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COMPARISON OF AGROPHYSICAL PARAMETERS AND HUMUS CONTENT IN THE VIRGIN SOIL AND ARABLE LAND

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Topicality*. Today, there are problems of soil humus loss and deterioration of its agrophysical properties, reducing the impact of agrophysical soil degradation, restoring and preserving soil fertility.* ***Purpose****. Comparison of agrophysical parameters and humus content in virgin and arable soil and development of scientific recommendations for the creation of favourable agrophysical properties and regimes for chernozem soils to suspend degradation processes and preserve fertility in these soils.* ***Material and Methods.*** *The study of ordinary chernozem was carried out both in virgin soil and experimental plots of the Erastivka Research Station of the Institute of Grain Crops of NAAS of Ukraine during 2010–2016. The following aspects were investigated: total humus content; structural and aggregate composition of the soil; soil pedality coefficient; soil density; water resistance of agronomically valuable peds. Soil samples were selected in May at equilibrium density after tillage. Sampling was carried out from the soil profile every 5 cm to a depth of 0–200 cm with four repetitions according to DSTU 4287.* ***Results.*** *As a result of long-term exploitation of ordinary chernozem, it has been established that agrophysical properties (structural and aggregate state, density, water resistance) deteriorate and the humus content and thickness of the humus horizon decrease compared to virgin soil.* ***Conclusions.*** *Comparison of the properties of the ordinary arable chernozem with virgin soil shows a significant degradation of arable land. Significant loss of humus and destruction of the soil structure lead to soil compaction and partial loss of the ability to resist degradation. For the preservation and sustainable use of arable chernozems, an improved agriculture system involving scientifically based crop rotations, the latest soil protection technologies, and the required amount of organic and mineral fertilisers to increase the humus content should be implemented.*

Key words: *ordinary chernozem, soil degradation, humus content, structural and aggregate state, soil density, water resistance*

Introduction. Chernozems are the most fertile soil types in the world. Ukraine ranks fourth in the world in terms of chernozem area after Russia, the USA and China. In Ukraine, about 10 million hectares are covered by ordinary chernozems, which have the most favourable agrophysical properties for growing crops [1, 2]. Chernozem soils are characterised by a thick humus layer, a pronounced granular structure, optimal structural density, a significant reserve of nutrients, and are the most developed soils with the potential for further expansion of their arable areas fully exhausted [3]. At the same time, Ukraine ranks first in the world in terms of arable land, which is about 80 %, but the overall efficiency of land utilisation in Ukraine is much lower than in advanced European countries.

It should be noted that chernozems are extremely sensitive to an increased level of anthropogenic load, which leads to the loss of valuable soil properties. Unfortunately, such changes are currently accelerating degradation processes. In particular, this also refers to the deterioration of agrophysical soil properties, which changes the physical structure and is the most common and dangerous type of degradation [4].

The main negative factor degrading the chernozem quality is the imbalance of organic matter. As a result of a decrease in the organic matter content and accelerated mineralisation, the humus profile loses its thickness as well as deterioration of the soil structure, water and air regime, over-compaction of the topsoil, which leads to a decrease in the root layer depth, etc.

Long-term moldboard tillage, the application of only mineral fertilisers, disruption of the sown area structure and non-compliance with

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recommended crop rotations have a negative effect on soil structure [5].

In general, the deterioration of soil conditions and soil degradation is a widely recognised problem in Ukraine. Today, agricultural science has already developed a number of recommendations aimed at preventing further soil degradation processes. Only adherence to scientificcally based recommendations for agriculture and improvement of existing agricultural technologies will reduce the intensity of mechanical load on the soil [6, 7].

However, science has not yet found reasonable answers to a number of questions. In particular, the influence of long-term exploitation of chernozems on changes in humus content and soil agrophysical parameters, which can be fully assessed by analysing the results of comparative surveys of virgin land and arable land. However, such studies have not been sufficiently conducted in Ukraine.

Materials and Methods. The research for comparing and evaluating changes in the humus content and main agrophysical parameters of ordinary chernozem was conducted in virgin soil and soil of experimental plots at the Erastivka Research Station of the Institute of Grain Crops of NAAS during 2010–2016. The standard of ordinary chernozem was a plot of virgin steppe in the Baikivka village of Piatykhatky district, Dnipropetrovsk region. The depth of the soil sections was 0–200 cm. Virgin land and arable land are located in the same plane with a distance of 250 m between them. We studied the total humus content according to the method of I. V. Tyurin (DSTU 4289-2004); structural and aggregate composition of the soil by the method of dry sieving according to M. I. Savin (DSTU 4744:2007); soil pedality coefficient was calculated as the ratio of the mass of peds with a diameter of 0.25–10 mm to the mass of peds over 10 and less than 0.25 mm; soil density – by the core cutter method with a ring volume of 500 cm3; water resistance of agronomically valuable peds by the accounting and statistical method of Andrianov.

Soil samples were selected in May, during which the equilibrium density state after mechanical tillage was recorded. They were selected from the soil profile every 5 cm, to a depth of 0–200 cm in accordance with DSTU 4287. All experiments were repeated four times.

Results and Discussion. The fertility of long-term cultivated soil depends not only on the nutrient content, but is also closely related to agrophysical properties. In particular, changes in the structural state, hardness, density, porosity and other parameters can only be observed by comparing the soils of virgin lands and arable land [4, 8].

The long-term agricultural exploitation of soil results in the degradation of morphological traits, which is manifested in the reduction of the soil humus horizon, due to the constant mechanical stress on the soil by agricultural machinery and implements, reduction of organic matter content, destruction of agronomically valuable peds, and increased erosion, which ultimately reduces the sustainability of arable land and the efficiency of its exploitation. These processes significantly affect the upper genetic horizons of soils, especially on slopes with a high slope angle. Our research has shown that the humus horizon thickness of arable land is less than 10 cm compared to virgin land.

At the same time, the upper humus horizon of arable chernozems differs in structure from virgin soils, namely, it is homogeneous with a granular structure on virgin lands, while two layers are clearly distinguished on arable lands: arable layer (0–30 cm) with a disturbed granular-crumble structure and subsoil layer (30–50 cm) with a well-defined crumble-granular structure. On arable land, these two layers of soil are separated by a plough sole with an increased density of more than 1.3 g/cm^3, which occurs when ploughing to the same depth for many years. The plough sole has a negative impact on the water, temperature and gaseous regimes of the soil, impedes the branching of plant root systems and the penetration of atmospheric precipitation into the lower soil layers [4, 8, 9].

A comparative evaluation of the humus content of ordinary chernozem on virgin soil and arable land was carried out. Humus content in the 0–5 cm and 5–10 cm layers of virgin soil was 8.25 and 6.76 %, while in arable soil it was only 4.2 and 4.1 %, respectively. A significant decrease in the upper 0–5 cm layer of arable land was by almost 50 %, and in the 5–10 cm layer – by 41.2 %. The decrease in humus content was slightly lower in the 10–15 cm layer of arable soil – 27.3 %, in the 15–20 cm layer – 29.6 %, and in the 20–25 cm layer –24.0 %. In the lower horizons of the arable layer (25–30 cm), the humus content decreased by 9.5 % compared to the virgin soil. Consequently, the humus content in the upper horizons of the arable layer decreased by almost half, and in the lower horizons by more than a quarter over the period of long-term cultivation.

Soil structure is a set of peds of different sizes, shapes, porosity, mechanical strength and water resistance, which is characteristic of each soil and individual genetic horizons. From an agronomic point of view, a structured soil consists of peds with a size of 0.25–10 mm. Structured soil creates more favourable conditions for plant growth and development, which leads to high yields of crops. The structure of the topsoil is considered optimal if the content of structural particles is 60–80 %. Such soil possesses higher erosion resistance and water resistance.

Plants with a well-developed root system and above-ground parts that cover the soil throughout the year and do not require mechanical cultivation during the growing season have the greatest positive impact on the structural state of the soil, as observed in virgin lands. A significant amount of plant mass accumulates on virgin soil, while in herbaceous vegetation the root mass exceeds the aboveground mass of plants. In our experiment on an area of uncultivated virgin steppe, the root mass of the total plant biomass was on average 59 %, while the aboveground part was 41 %. On virgin chernozems, the surface layer, saturated with plant residues with high humus content, is a biologically active layer where humus formation, decomposition and mineralisation of fresh organic matter take place. These processes ensure the reproduction of the potential and effective fertility of these chernozems.

Virgin vegetation has a greater structuring effect on the soil than annual crops, which have a significant part of their biomass alienated with the harvest and not returned into the soil. In addition, the root and crop residues of most annual crops contain a significant amount of fibre during their maturation, which is unsuitable for humus formation, and they have a lower root system density compared to the natural cenosis of virgin lands. Low root system density in the soil profile is formed by both row crops and close-growing crops, for example, winter wheat with a low humus accumulation capacity of the roots. We found that winter wheat with a grain yield of 4.0 t/ha has an aboveground mass of 6.5 t/ha, and an underground mass of no more than 3–4 t/ha. As a result, the root system of crops, after dying off, forms significantly less humus substances in the soil than the root system of natural cenosis on virgin lands.

By the dry sieving method, it was established that the upper layers (0–5 and 5–10 cm) of the virgin soil structure are characterised by a rather high content of particles of agronomically valuable fraction of 10–0.25 mm. In these layers, they accounted for 84.3 and 82.2 %; in the 10–15 and 15–20 cm horizon, 75.1 %; in the 20–25 cm layer, 72.9 %; and in the 25–30 cm layer, 70.6 %. We found that the indicators of the agronomically valuable fraction in the 0–30 cm layer of arable soil were negatively affected. The share of valuable peds in the 0–5 cm layer of arable soil was 69.9 %, in the 5–10 and 10–15 cm soil layer – 70.0 % and 68.6 %, respectively. Consequently, the number of particles in the agronomically valuable fraction of the soil in these soil layers decreased compared to virgin soil by 14.4, 12.2 and 6.5 %, respectively. This indicator decreased by 5.2–6.1 % in the lower layers of the arable horizon (20–30 cm), and by 2.9–5.5 % in the subsoil layer.

This means that long-term cultivation had a negative effect on the soil and changed the aggregate composition of other fractions, especially in the upper soil layers. So, in the soil layer of 0–5 cm and 5–10 cm, the lumpy fraction on arable land was 23.3 and 25.3 %, which exceeded the virgin soil by 9.9 and 8.6 %, respectively. With depth, the content of the lumpy fraction slightly increased compared to virgin soil, but this difference was insignificant. The difference was 4.0 and 4.8 % in the 10–15 and 15–20 cm soil layers, respectively. In the soil layer of 20–25 cm and 25–30 cm, the difference on arable land compared to virgin soil was 4.8 and 5.4 %. The content of the lumpy fraction increased up to a depth of 100 cm, and then indicators were practically similar.

The analysis of virgin soil by silt content (soil particles with a diameter of less than 0.25 cm) showed that the silt content in the 0–5 cm layer was 2.3 %, in the 5–10 cm horizon –1.1 %, and in the 10–15 cm layer –1.9 %. In the 15–20 cm and 25–30 cm soil layers, this indicator was 1.3

and 1.4 %, respectively. In deeper soil layers (up to 70 cm), the silt content varied between 1.5 and 1.7 %, and from a depth of 70 and up to 150 cm – from 1.9 to 2.5 %. Intensive tillage significantly increased the proportion of silt in the 0–5 cm layer. Silt content increased almost three times (6.8 %), and in the 5–10 cm and 10–15 cm layers – 4.7 % and 4.4 %, respectively. Silt fraction in arable soil at a depth of 30–40 cm is almost equal to its quantitative indica-tors in virgin soil.

Soil pedality coefficient is a critical indicator, which describes the ratio of agronomically valuable fraction to the sum of the indicators of the lumpy and silty parts of the soil.

The soil pedality coefficient in the 0–5 and 5–10 cm soil layers of virgin soil was 5.37 and 4.62, and in arable soil –2.32 and 2.33, respectively. This indicator on virgin soil in the 10–15, 15–20 and 25–30 cm soil layers was 3.02 and 2.40, and on arable land –2.18, 2.10 and 1.82, respectively. In the deeper soil layers (30–100 cm), the soil pedality coefficient varied from 1.67 to 1.88 on virgin soil, and from 1.36 to 1.62 on arable land. The decrease in this coefficient was due to an increase in the lumpy and silty fractions.

The research proved that virgin soil has an excellent structural state throughout the two-metre profile, while long-term agricultural exploitation worsens this state. This is clearly seen in the change in soil pedality coefficients, especially in the 60–80 cm soil layer. The significant increase in the number of micro-peds can be explained by the intensive crushing of soil peds during tillage, a decrease in the organic matter content in the soil (the main structure-building agent), which eventually leads to the degradation of large particles and an increase in the silty fraction.

Soil density is one of the critical indicators of agrophysical properties of soil, which describes the ratio of solid to gaseous parts. Heavy agricultural machinery compact the soil, limiting the space between soil particles. Plant roots in compacted soil are usually located in the top layer and do not penetrate deeper into the layers containing a significant portion of productive moisture, and this negatively affects the future yield. The bulk density as the main indicator of the level of looseness or compaction depends on the mechanical composition, organic matter content, and is interrelated with the soil structure. Soil density is significantly reduced under the favourable conditions for the formation of agronomically valuable structural peds, which was observed on virgin soil [6, 7, 9].

Our research results showed that lower soil density values were typical for virgin soil. The density in the 0–5 cm soil layer was 0.73 g/cm^3, and in the 5–10, 10–15 and 15–20 cm soil layers it was 0.85, 0.87 and 0.22 g/cm^3, respectively. Under the current system of primary tillage and long-term soil exploitation, the arable soil density in the 0–5 cm horizon was 0.88 g/cm^3, and in the 5–10 and 10–15 cm soil layers it was 0.95 and 0.96 g/cm^3, respectively. With this arable land exploitation, the density in the 0–5, 5–10 and 10–15 and 15–20 cm soil layers increased by 20.5, 11.8 and 10.3 and 7.6 %, respectively. In the deeper soil layers of 20–25, 25–30 and 30–40 cm, the compaction increased from 5.3 to 8.2 %. At the depth of 40–50 cm, the density indicators level-led out and became close to the level of virgin soil.

The increase in soil density on cultivated plots in comparison with virgin soil can be explained by a decrease in humus content and the effects of heavy agricultural machinery, which significantly compact the subsoil layers throughout the soil profile. It should be emphasised that arable land remains in a loose state, i.e. close to virgin soil compaction, for no more than two months. For the rest of the year (at least 10 months), the arable land is over-compacted. This means that the arable land cannot be less compacted to the level that is recorded in the natural state of virgin soil.

When comparing the water resistance of ordinary virgin chernozem and arable land, it was found that the water resistance on virgin land is mostly more than 50 %, and the water resistance coefficient is 0.5–0.7, while on arable land it is only 0.2–0.5. Long-term soil cultivation reduces the number of water-resistant peds of 1–3 mm, i.e. disperses the soil structure. Under the current farming technologies, the water resistance of arable soils is deteriorating, and the main reasons for this are excessive mechanical tillage and a deficient balance of organic matter. Consequently, minimising tillage and improving the humus balance are the critical measures to maintain water resistance.

The analysis of ordinary chernozems in terms of agrophysical properties and humus content after intensive and long-term agricultural exploitation shows their significant degradation in all indicators compared to virgin soils, which causes a significant difference between ordinary chernozems on virgin soils and arable land. Ploughing up virgin chernozems with their subsequent agricultural exploitation leads to a shift in the equilibrium towards mineralisation of soil organic matter. At the same time, the fresh organic matter input to the soil decreases in agrocenosis due to the alienation of a significant part of organic matter with the harvest. As a result, the continuous and annual sustainable supply of organic residues to the soil on virgin lands is replaced by insufficient and unbalanced supply on arable lands. When virgin lands are ploughed up, humus losses occur primarily due to the most mobile humus substances, which are weakly bound to the mineral part of the soil, and detritus, which is a weakly humified organic residue.

On virgin soil, on the contrary, all organic substances contained in the vegetative organs of plants and their roots remain in the soil and form new humus substances, which increase the total humus content. And the following growing season, part of the humus is used to form the biomass of the natural biocenosis again, so the humus content on virgin lands is balanced.

The evolution of ordinary chernozems, the rate and direction of changes in agrophysical parameters are closely related to farming systems. Continued low farming practices, accompanied by low humus content in ordinary chernozems, will lead to a further increase in their density and deterioration of the structural and aggregate state due to an increase in the number of lumpy and silty soil fractions. This negative humus balance is the result of extremely low application of organic fertilisers in recent years.

Further development of physical degradation of ordinary chernozem on arable land should be prevented by avoiding overcompaction and destruction of the soil structure. To achieve this, we need to implement high-standard farming practices, create a deficit-free humus balance and biophilic mineral nutrients, minimise mechanical stress on the soil, and implement zonal crop rotations. Simultaneously, the burning of stubble after harvesting grain crops should be completely banned, and mulch should be mandatory on the soil surface, as well as perennial legumes and green manure pairs should be introduced into the crop rotation. All of the above agricultural measures have long been known, but for various reasons they are not used in agricultural production.

Conclusions. According to the results of the research, it was found that the humus content and its agrophysical properties significantly degrade after long-term exploitation of ordinary chernozems in the agricultural sector and negatively affect the crop productivity compared to virgin lands.

The deterioration of soil agrophysical indicators results from the non-compliance of traditional agrotechnical practices with modern requirements. To preserve and sustainably utilise arable chernozems in Ukraine, an improved farming system should be implemented with the main components being an adapted structure of sown areas, scientifically based crop rotations, the latest soil protection technologies, and rational application of organic and mineral fertilisers. Soil compaction is reduced by using tracked vehicles and the combined use of combined machines and aggregates to minimise tillage and combine several technological operations.

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Актуальність обумовлена необхідністю вирішення проблеми втрати ґрунтом гумусу і погіршення агрофізичних властивостей ґрунту, зменшення впливу агрофізичної деградації ґрунтів, відновлення і збереження родючості. **Мета** проведення порівняння агрофізчних показників та вмісту гумусу в ґрунті цілини та орних земель і розробці наукових рекомендацій щодо формування сприятливих агрофізичних властивостей і режимів чорноземних ґрунтів з метою призупинення розвитку в них деградаційних процесів і збереження родючості. **Матеріал та методи.** Дослідження чорнозему звичайного проводили в цілинному ґрунті та у ґрунті дослідних ділянок Ерастівської дослідної станції ДУ Інститут зернових культур НААН України впродовж 2010–2016 рр. Досліджували: вміст загального гумусу; структурно-агрегатний склад ґрунту; коефіцієнт структурності ґрунту; щільність складення ґрунту; водостійкість агрономічно-цінних структурних агрегатів. Зразки ґрунту відбирали у травні при рівноважній щільності після механічних обробітків. Відбір проводили з ґрунтового профілю через кожні 5 см, на глибину 0–200 см в чотирикратній повторності згідно з ДСТУ 4287. **Результати.** Встановлено, що внаслідок довготривалої експлуатації чорнозему звичайного відбувається погіршення агрофізичних властивостей (структурно-агрегатний стан, щільність, водостійкість) та зменшується вміст гумусу і потужність гумусного горизонту порівняно з цілиною. **Висновки.** Порівняння властивостей чорнозему звичайного орних земель з цілиною свідчить про їх суттєву деградацію. Із значною втратою гумусу і руйнуванням структури зростає щільність, частково втрачається здатність протистояти деградації. Для збереження та сталого використання орних чорноземів слід впроваджувати удосконалену систему землеробства, основними складовими якої є науково обґрунтовані сівозміни, новітні ґрунтозахисні технології, необхідний обсяг внесення органічних і мінеральних добрив з метою підвищення вмісту гумусу.

Ключові слова: *чорнозем звичайний, деградація ґрунту, вміст гумусу, структурно-агрегатний стан, щільність, водостійкість*