

**CHANGES IN HUMUS CONTENT AND PHYSICOCHEMICAL
PROPERTIES OF TYPICAL CHORNOZEM DEPENDING ON
CULTIVATION AND MINERAL FERTILIZER SYSTEMS**

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Goal. To determine the influence of tillage and mineral fertilizer systems on humus content and reserves, changes in the physicochemical properties of typical low-humus chernozem in short crop rotations. **Methods.** Field – to determine the interaction of research objects with natural and agrotechnical factors; laboratory – to determine humus content, pH_{salt} , amount of absorbed bases, hydrolytic acidity, the content of exchangeable cations; statistical-mathematical – to conduct dispersion analysis and statistical processing of research results. **Results.** The research (2019–2022) showed that the use of a typical chernozem cultivation system against the background of minimized mineral fertilizing ($N_{16}P_{16}K_{16}$) in a layer of 0–20 cm contributed to an increase in humus content at plowing by 12 %, disking – by 8.9, use of no-till technology – by 0.25 %, compared to the control (without fertilizers). Against the background of intensive mineral fertilization ($N_{90}P_{90}K_{90}$), humus reserves in the soil layer of 0–20 cm increased by 7.1 t/ha with plowing, 6.0 t/ha – with shallow disc tillage, and 6.8 t/ha – with no-till technology compared to the control

(without fertilizers). For carrying out shallow disc tillage and using minimized mineral fertilizing ($N_{16}P_{16}K_{16}$), optimal indicators of the amount of absorbed bases in the soil layer of 0–20 cm were noted compared to indicators of the amount of absorbed bases for plowing and no-till technology. The largest losses of exchangeable cations (Ca^{2+} and Mg^{2+}) against the background of intensive mineral fertilization ($N_{90}P_{90}K_{90}$) using no-till, disking, and plowing technologies were determined. The highest values of hydrolytic acidity (3.06 m-equiv./100 g of soil) were recorded when intensive mineral fertilizing was applied in the 0–20 cm layer for plowing, the lowest values were in the 20–40 cm layer for no-till technology.

Conclusions. It was determined that the content of humus in the arable layer of typical chernozem increased due to shallow disc tillage against the background of minimized mineral fertilization ($N_{16}P_{16}K_{16}$) compared to the content of humus during plowing and no-till technology. It was proved that the system of cultivation of typical chernozem under intensive mineral fertilization ($N_{90}P_{90}K_{90}$) had no significant effect on the number of absorbed bases. It was established that intensive mineral fertilization had a significant effect on exchangeable cations (Ca^{2+} and Mg^{2+}) and indicators of hydrolytic acidity in typical chernozem for all treatments carried out.

Key words: humus reserves, hydrolytic acidity, disking, plowing, amount of absorbed bases, no-till technology.

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One of the most important soil properties is fertility, which is formed in the process of soil formation and is characterised by a combination of all its indicators. Optimal conditions for plant growth and development are ensured by a complex of soil properties: physical, physicochemical, biological and agrochemical [1, 2]. Soil fertility is highly dependent on its properties, which are subject to anthropogenic impact. Preserving soil fertility and its reproduction should be a priority for modern farming, as it is one of the important reserves for increasing agricultural production. This is only possible through the integrated implementation of soil protection

agricultural technologies – such as tillage and fertilisation systems. Fertilisation plays a leading role in this complex of measures [3, 4].

Changes in soil physicochemical properties, potential acidity and humus formation under the influence of mineral fertilisation depend on many factors [5, 6]. It should be noted that the reaction of the soil has a significant impact on the growth and development of crops. High soil acidity increases the solubility of aluminium and manganese compounds, which increase the negative impact on plants and soil microorganisms, the speed and direction of chemical and biological processes. The acidity of the soil depends on climatic conditions, properties of the parent rock, and human activity [1, 3, 7].

Increased acidity of arable land is caused by the application of high doses of physiologically acidic fertilisers, removal of biophilic elements from the soil by crops, and loss of exchangeable cations with downward moisture flows [8].

Thus, the use of mechanical tillage and high doses of mineral fertilisers, especially their physiologically acidic forms, has a significant impact on changes in the physical and chemical properties of chernozems. Therefore, it is important to determine the intensity and direction of these changes, which are formed under the influence of agrotechnical factors.

The aim of the research is to determine the influence of tillage systems and mineral fertilisation on the dynamics of humus content and physical and chemical properties of typical chernozem in short rotation crop rotations.

Materials and methods of research. The research was conducted in a long-term stationary experiment during 2019–2022 in the subzone of unstable moisture of the Left-Bank Forest-Steppe at the Panfilska Research Station of the National Research Centre «Institute of Agriculture of NAAS». The climate of the research area is temperate continental with an average annual air temperature of +6...+8 °C. According to the average annual data, 558 mm of precipitation falls during the year, and 355 mm during the growing season, which is 60 % of the annual amount.

Experimental design: factor A – soil tillage: ploughing by 25–27 cm; shallow disc cultivation by 10–12 cm; no-till technology – sowing with a Siva SZM 3.6

grain seeder. Factor B – fertilisation systems: no fertiliser – control; minimised – $N_{16}P_{16}K_{16}$ + by-products of the predecessor; intensive $N_{90}P_{90}K_{90}$ + by-products of the predecessor. Crop rotation in short rotation crop rotations: 1 – spring barley – soya – winter wheat – sunflower; 2 – spring rape – winter wheat, corn, spring barley. The research was conducted in the agrocenosis of winter wheat. The soil of the experimental plot is a typical shallow coarse-dusty light loamy chernozem on loess, characterised by the following physicochemical and agrochemical parameters of the arable layer: pH_{sol} – 6.15, humus content in the arable layer – 3.08–3.15 %, in the subsoil – 2.7–2.9 %, availability of mobile phosphate and mobile potassium compounds – 300 and 96 mg/kg of soil, respectively. The content of alkaline hydrolysed nitrogen in the topsoil is very low – 72.8 mg/kg of soil. The experiment was repeated 3 times, with a sowing plot of 140 m² and a control plot of 105 m², and a sequential arrangement of plots. Phosphorus (granular superphosphate) and potassium (potassium chloride) fertilisers were applied for autumn tillage, nitrogen (ammonium nitrate) – for pre-sowing cultivation and top dressing.

Soil samples were taken from a depth of 0–20 cm and 20–40 cm according to DSTU [9]. The humus content was determined by the method of I.V. Tyurin in modification B. Simakov in accordance with DSTU [10], humus reserves – by the calculation method, hydrolytic acidity (Hr) – by the Kappen method in accordance with DSTU [11], and the content of absorbed bases (S) – in accordance with MVV 31 – 497058 – 007 – 2005. Statistical data processing was carried out by the method of analysis of variance using computer technologies (PIC «Agrostat», MSOfficeExcel).

Research results. Most nutrients are supplied to plants from the 0–40 cm layer, so increasing the humus content in the upper soil layers is an important condition for friendly germination and good plant development throughout the growing season [12]. In typical chernozem, changes in humus content and reserves are determined by the ratio of humification and mineralisation processes under certain agricultural technologies. This ratio is most strongly influenced by the amount

of organic fertiliser applied to the soil and the intensity of tillage and mineral fertilisation systems [2].

The results of the research show that the use of tillage systems and mineral fertilisation had a significant impact on changes in humus content and its reserves in typical chernozem (Table 1).

1. Changes in humus content and reserves of typical chernozem under different tillage and mineral fertilisation systems.

Fertiliser, dose	Soil layer, cm	Humus content, %.			Humus reserves, t/ha		
		no-till	debate	ploughing	no-till	debate	ploughing
No fertiliser (control)	0–20	3.90	3.92	3.77	74.0	70.5	63.3
	20–40	3.35	3.49	3.58	63.8	62.8	60.1
Minimized N ₁₆ P ₁₆ K ₁₆	0–20	3.91	4.27	4.23	74.4	76.8	71.0
	20–40	3.95	4.05	4.02	74.5	72.9	67.5
Intensive N ₉₀ P ₉₀ K ₉₀	0–20	4.19	4.25	4.19	79.8	76.5	70.4
	20–40	3.80	4.09	4.17	72.4	73.6	70.0
HIP05		0.20	0.25	0.15			

With the use of minimal mineral fertiliser (N₁₆P₁₆K₁₆) in the 0–20 cm soil layer, the humus content increased by 12 % under ploughing, 8.9 % under shallow disc cultivation, and 0.25 % under no-till technology compared to the control (without fertiliser). It was noted that the humus content in the control (without fertilisers) was the lowest for all soil tillage. It was determined that the use of shallow disc cultivation compared to ploughing against the background of intensive mineral fertilisation (N₉₀P₉₀K₉₀) in the soil layer 0–20 cm contributed to an increase in humus content by 0.06 %, and in the layer 20–40 cm – to its decrease by 0.08%. Under no-till technology with intensive mineral fertilisation (N₉₀P₉₀K₉₀), compared to the control (without fertiliser), a significantly higher humus content (by 0.29 %) was observed in the 0–20 cm soil layer.

With ploughing in the 0–20 cm soil layer, the humus content in the control (without fertilisation) decreased by 0.15 %, in the 20–40 cm layer, on the contrary, it increased by 0.09 % compared to the humus content in shallow disc tillage. The increased humus content in the tilth layer of the soil was observed under disking.

Under the tillage system, the humus content in the lower layer (20–40 cm) decreased by 6–10 % compared to its content in the upper layer (0–20 cm), which is due to the peculiarities of the morphological structure of chernozems and the limited supply of fresh organic matter.

Humus reserves in the soil are the most informative indicator of the potential fertility of typical chernozems. The research results indicate the accumulation of humus reserves in the 0–40 cm layer, where the bulk of the plant root system is located and conditions for their growth and development are formed. The humus reserves are naturally distributed in the soil layers according to its content, which is associated with the density of the upper layers of chernozem under different tillage systems and mineral fertilisation.

In the control (no fertiliser), humus reserves decreased under no-till, disking and ploughing technologies. Intensive mineral fertilisation (N₉₀P₉₀K₉₀) compared to the control (no fertiliser) increased humus reserves in the 0–20 cm soil layer by 7.1 t/ha under ploughing, 6.0 t/ha under disking, and 5.8 t/ha under no-till. Under shallow disc cultivation and intensive mineral fertilisation, a noticeable differentiation of the topsoil in terms of humus reserves restoration was observed.

It is proved that the amount of absorbed bases depends on the absorption capacity of the particles that make up the soil, so this indicator is influenced by the humus content, mineralogical and particle size distribution of the soil [13]. Humus and its reserves directly or indirectly determine the potential fertility of the soil, affect the formation of indicators of physical and chemical properties, especially the capacity of cation exchange and buffering capacity of typical chernozem (Table 2).

2. *Hydrolytic acidity and the sum of absorbed bases of typical chernozem under different tillage systems and mineral fertilisation, m-eq/100 g of soil.*

Fertiliser, dose	Soil layer, cm	No-till		Debate		Ploughing	
		Hr	S	Hr	S	Hr	S
No fertiliser (control)	0–20	1.02	29.4	1.46	30.2	1.69	30.1
	20–40	0.66	27.1	1.04	28.2	1.52	28.5
Minimized (N ₁₆ P ₁₆ K ₁₆)	0–20	2.40	31.8	2.49	33.0	2.69	31.3
	20–40	1.80	28.5	1.88	33.8	2.45	29.4
Intensive	0–20	2.62	30.5	2.75	31.9	3.06	30.6

(N ₉₀ P ₉₀ K ₉₀)	20–40	2.04	28.9	2.26	30.3	2.87	28.6
HIP ₀₅	0–20	0.24	F _φ < F ₀₅	0.32	2.82	0.35	F _φ < F ₀₅
	20–40	0.10	F _φ < F ₀₅	0.43	F _φ < F ₀₅	F _φ < F ₀₅	1.31

A low amount of absorbed bases was noted against the background of intensive mineral fertilisation (N₉₀P₉₀K₉₀) under the cultivation system. However, a slight increase in hydrolytic acidity (by 1.1–1.3 m-eq/100 g of soil) in the soil layer 0–20 cm was facilitated by the use of minimal mineral fertilisation (N₁₆P₁₆K₁₆) and shallow disc cultivation.

The control (without fertilisers) under no-till technology had the lowest amount of absorbed bases in soil layers 0–20 and 20–40, which is explained by a slight decrease in hydrolytic acidity. The hydrolytic acidity indicators mainly increased under all studied agricultural technologies. Thus, its highest values (3.06 m-eq/100 g of soil) were in the layer 0–20 cm for ploughing, the lowest (0.66 m-eq/100 g of soil) – in the layer 20–40 cm for no-till technology.

With the use of intensive mineral fertilisation (N₉₀P₉₀K₉₀), hydrolytic acidity in the 0–20 cm layer increased by 0.31 m-eq/100 g of soil, and in the 20–40 cm layer by 0.61 m-eq/100 g of soil, compared to disking.

The application of mineral fertiliser with a dose of N₉₀P₉₀K₉₀ led to an increase in hydrolytic acidity, but it should be noted that the studied chernozem is typical with a pH_{sol} value of 6.15 and a humus content of 3.17 % and was already characterised by rather high initial hydrolytic acidity values of 3.2–3.4 m-eq/100 g of soil.

The content of exchangeable calcium in SOC is closely related to the cycle of organic matter in the soil [7]. The supply of sufficient organic matter to the soil helps to reduce the loss of exchangeable calcium due to the formation of hardly soluble humates [14]. The decrease in the content of exchangeable cations under some agrotechnological measures can be explained by their removal with the crop, oxidation of organic matter and leaching into the lower soil layers (Table 3).

3. The content of exchangeable cations in chernozem is typical for different tillage systems and mineral fertilisation, m-eq/100 g of soil (0–20 cm layer).

Fertiliser, dose	No-till		Debate		Ploughing	
	Ca ²⁺	Mg ²⁺	Ca ²⁺	Mg ²⁺	Ca ²⁺	Mg ²⁺

No fertiliser (control)	12.7	2.4	13.7	2.4	16.3	2.8
Minimized (N ₁₆ P ₁₆ K ₁₆)	12.3	2.2	13.3	2.3	14.8	2.6
Intensive (N ₉₀ P ₉₀ K ₉₀)	11.7	2.1	12.8	2.1	12.3	2.2
HIP ₀₅	F _φ <F ₀₅	F _φ <F ₀₅	F _φ <F ₀₅	F _φ <F ₀₅	F _φ <F ₀₅	F _φ <F ₀₅

The lowest content of exchangeable cations was observed when applying intensive mineral fertilisation (N₉₀P₉₀K₉₀) under the tillage system. It was found that the systematic use of mineral fertiliser with a dose of N₉₀P₉₀K₉₀ compared to the control (without fertiliser) leads to a decrease in the content of exchangeable cations under no-till technology by 1.0 m-eq/100 g of soil, shallow disc cultivation – 0.9, and ploughing – by 4.0 m-eq/100 g of soil.

It was determined that the content of exchangeable Mg²⁺ in the soil of the control variant without fertiliser application was 2.4–2.8 m-eq/100 g of soil, while with the use of intensive mineral fertiliser (N₉₀P₉₀K₉₀) its content decreased by 0.3–0.6 m-eq/100 g of soil compared to the control. With the use of minimal mineral fertiliser at a dose of N₁₆P₁₆K₁₆, a slight decrease in the content of exchangeable magnesium was observed compared to the control (without fertiliser).

Conclusions. The influence of the tillage system of typical chernozem on the increase of humus content in the soil layer 0–20 cm on the background of minimised mineral fertilisation (N₁₆P₁₆K₁₆) compared to the control was noted. It increased by 12 % under ploughing, by 8.9 under shallow disc cultivation, and by 0.25 % under no-till technology. The humus content in the upper soil layer increased with shallow disc tillage, while ploughing resulted in its uniform distribution over all soil layers.

Using the tillage system on typical chernozem against the background of intensive mineral fertilisation (N₉₀P₉₀K₉₀), compared to the control (without fertiliser), the humus reserves in the 0–20 cm soil layer increased by 7.1 t/ha under ploughing, 6.0 t/ha under shallow disc tillage, and 5.8 t/ha under no-till technology.

Under the system of soil cultivation against the background of minimal mineral fertilisation (N₁₆P₁₆K₁₆), an increase in the amount of absorbed bases by 0.7–1.3 m-eq/100 g of soil was noted in contrast to its value under intensive fertilisation (N₉₀P₉₀K₉₀). It has been proved that under shallow disc cultivation on typical chernozem with the use of minimal mineral fertilisation, the amount of absorbed

bases in the soil layer 0–20 cm was 1.2 m-eq/100 g of soil higher than under no-till technology and 1.7 m-eq/100 g of soil higher than under ploughing.

It was found that in the black soil, typical for the soil cultivation system, the greatest losses of exchangeable cations (Ca^{2+} and Mg^{2+}) occur when applying intensive mineral fertilisation with a dose of $\text{N}_{90}\text{P}_{90}\text{K}_{90}$. Quite high indicators of hydrolytic acidity (3.06 m-eq/100 g of soil) were in the layer 0–20 cm on the background of intensive mineral fertilisation ($\text{N}_{90}\text{P}_{90}\text{K}_{90}$) during ploughing, the lowest (0.66 m-eq/100 g of soil) – in the layer 20–40 cm on the control (without fertiliser) under no-till technology.

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Changes in humus content and physicochemical properties of typical chornozem depending on cultivation and mineral fertilizer systems

Goal. To determine the influence of tillage and mineral fertilizer systems on humus content and reserves, changes in the physicochemical properties of typical low-humus chornozem in short crop rotations. **Methods.** Field – to determine the interaction of research objects with natural and agrotechnical factors; laboratory – to determine humus content, pH_{salt} , amount of absorbed bases, hydrolytic acidity, the content of exchangeable cations; statistical-mathematical – to conduct dispersion analysis and statistical processing of research results. **Results.** The research (2019–2022) showed that the use of a typical chornozem cultivation system against the

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Conclusions. It was determined that the content of humus in the arable layer of typical chornozem increased due to shallow disc tillage against the background of minimized mineral fertilization ($N_{16}P_{16}K_{16}$) compared to the content of humus during plowing and no-till technology. It was proved that the system of cultivation of typical chornozem under intensive mineral fertilization ($N_{90}P_{90}K_{90}$) had no significant effect on the number of absorbed bases. It was established that intensive mineral fertilization had a significant effect on exchangeable cations (Ca^{2+} and Mg^{2+}) and indicators of hydrolytic acidity in typical chornozem for all treatments carried out.

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