The article presents the results of studies on the effectiveness of various systems of basic soil cultivation and fertilizer systems for growing winter wheat, and their impact on the physicochemical properties of typical black soil and organic matter content. The experiment included plough tillage, tillage with a 10-12 cm disc harrow, "No-till" technology, and a mineral fertilizer system - source-saving minimized and intensive. The study was conducted in the agroecosystem of winter wheat. The results showed that shallow tillage with a disc harrow and resource-saving minimized mineral fertilizer increased the humus content in the 0-15 cm layer by 0.04% and in the 15-30 cm layer by 0.03% compared to inversion tillage. High rates of hydrolytic acidity (1.61-2.92 mol/m³/100 g of soil) were noted at all doses of mineral fertilizer when using inversion tillage. More optimized indicators of the sum of exchangeable bases of typical chernozem in a layer of 15-30 cm were noted during inversion tillage - 28.0 mol/m³/100 g of soil. The lowest value of the sum of exchangeable bases in the 15-30 cm layer was noted using the No-till technology - 27.6 mol/m³/100 g of soil. High rates of hydrolytic acidity (1.61-2.92 mol/m³/100 g of soil) were observed at all doses of mineral fertilizer using surface tillage. More optimized indicators of the sum of exchangeable alkaline of typical black soil in a layer of 15-30 cm were noted during shelf tillage - 28.0 mol/m³/100 g of soil. The lowest value of the sum of exchangeable alkalines in the soil layer of 15-30 cm according to the No-till technology was 27.6 mol/m³/100 g of soil.

Key words: humus, physical and chemical indicators, tillage.

INTRODUCTION

Soil organic matter is an essential indicator of the potential level of soil fertility and plays a crucial role in regulating biological, physicochemical, and chemical processes. It provides plants with nutrients and favorable soil conditions (Balaev & Tonkha, 2014). Black soils have significantly lost their natural fertility due to systematic intensive use, resulting in a decrease in the level of self-regulation of humus, biological, physicochemical, agrophysical state, gas-temperature, nutrient, redox, and water capacities, leading to their morphological genetic degradation. The organic matter content of the soil has decreased over the last 20 years (Balyuk et al., 2016). Research conducted by Rhoton (Rhoton, 2000) during four years of soil cultivation determined a 10% loss of the initial content of organic matter in the soil with the use of surface tillage. According to Mann (Mann, 1986), soil depletion of 16 to 77% of organic matter depends on tillage. Insufficient inflow of biomass into the soil during non-inversion tillage shows a steady decrease in humus potential, leading to the mobilization of nitrogen compounds contained in humus. Intensive tillage leads to a decrease in soil carbon content and nitrogen uptake by the crop, and a reduction in the amount and depth of tillage significantly reduces CO2 losses from soils with high organic matter content."

The reasons for the decrease in black soil fertility are intensive mechanical tillage, insufficient use of organic fertilizers, crop rotations with high-yielding crops, which leads to a deficient balance of humus and nutrients in the soil. Important areas of preservation and reproduction of black soil fertility are the
reduction of intensive tillage and mineral load, while applying minimal tillage using green manure, by-products and optimized doses of mineral fertilizers (Dotsenko, 2012; Demidenko, 2013; Tsyuk, 2015; Pikovskaya & Vitvitskaya, 2016; Balayev et al., 2020). The systematic application of high doses of mineral fertilizers without organic fertilizers leads to an imbalance in the synthesis and mineralization processes. Under these conditions, the mineralization of organic matter prevails (Volkohon et al., 2019). Organic farming helps to increase the biological activity of the soil, which is achieved by increasing the content of organic matter. The increased content of humus in soils in organic production is the result of using intermediate crops, greening, manure, and inversion tillage (Wang et al., 2001; Osman, 2013; Krauss et al., 2020). Literature sources indicate that the humus content in the upper arable layer of the soil is higher in the system of organic farming than in traditional farming. A significant amount of organic matter improves the biological and biochemical activity of the soil, increases biodiversity, and provides appropriate conditions for the growth and development of crops (Ghabbour et al., 2017; Bünemann et al., 2018; Audette et al., 2021).

Despite the significant number of studies on the impact of different tillage systems combined with organic and mineral fertilizers, the issue of a comprehensive assessment of the impact on maintaining the fertility of black soil hasn't been fully studied (Balaev et al., 2013; Tsyuk et al., 2018). This assessment should be based not on crop yields, which are often used in scientific papers, but on the fundamental properties of soil fertility.

The purpose of this research is to determine the interaction and influence of tillage systems and mineral fertilizers on the changes in physical and chemical properties of typical black soil, as well as the content of organic matter.

**MATERIALS AND METHODS**

Research was conducted at the National Research Center "Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine". The study investigated the influence of different systems of basic soil cultivation and mineral fertilizers in a short-rotation period from 2017 to 2021.

Factor A - Tillage: 1) Plow tillage 25-27 cm (control); 2) Shallow tillage with a disc harrow 10-12 cm; 3) "No-till" technology - sowing with a grain seeder for "No-till" technology.

Factor B - Fertilizer System: 1) without fertilizers (control); 2) source-saving minimizing - N16P16K16 + a by-product of the predecessor; 3) intensive - N120P90K90 + a by-product of the predecessor. Short crop rotation: spring barley - sunflower - soybean - winter wheat. The study was conducted in the cyanosis of winter wheat. The soil in the experimental plot is a typical shallow, coarse-grained, light loam black soil on loesses. It is characterized by the following parameters of the arable layer: pHKCl - 6.15. The content of humus in the arable layer is 3.08-3.15%, and in the subarable layer, it is 2.72-2.9%. The availability of mobile phosphate compounds and mobile potassium is 300 and 96 mg/kg of soil, respectively. The content of alkaline hydrolyzed nitrogen compounds in the arable layer of the soil is very low - 72.8 mg/kg of soil.

Soil samples were taken from depths of 0-15 cm and 15-30 cm in accordance with ISO 18400-101:2017. The samples were then air-dried and sieved to a size of less than 2 mm. Humus content was determined in accordance with Ukraine's standards (DSTU 4289, 2004), while total alkalinity (GOST 27821-88) and hydrolytic acidity (GOST 26212-91) were also measured in the prepared soil samples. The results of these indicators are presented in the article as average values over a period of five years of research. Statistical analysis of the results was performed using the software Statistica PL. Our indicators were statistically analyzed using the analysis of variance (ANOVA) for R.C.B.D, with a split plot arrangement and the use of the least significant difference test (LSD) to compare the arithmetic means of treatments at a probability level of 5%.

**RESULTS AND DISCUSSIONS**

The issue of preserving and reproducing the humus content in arable soils remains a top priority in Ukrainian agriculture (Tkachenko et al., 2019). Many of the black soils require immediate action to restore their potential
fertility. Therefore, significant attention has been given to studying the effects of different treatments and mineral fertilization systems on the humus content and reserves, as well as their impact on other physicochemical properties.

It is noted that possible agricultural measures to reproduce the fertility of black soil are divided into two groups: material and technological (Balaev et al., 2009). It was investigated that when applying the system of minimum tillage, the humus content in the soil increased by 0.8-22.1%. The systematic application of organic and mineral fertilizer helps to restore the humus content and optimize other physicochemical properties. The content of organic matter in the upper part of the treated soil layer has a significant impact on the course and direction of humification processes. Studies have shown that the use of shallow tillage led to a redistribution of humus in the 0-30 cm layer of soil (Figure 1). Localization of plant residues, organic, and mineral fertilizers occurs in the upper part of the treatment layer when applying tillage without rotation of the slice, which increases the content and reserves of humus (Przyzyznyuk et al., 2011; Yang et al., 2018). It was noted that with shallow cultivation using a disc harrow against the background of resource-saving minimized mineral fertilizer, the humus content in the layer 0-15 cm increased by 0.04%, and in the layer 15-30 cm by 0.03% compared to surface tillage. It was noted that in the upper layer of 0-15 cm during surface tillage, the humus content was 0.20-0.34% higher than during plowing. It was investigated that shallow cultivation with a disc harrow provided an increase in the labile part of humus by 17-35% compared to inversion tillage. A significant difference in humus content is observed depending on tillage, particularly in the context of an intensive mineral fertilizer system. In the 0-15 cm layer, shallow tillage with a disc harrow and intensive fertilization resulted in a 0.17% increase in humus content, while in the 15-30 cm layer, its content decreased by 0.07% compared to surface tillage. It was investigated that when using typical black soil without fertilizers (control) for shallow tillage, the humus content in the upper 0-15 cm layer of soil was the lowest at 3.43%, and for shallow cultivation, it was 3.58%. The tendency to reduce humus in the 0-30 cm layer of soil and its higher content in the upper 0-15 cm layer was noted during surface tillage. The lower layers of the soil were depleted of humus content and reserves in comparison with the upper layer by 0.25%.

Humus reserves in soil layers are a more informative indicator of the potential fertility of typical black soil than its content. It is important that the accumulation of humus takes place in a layer of 0-30 cm, where the root system of plants is located and the conditions for their growth and development are formed (Yevtushenko & Tonhka, 2017). It has been established that most of the nutrients come to plants from a layer of 0-30 cm. Therefore, increasing the humus content of the upper soil layers is an important condition
for friendly seedlings and the full development of plants throughout the growing season. Humus reserves were naturally distributed throughout the profile of typical black soil, although they had certain features associated with the differentiation of the density of the topsoil under different tillage systems. The application of surface tillage causes the preservation and accumulation of humus reserves in the 15-30 cm layer of soil with an intensive fertilizer system of 1.8 t/ha, and in the 0-15 cm layer by 13.3 t/ha compared to the variant without fertilizers. Shallow tillage with a disc harrow under the resource-saving fertilizer system contributes to the accumulation of humus reserves in the 0-15 cm layer of soil by 0.3 t/ha compared to the intensive system. The reserves of humus decrease without using fertilizers (control), and this is manifested when all tillage options are used. It was found that the highest reserves of humus were formed by shallow tillage, at 1.3 t/ha, compared to inversion tillage. Additionally, the No-till technology resulted in an average of 12.0 t/ha for all variants of the fertilizer system (Figure 2).

The intensive fertilization system contributed to humus accumulation in the 0-15 cm layer for field cultivation, resulting in 13.3 t/ha. Shallow tillage resulted in 10.2 t/ha, while No-till technology resulted in 20.2 t/ha, even without the use of fertilizers. The content and reserves of humus in black soil depend on the technology used to grow crops, and changes in content and reserves are determined by the ratio of humification and mineralization processes for certain agricultural technologies. The greatest influence on this ratio is the amount of organic fertilizers and plant residues entering the soil, as well as the intensity of tillage systems (Saenko, 2017; Tkachenko et al., 2019). The main directions for preserving and restoring humus content are minimizing cultivation and biologizing fertilizer systems. Reducing the intensity of tillage helps preserve humus reserves by reducing air access and the intensity of mineralization processes, especially in the lower layers of the soil. The entry of fresh organic matter into the upper layer of the soil coincides with the zone of the most intensive microbiological activity during surface tillage (Kokhan et al., 2009).

The content and reserves of humus directly or indirectly determine soil fertility. They also affect the physicochemical and agrochemical properties of typical black soil, particularly the amount of exchange bases and cation exchange capacity, soil buffering, and soil nitrogen and phosphorus content. Due to their correlation, increasing the humus content is always perceived as improving these properties and soil fertility in general. Figure 3 shows the changes in hydrolytic acidity (Hr) of a typical black soil under the influence of basic tillage and fertilization systems. It was investigated that the tillage and mineral fertilization systems had an influence on the physical and chemical properties of typical chernozem. It was noted that an increase in the degree of minimization of soil cultivation...
without fertilizer application (control) led to a decrease in hydrolytic acidity. The lowest hydrolytic acidity indicators were obtained when using the No-till technology. With an intensive mineral fertilizer system, the highest rates were observed when using inversion tillage of 1.61-2.92 mol/m³/100 g of soil. However, shallow tillage with a disc harrow was not inferior to inversion tillage, with rates of 1.39-2.62 mol/m³/100 g of soil.

It was observed that the indicators of hydrolytic acidity increased in the 0-15 cm layer of the soil with the application of intensive mineral fertilizer and inversion tillage, up to 2.92 mol/m³/100 g of soil. Consequently, the use of mineral fertilizers with an intensive fertilization system led to a significant increase in hydrolytic acidity, which is consistent with preliminary studies. As hydrolytic acidity increased, fewer cationic bases remained in the exchange form (r=-0.82). The released hydrogen ions replaced exchangeable cations in the soil absorption complex and displaced them into the soil solution, altering the pH of the soil's solutions (ISO 18400-101, 2017; Zhang et al., 2017; Tkaczyk et al., 2020). The use of a source-saving, minimized mineral fertilizer system contributed to a decrease in the upper 0-15 cm and the processing 15-30 cm layers compared to the intensive one by 0.4 and 0.32 mol/m³/100 g of soil, respectively.

It was noted that when we used the control (without fertilizers) and an intensive system of mineral fertilizers, the amount of exchangeable bases was low but increased with resource-saving minimized fertilizer. In our opinion, this can be explained by a decrease in hydrolytic acidity and an increase in the humus content in the 0-15 cm layer. A decrease in acidity and an increase in humus content with tillage without surface tillage contributed to an increase in the amount of exchangeable alkalines in the soil water complex (Rusu et al., 2013). This is due to the fact that, in our case, the sum of exchange areas is confirmed by the indicators of organic material content in a typical black soil (Table 1).

The level of exchangeable bases decreases with intensive fertilization and all treatments, but there is not a significant increase in resource-saving mineral fertilizer. This is due to a reduction in hydrolytic acidity, as high doses of mineral fertilizers can cause soil acidification and the rapid leaching of humic substances into lower layers.

<table>
<thead>
<tr>
<th>Fertilizers</th>
<th>Soil layer, cm</th>
<th>Plow tillage</th>
<th>Shallow tillage</th>
<th>No-till</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without fertilizers (St)</td>
<td>0-15</td>
<td>28.7</td>
<td>28.8</td>
<td>28.0</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>27.2</td>
<td>26.9</td>
<td>25.8</td>
</tr>
<tr>
<td>Source-saving minimized Intensive</td>
<td>0-15</td>
<td>29.8</td>
<td>31.5</td>
<td>30.3</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>28.0</td>
<td>29.4</td>
<td>27.2</td>
</tr>
<tr>
<td>Intensive</td>
<td>0-15</td>
<td>29.2</td>
<td>30.4</td>
<td>29.1</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>27.2</td>
<td>28.6</td>
<td>27.6</td>
</tr>
<tr>
<td>LSD95 fertilizers</td>
<td></td>
<td></td>
<td></td>
<td>1.07</td>
</tr>
<tr>
<td>LSD95 soil layer</td>
<td></td>
<td></td>
<td></td>
<td>0.38</td>
</tr>
</tbody>
</table>
In our opinion, this can be explained by a reduction in hydrolytic acidity and an increase in the humus content within the 0-15 cm layer. The decrease in acidity and increase in humus content resulting from tillage without surface tillage has contributed to an increase in the quantity of exchangeable alkalines within the soil water complex (Seitz et al., 2018).

Using a minimized system of mineral fertilization contributed to an increase in the index of the sum of exchangeable alkalines in the 0-15 cm layer of the soil in all studied treatments by 0.6-1.1 mol/m³/100 g of soil. Based on the sum of exchangeable bases, it was found that shallow tillage had an advantage over inversion tillage and No-till technology, especially in the top layer of soil from 0.8 to 1.7 mol/m³/100 g of soil on average for the system of mineral fertilizers.

**CONCLUSIONS**

The application of different tillage practices has affected the differentiation of humus content and reserves. With surface tillage, humus was uniformly distributed in the cultivated layer (0-30 cm), while unsurfaced tillage resulted in an accumulation in the upper layer of 0-15 cm. No-till technology showed a more intensive reduction of humus reserves in the 15-30 cm soil layer. Surface tillage contributed to the restoration of humus content and reserves, optimization of the soil water complex, and preservation of the fertility of typical black soil.

It was observed that the humus content increased by 0.56% in the 0-15 cm layer with the use of an intensive mineral fertilizer system compared to the control. With inversion tillage, the increase was 0.58%, and with shallow tillage, it was 0.92%. According to the No-till technology, the increase was the highest at 0.92%. The use of intensive mineral fertilizer also led to an increase in the hydrolytic acidity index to 2.92-2.50 mol/m³/100 g of soil. The optimal number of exchangeable alkalines in the typical black soil was found to be 28.0 mol/m³/100 g of soil in the 15-30 cm layer for surface tillage and 29.4 mol/m³/100 g of soil for shallow tillage. The lowest values of exchangeable alkalines were observed in the No-till technology at 27.6 mol/m³/100 g of soil in the 15-30 cm layer.

**REFERENCES**


***GOST 27821-88 soil. Determination of the sum of absorbed bases by the Kappen method (Soils. Determination of the amount of absorbed bases by the Kappen method).

***GOST 26212-91. Soils. Determination of hydrolytic acidity by the Kappen method in the CINAo modification. (Soils. Determination of hydrolytic acidity by the Kappen method in the CINAo modification).