPICAL COARSE-DUSTY LIGHT LOAMY CHERNOZEM UNDER DIFFERENT TECHNOLOGIES OF WINTER WHEAT CULTIVATION

Kucher L.I. *– Candidate of Agricultural Sciences,*
Associate Professor at the Department of Soil Science and Soil Protection
named after Prof. M.K. Shykula,
National University of Life and Environmental Sciences of Ukraine
Bogdanovich R.P. *– Candidate of Agricultural Sciences,*
Associate Professor at the Department of Soil Science and Soil Protection
named after Prof. M.K. Shykula,
National University of Life and Environmental Sciences of Ukraine
Panchuk T.V. *– Ph.D.,*
Assistant Professor at the Department of Agrochemistry and Quality of Plant Products
named after O.I. Dushechkin,
National University of Life and Environmental Sciences of Ukraine
Kucher T.R. *– 2nd year student of the Faculty of Plant Protection and Quarantine,*
National University of Life and Environmental Sciences of Ukraine

The article describes the study of the humus state of typical light loamy chernozem in the forest of the Right-Bank Forest-Steppe of Ukraine and the yield of winter wheat under the conditions of the application of various cultivation technologies. The researchers conducted a comparative study of the effectiveness of the following technologies: 1. Traditional, based on shelf plowing at 25-27 cm. 2. Soil protection based on shallow flat-cut tillage at a depth of 10-12 cm. Against the background of the above cultivation technologies, the effects of fertilization systems with application per 1 ha of crop rotation area were studied: 1. Control (no fertilizers); 2. Straw 1,2 t/ha + N_{12} + N_{55} P_{45} K_{45}; 3. Straw 1,2 t/ha + N_{12} + N_{78} P_{68} K_{68}; 4. Straw 1,2 t/ha + N_{12} + green manure + N_{55} P_{45} K_{45} ; 5.Straw 1,2 t/ha + N_{12} + green manure + N_{78} P_{68} K_{68}.

It has been determined that the use of soil protection technology compared to the traditional one did not significantly change the humus content in the arable layer, but affected its redistribution.

Increasing the saturation of crop rotation with various types of organic fertilizers (straw and green manure) contributed to the increase in the formation of humus substances. The highest humus content of 3,77% was recorded in the variant: straw 1,2 t/ha + N_{12} + green manure + $N_{78}P_{68}K_{68}$ against the background of soil protection technology in the upper soil layer under study.

It was found that different cultivation technologies affect the content of mobile humic substances in typical chernozem. The article contains research data on the carbon content of humic and fulvic acids in the soil. Organic fertilizers increased the content of mobile organic matter in the 0-30 cm layer against the background of plowing by 0,063 relative %, and against the background of soil protection technology – by 0,176%. When applying straw with mineral *fertilizers, the content of humic acids in chernozem typically amounted to 0,042-0,052% on the background of traditional technology and 0,055-0,088% on soil protection technology. In the variant with the introduction of straw 1,2 t/ha + N_{12} + green manure + $N_{78}P_{68}K_{68}$, the content of humic acids was 1.5 times higher than in the same variant when plowing. It was noted that the use of technology based on shallow flat-cut soil cultivation provided an increase in the yield of winter wheat grain by 3,5 c/ha compared to technology based on shelf plowing.*

***Key words:** humus substances, winter wheat, typical chernozem, tillage, cultivation technologies, yield.*

Кучер Л.І., Богданович Р.П., Панчук Т.В., Кучер Т.Р. Зміна гумусного стану чорнозему типового крупнопилувато-легкосуглинкового за різних технологій вирощування пшениці озимої

У статті викладено дослідження гумусного стану чорнозему типового легкосуглинкового на лесі Правобережного Лісостепу України та врожайність озимої пшениці в умовах застосування різних технологій вирощування. У дослідженнях проводилось порівняльне вивчення ефективності наступних технологій: 1.Традиційна, що базується на полицевій оранці на 25-27 см. 2. Ґрунтозахисна, що базується на мілкому плоскорізному обробітку на 10-12 см. На фоні перерахованих технологій вирощування вивчалась післядія систем удобрення із внесенням на 1 га сівозмінної площі: 1. Контроль (без добрив); 2. Солома 1,2 т/га + N_{12} + $N_{55}P_{45}K_{45}$; 3. Солома 1,2 т/га + N_{12} + $N_{78}P_{68}K_{68}$;4. Солома 1,2 т/га + N_{12} + сидерати + $N_{55}P_{45}K_{45}$; 5. Солома 1,2 т/га + N_{12} + сидерати + $N_{78}P_{68}K_{68}$.

Визначено, що застосування ґрунтозахисної технології порівняно з традиційною не сприяло істотній зміні вмісту гумусу в орному шарі, проте вплинуло на його перерозподіл. Збільшення насичення сівозміни різними видами органічних добрив (соломи і сидератів) сприяло підвищенню вмісту гумусових речовин. Найвищий вміст гумусу – 3,77% зафіксовано на варіанті: солома 1,2 т/га+N_{12}+сидерати+$N_{78}P_{68}K_{68}$ на фоні ґрунтозахисної технології в верхньому дослідженому шарі ґрунту.

З'ясовано, що різні технології вирощування впливають на вміст рухомих гумусових речовин в чорноземі типовому. Стаття містить дані дослідження вмісту в ґрунті вуглецю гумінових і фульвокислот. Органічні добрива підвищували вміст рухомих органічних речовин в 0-30 см шарі на фоні оранки на 0,063 відносних %, а на фоні ґрунтозахисної технології – на 0,176%. За внесення соломи з мінеральними добривами вміст гумінових кислот у чорноземі типовому склав 0,042-0,052% на фоні традиційної технології та 0,055-0,088% на фоні ґрунтозахисної. У варіанті з внесенням соломи 1,2 т/га+N_{12}+сидерати+$N_{78}P_{68}K_{68}$ вміст гумінових кислот становив у 1,5 рази більше, ніж на аналогічному варіанті при застосуванні традиційної технології. Відмічено, що використання технології на основі мілкого плоскорізного обробітку ґрунту забезпечило підвищення врожайності зерна пшениці озимої на 3,5 ц/га порівняно з технологією на базі полицевої оранки.

***Ключові слова:** гумусні речовини, пшениця озима, чорнозем типовий, обробіток ґрунту, технології вирощування, урожайність.*

Problem statement. Increasing agricultural productivity and providing the population with high-quality food is inextricably linked to the problem of preserving and restoring soil fertility.

Land reform and the opening of the land market in Ukraine, along with the difficult economic situation caused by the war, have led to the emergence of new land users who use soil resources thoughtlessly, leading to irreversible processes. This has become a major cause of concern for the international soil science community, as chernozem soils are degrading. Despite the favorable climatic conditions of the Forest-Steppe zone of Ukraine, the state of agricultural production does not meet modern requirements and the potential of chernozems, which are the zonal soils of this area, is not fully realized.

Conducting research to assess the state and direction of soil humus change and developing scientific principles for managing its level, taking into account all factors of the zone, is relevant and of scientific and practical importance.

Analysis of recent research and publications. Humus substances are generally important in soil formation, soil fertility and plant nutrition. In these processes, the role of individual humus components is not the same, as they have different properties [1, p. 356]. The content of humic acids in the soil contributes to the dark color of the soil, even with a small amount of them in the soil. Compared to light soils, such soils have a better thermal regime due to better absorption of solar radiation, are considered warm and have better vegetation growth. Humic acids have poor solubility in water and tend not to be washed out into the lower horizons, thus forming a humus horizon [2, p. 57].

Soils with a high humus content can be somewhat self-regenerating and can produce high crop yields under different weather conditions. The higher the humus content in the soil, the higher its buffering and absorption capacity. Highly humic soils that are rich in three-layer silicates have a water-resistant structure. The structure, moisture capacity, water, air and thermal regime are directly dependent on the content of organic matter in the soil [3, p. 773].

Decomposition of organic matter in the soil can take place in two ways: mineralization – rapid decomposition to final products (very pronounced in tropical areas) and humification – slow decomposition. The predominance of humification processes ensures a supply of nutrients for a long period of time [4, p. 2520]. 10-20% of organic substances contribute to the formation of humus, and 80-90% of their amount is mineralized. The rate of decomposition is significantly affected by crops. It is known that when growing row crops, 1,5-3,0 t/ha of humus is lost annually, and when growing cereals – 0,5-1,0 t/ha [5, p. 154]. The loss of soil humus is affected by low supply of organic residues, insufficient calcium content, acidic reaction of the soil environment and dry weather conditions [6, p. 30].

When growing crops that were grown without fertilizers, it was found that this ultimately leads to a decrease in soil fertility, deterioration of physical, physicochemical and agrochemical properties, and conditions for the life of microorganisms [7, p. 14].

The increase in humus content is achieved by applying measures that increase the content of soil organic matter. These include sowing perennial grasses in crop rotation, applying organic and mineral fertilizers, leaving stubble on the field, and regulating the acidity and alkalinity of the soil solution [8, p. 319].

Crop rotation is also important in increasing the humus reserves of the topsoil, as crop residues serve as a source of replenishment of soil organic matter. For the introduction of 1 ton of straw into the soil, 5-10 kg of nitrogen fertilizers should be added for better decomposition and intensive bacterial growth [8, p. 320]. Fertilizers, when used for a long time and systematically, interact with the soil and plants and cause certain changes in soil properties, which ultimately determine the level of fertility of agrobiocenosis and plant productivity [9, p. 204].

The introduction of all types of organic fertilizers against the background of technologies based on no-till tillage is the main direction of biologization of agriculture. With no-till tillage, plant residues are concentrated in the surface soil layer, which to some extent models the course of the sod process, which is typical for virgin steppe soils. As a result, microbial activity in the surface layer of soils under moldboardless tillage significantly increases, and soil self-regulation is activated, which is typical for virgin soils [10, p. 86; 11, p. 216].

Materials and methods of research. The research was conducted in 2021-2023 on a long-term experiment of the Department of Soil Science and Soil Protection named after Prof. M.K. Shykula of NUBiP of Ukraine, which was established in 1995 on a typical coarse-dusty light loamy chernozem on loess. The humus content in the topsoil was 3,54-0,03%, and in the subsoil – 3,52-0,04%. This soil is characterized by a close to neutral reaction of the soil solution. In the topsoil, the pH is 6,8, the hydrolytic acidity is 0,7 mg-eq, the amount of absorbed cations is 35,17 mg-eq/100g of soil, and the degree of saturation with bases is 93,0%. In the subsoil layer, the pH is 7,4, the hydrolytic acidity (Hg) is 0,54 mg-eq/100g of soil, the sum of absorbed cations is 30,22 mg-eq/100g of soil, and the degree of saturation with bases is 94,6%. The research was conducted in the following crop rotation: winter wheat, corn, barley. The winter wheat crop studied was Poliska 90.

The researchers conducted a comparative study of the effectiveness of the following technologies:

1. Traditional, based on shelf plowing to a depth of 25-27 cm.
2. Soil-protection technology based on shallow flat-cut soil cultivation of 10-12 cm.

Against the background of the above tillage systems, the effect of four fertilizer systems with application per 1 ha of crop rotation area was studied against the control background:

1. Control (no fertilizer); 2. Straw 1,2 t/ha + N_{12}+$N_{55}P_{45}K_{45}$; 3. Straw 1,2 /ha + N_{12}+$N_{78}P_{68}K_{68}$; 4. Straw 1,2 t/ha + N_{12} + green manure + $N_{55}P_{45}K_{45}$; 5. Straw 1,2 t/ha + N_{12} + green manure + $N_{78}P_{68}K_{68}$; Variants are placed by the method of split plots. The size of the elementary plot is 180 m^2, the accounting plot is 100m^2.

Soil cultivation was carried out by tillage machines: shelf plowing – PLP – 6-3,5; minimum tillage – BDT-7. Mineral fertilizers were used in the experiment: ammonium nitrate with a nitrogen content of 34,5%, granular superphosphate with a P_2O_5 content of 19,5% and potassium salt with a K_2O content of 60%. Mineral fertilizers and straw were applied superficially, followed by incorporation.

Soil samples mixed from 5-6 samples were taken 4 times during the growing season: III decade of April, III decade of June, III decade of August and after harvesting – III decade of September. The depth of sampling was 0-15 and 15-30 cm. The content of total humus was determined by the Turin method in the modification of Simakov; the group composition of humus by Kononova and Belchikova [12]. The gluten content was determined by the washing method (GOST 13586.1-86), and the protein content by the Kjeldahl method (GOST 10846-74). Statistical processing was performed by ANOVA. The yield of winter wheat was determined manually.

Summary of the main research material. Analyzing the data (Fig. 1), there was a tendency to increase the humus content in the 0-15 cm soil layer under moldboardless tillage both in the variant without fertilizers and with fertilizer application.

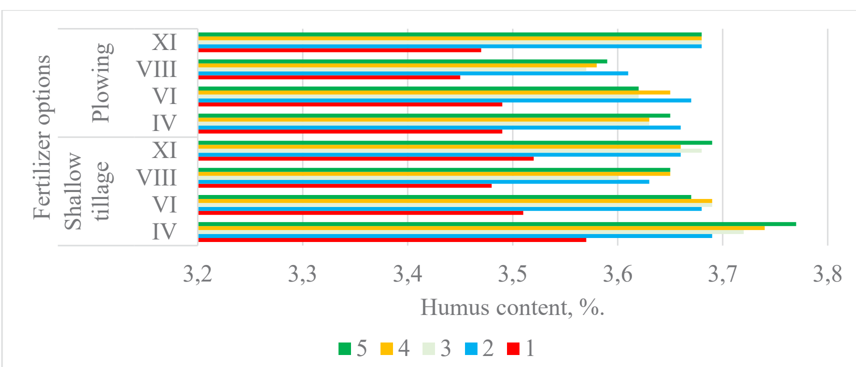

Fig. 1. Humus content in typical chernozem in the soil layer 0-15 cm depending on tillage and fertilization systems (2021-2023) NIR_{05} – 0.11

There is a clear tendency of redistribution of humus across the studied horizons: the difference in humus content in the 0-15 and 15-30 cm layer on the background of shallow flat-cut soil cultivation was 0,06-0,10%, while on the background of plowing it was much less – 0,01-0,03% (Fig. 2).

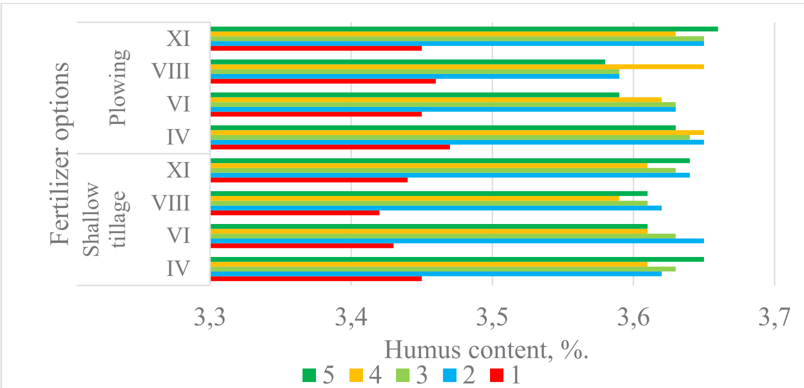

Fig. 2. Humus content in typical chernozem in the soil layer of 15-30 cm depending on tillage and fertilization systems (2021-2023) NIR_{05} – 0.11

Against the background of straw application, an increase in the rate of mineral fertilizers did not significantly affect the increase in humus content.

However, the gradual increase in the saturation of crop rotation with different types of organic fertilizers contributed to the increase in the formation of humus substances. The highest humus content in soil protection technology is 3,77% and is observed in the variant with the introduction of straw 1,2 t/ha + green manure + $N_{78}P_{45}K_{45}$, while in plowing it is slightly lower – 3,65%.

The dynamics of humus during the growing season in the variants with soil protection technology was more noticeable than in plowing. Thus, the humus content with this technology changed from 3,77% at the beginning of the growing season to 3,61% in the middle, that is, by 0,14%, while with the traditional technology these changes amounted to only 0,03%. The same patterns were observed in the variant with the introduction of straw 1,2 t/ha + green manure + $N_{78}P_{45}K_{45}$ per hectare of crop rotation area.

Thus, it can be concluded that the use of soil protection technology compared to traditional technology did not significantly change the humus content in the topsoil, but contributed to the redistribution of its amount in the layers 0-15 and 15-30 cm in the variants with the application of organic fertilizers against the background of mineral fertilizers. In the layer of 0-15 cm, a higher humus content was observed in the soil protection system, and in 15-30 cm – in the traditional system.

Long-term use of organic and mineral fertilizers affects the content of mobile organic matter. The application of organic fertilizers increased their content in the 0-30 cm layer against the background of traditional technology by 0,063%, and against the background of soil protection technology – by 0,176% (Table 1).

At the same time, the scale of the increase in the content of mobile humus substances increased against the background of green manure, where their highest content in the 0-30 cm layer was 0,346% against the background of soil protection technology.

Table 1

Influence of cultivation technologies on the content of mobile humus substances, % (2021-2023)

Soil layer, cm	Traditional technology			Soil protection technology		
	$C_{tot.}$	$C_{H.A.}$	$C_{F.A.}$	$C_{tot.}$	$C_{H.A.}$	$C_{F.A.}$
Control						
0-15	0,147	0,030	0,115	0,157	0,046	0,110
15-30	0,123	0,018	0,103	0,125	0,031	0,092
0-30	0,136	0,024	0,110	0,208	0,038	0,168
Straw 1,2 t/ha+ N_{12}+$N_{55}P_{45}K_{45}$						
0-15	0,196	0,048	0,146	0,306	0,061	0,243
15-30	0,160	0,032	0,124	0,212	0,050	0,160
0-30	0,177	0,041	0,134	0,260	0,055	0,202
Straw 1,2 t/ha+ N_{12}+$N_{78}P_{68}K_{68}$						
0-15	0,207	0,058	0,147	0,330	0,096	0,232
15-30	0,176	0,045	0,129	0,300	0,081	0,217
0-30	0,191	0,052	0,137	0,315	0,088	0,225
Straw 1,2 t/ha + N_{12} + green manure + $N_{55}P_{45}K_{45}$						
0-15	0,226	0,053	0,171	0,306	0,080	0,224
15-30	0,161	0,047	0,114	0,211	0,070	0,140
0-30	0,193	0,050	0,141	0,260	0,074	0,182
Straw 1,2 t/ha + N_{12} + green manure + $N_{78}P_{68}K_{68}$						
0-15	0,230	0,061	0,165	0,360	0,071	0,287
15-30	0,172	0,050	0,120	0,333	0,063	0,268
0-30	0,201	0,056	0,143	0,346	0,067	0,277

Notes: C tot. – total humus concentration; CH.A – humic acid concentration; CF.A – fulvic acid concentration

This phenomenon can be recognized as positive, since in chernozems of typical low-humus coarse-dusty-light loam granulometric composition with reduced buffering capacity, the probability of increasing the intensity of mineralization and migration to the lower layers increases and thus depleting the treated layer of this fraction of humus substances. The processes of excessive humus mobilization are accompanied by significant acidification of chernozems not saturated with bases, which should not contribute to an increase in humus. When applying straw with mineral fertilizers, the content of humic acids in chernozem typically amounted to 0,042-0,052% under conventional technology and 0,055-0,088% under soil protection technology. The highest content of humic acids – 0,088% was in the variant with the introduction of straw 1,2 t/ha + N_{12} + green manure + $N_{78}P_{68}K_{68}$, which is 1,5 times higher than in the same variant when using traditional technology.

Table 2 shows the yield and quality of winter wheat.

The highest yield was observed in the variant with soil protection technology and the introduction of straw, mineral fertilizers and green manure – 43,4 c/ha. The yield of winter wheat was significantly affected by the use of mineral fertilizers and organic residues. Thus, in the variants with traditional technology, the yield increase compared to the control was 9,4-12,6 c/ha, and with soil protection technology – 11,2-16,1 c/ha. The application of mineral fertilizers, straw and green manure significantly affected the protein content of wheat grain compared to the control. The highest protein content was observed in the variants with the application of mineral fertilizers and straw on the background of soil protection technology – 15,1%.

Table 2

Yield of winter wheat depending on tillage and fertilization, (2021-2023)

Cultivation technology	Fertilizer options	Yield, c/ha	Yield increase, c/ha	Protein content, %	Gluten content, %
Traditional technology	Control	27,1	-	14,0	29,0
	Straw 1,2 t/ha + N_{12}+$N_{55}P_{45}K_{45}$	39,9	12,6	14,2	30,9
	Straw 1,2 t/ha + N_{12}+$N_{78}P_{68}K_{68}$	36,7	9,4	14,7	31,7
	Straw 1,2 t/ha+N_{12} + green manure+ $N_{55}P_{45}K_{45}$	37,8	10,5	14,3	28,7
	Straw 1,2 t/ha +N_{12} + green manure + $N_{78}P_{68}K_{68}$	39,7	12,4	14,6	30,1
Soil protection technology	Control	28,6	1,3	13,6	28,0
	Straw 1,2 t/ha + N_{12}+$N_{55}P_{45}K_{45}$	38,5	11,2	15,1	30,9
	Straw 1.2 t/ha + N_{12}+$N_{78}P_{68}K_{68}$	41,1	13,8	15,1	30,6
	Straw 1,2 t/ha +N_{12} + green manure + $N_{55}P_{45}K_{45}$	41,6	14,3	14,6	29,7
	Straw 1,2 t/ha +N_{12} + green manure + $N_{78}P_{68}K_{68}$	43,4	16,1	14,7	30,9
NIR_{05}		0,53	2,1	0,1	0,35

Conclusions. The use of soil protection technology in comparison with the traditional one did not significantly affect the humus content in the tilth layer, but it did affect its redistribution. The highest humus content (3,77%) was in the variant: straw 1,2 t/ha + N_{12} + green manure + $N_{78}P_{68}K_{68}$ on the background of shallow flat-cut tillage (0-15 cm layer). Organic fertilizers increased the content of mobile organic matter in the 0-30 cm layer on the background of plowing by 0,063 relative %, and on the background of shallow flat-cutting – by 0,176%. At the same time, the scale of the increase in the content of mobile humus substances increased against the background of green manure, where their highest content in the 0-30 cm layer was 0,346% against the background of shallow flat-cutting. When applying straw with mineral fertilizers, the content of humic acids in chernozem was typically 0,042-0,052% on the background of plowing and 0,055-0,088% on shallow flat-cutting. The highest content of humic acids – 0,088% was in the variant with the introduction of straw 1.2 t/ha + N_{12} + green manure + $N_{78}P_{68}K_{68}$, which is 1,5 times more than in the same variant for plowing.

Shallow flat-cut tillage increased the yield of winter wheat grain by 3,5 c/ha compared to shelf plowing, but its use did not significantly affect the crude gluten content in winter wheat grains.

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