

DEHUMIDIFICATION OF THE ORDINARY CHERNOZEM IN THE CONDITIONS OF THE STEPPE ZONE OF UKRAINE

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Topicality. This study is relevant due to the need to address the problem of intensifying the negative impact of intensive agricultural activities on the zonal soil subtype of ordinary chernozem. In the northern sub-zone of the Steppe of Ukraine, the ordinary chernozem undergoes significant changes in all agrochemical parameters, especially in its humus content, due to the long-term impact of anthropogenic factors. **Purpose.** The research is aimed at generalising the research on the historical development of chernozems, assessing changes in the humus content of ordinary chernozem under the long-term influence of anthropogenic factors, comparing its content in the soil with virgin plots, and developing scientific recommendations for agrochemical methods of preserving soil fertility and stopping the loss of humus. **Material and Methods.** Long-term studies were conducted at the main experimental facilities of the SE Institute of Grain Crops of NAAS of Ukraine - Erastivska Research Station and the Educational and Research Centre of Dnipro State Agrarian and Economic University. Analytical studies of the selected soil samples were carried out according to standardised methods at the Dnipro branch of the Soil Protection Institute of Ukraine. Studies to determine soil quality and organic matter content were carried out in accordance with DSTU 4289:2004. **Results.** The studies have convincingly shown that the most significant changes in humus content were observed in the 0–5 cm layer – 8.25 % on virgin soil and 4.2 % on arable land, i.e. the difference between them was 4.05 %. The virgin soil significantly exceeded the arable land in terms of humus content up to a depth of 0–60 cm, and only from a depth of 60–65 cm and deeper did the humus content of the arable land begin to exceed the virgin soil. The increase in humus content from a depth of 60 cm on arable land is explained by the formation of labile humus, which migrated to the lower subsoil layer together with precipitation. **Conclusions.** The results of the research have shown that long-term ploughing of chernozem soils and their intensive use in agricultural production not only leads to the development of dehumification processes, but also contributes to alkalisation of the arable layer of soil as a result of the rise and concentration of calcium and magnesium hydrocarbons in soil. Forecasts of the humus balance indicate that to fully compensate for its losses from mineralisation in the current structure of agricultural areas in the Steppe zone of Ukraine, it is necessary to apply annually semi-rotted manure at a rate of 8.0 t/ha.

Key words: dehumification, humus, nutrient migration, humus balance, virgin soil, arable soil

Introduction. Chernozem soils occupy 393.6 million hectares or 2.4 % of the global soil area [1, 2]. The term "chernozem" was included without translation in the World Reference Base for Soil Resources (WRB) (1998) and the FAO-UNESCO Soil Map of the World (SMW) (1997). Ukrainian chernozems rank first

in the world, with 26 million 566 thousand hectares (44 % of the total area of Ukraine), or 6.7 % of the global chernozem reserves, and the agricultural land area with chernozem soils is 23 million 198 thousand hectares, or 5.9 % of the global chernozem area [1, 3]. In the northern subzone of the Steppe, the main genetic group of

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soils is ordinary chernozem [1, 2, 4], which occupies an area of 9,157,700 ha, which is 81.1 % of the total area, including 7,902,500 ha (90 %) of arable land.

Ordinary chernozem is a zonal sub-type of soil in the Steppe zone and the most developed soil [1, 5].

Before the research of V. V. Dokuchaev, the chernozems were studied by Kharkiv scientists, professors N. D. Borysiak and I. F. Levakovskiy. In his paper "On chernozem" (1852), Borysiak substantiated the terrestrial-plant origin of chernozems, described the properties of chernozems and ways of using them. A significant contribution to the study of chernozems in Galicia and Podillia was made by Austrian scientist L. Buber in his book "Galician-Podillia chernozems, their origin and natural structure, as well as modern agricultural conditions of exploitation in the North-Eastern zone of Galicia" (1910)[5].

Under the impact of long-term anthropogenic factors, chernozem soils have undergone significant changes [2, 6, 7]. A close correlation exists between humus content and crop yields. Humus content has an indirect effect on crop yields, but ultimately this dependence is very high ($r = 0.85-0.91$) [2, 4]. Humus is an organic substance of a complex chemical nature with a significant content of humic acids, among which soluble fulvic acids predominate, bound mainly to calcium, which gives stability and high absorption capacity [1, 5]. Humus is distributed evenly in the profile, gradually decreasing to the bottom of the soil horizon and reaching a depth of 60–80 cm [1, 8, 4, 5]. There are about 3.5 million living organisms in 1 g of chernozem, and 55 million in 1 g of humus [5]. The most powerful chernozem contains less than 0.5 % of living organisms, and the organic matter (humus) – less than 8–10 %, the rest is mineral mass [1, 4, 5]. According to V. I. Vernadskiy, soil is a combination of living and nonliving organisms, i.e. a bioinert natural body [5].

Over the past 130 years, chernozems have lost almost 30 % of their humus [8]. It should be noted that the soil dehumidification is a consequence of human activity [2, 6, 7]. This is primarily due to the fact that the development of agriculture in Ukraine is characterised by significant changes within a historically short period of time. Only 7% of agricultural land is

used for fodder crops, which is due to the decline in livestock production. Currently, a sharp decline in the application of organic fertilisers has resulted in a negative humus balance in chernozem soils of Ukraine.

The most important parameters that characterise the soil cover are the humus content, which determines the physical, chemical, physicochemical, biological properties of the soil and the level of moisture availability and mineral nutrition of plants [3]. Among the 13 types of degradation processes, dehumification is the most important and global process [2]. It is relevant to note here that a significant part of soil degradations are directly or indirectly caused by a decrease of humus content [8]. Significant losses of humus in the 60s and 80s of the last century reached 0.55–0.60 t/ha that were caused by a significant expansion of row crops. Today, the actual humus content in the chernozems of the Northern Steppe is 3.5 %, while the norm is 4.3 %. A humus content of 3.0–3.5 % is considered critical, which is an environmentally hazardous condition [9]. The annual loss of humus in the chernozems of the Steppe of Ukraine averages 0.5 t/ha. Changes in the humus content in arable land can be monitored only by comparing it to its virgin counterpart. In Ukraine, chernozems have been preserved in their virgin state only in nature reserves: Michael's Virgin Land Nature Reserve in Sumy region, Khomutivskiy Steppe Nature Reserve in Donetsk region, Striltsivskiy Steppe Nature Reserve in Luhansk region, and Kamiana Mohyla Nature Reserve in Zaporizhzhia region, as well as in the Kasova Mountain Nature Reserve in Ivano-Frankivsk region [2, 5]. Ordinary chernozem in virgin condition, which was used for scientific research, has been preserved on an area of 5.0 ha at the Erastivska Research Station of the State Enterprise Institute of Grain Crops of NAAS of Ukraine near the Baikivka village, Piatykhatky district, Dnipropetrovsk region. The unsustainable utilisation of chernozems in agriculture is a matter of considerable concern and alarm [10, 11, 12, 13]. These circumstances have prompted scientific research because dehumification processes have covered the entire chernozem zone of Ukraine.

The research is aimed at summarising long-term scientific studies on the historical development of ordinary chernozem, as well as at

assessing the changes in humus content in the ordinary chernozems under the constant anthropogenic influence, comparing the humus content in the arable and virgin soils. In order to prevent soil dehumidification, scientific recommendations on agrochemical methods of soil fertility preservation should be developed.

Materials and Methods. The research was carried out at the Erastivska Research Station (the experimental base of the SE Institute of Grain Crops of NAAS of Ukraine) in 2013–2015, and at the Educational and Research Centre of Dnipro State Agrarian and Economic University in 2016–2018. The soil cover is ordinary low-humus, heavy loamy chernozem on loess. In the topsoil, the humus content was 3.8–4.1 % (Tyurin method), gross nitrogen was 0.22–0.23, phosphorus was 0.12–0.13, and potassium was 2.0–2.3 %. After seven days of composting, the level of nitrate nitrogen varied from 31 to 52 mg/kg of soil, mobile phosphorus (according to Chirikov) – 110–112 mg/kg, exchangeable potassium – 105–130 mg/kg. The soil solution has neutral reaction (pH 7.0–7.2). The absorption capacity is 30–35 mg-eq. per 100 g of soil. Calcium dominates in the composition of the soil matrix [14]. Analytical studies of the selected soil samples were carried out according to standardised methods at the Dnipro branch of the Soil Protection Institute of Ukraine.

To study changes in ordinary chernozems under the influence of long-term anthropogenic factors, two soil transects were made: the first one was on a virgin plot near the Baikivka village of Piatykhatky district of Dnipropetrovsk region, and the second one was on arable land at a distance of 300 m from the first one. On the ground, the two soil profile cuts were positioned so that the front wall of the pit was fully illuminated by the sun at the time of the description. Starting from the top of the cuts, we took soil samples every 5 cm to a depth of two metres. Layered sampling of soil in the soil profile cut eliminates the contaminating soil particles from adjacent horizons that can happen when sampling is carried out with a drill. In the selected samples, the humus content was determined by the Tyurin method in the modification of Simakov [15], and labile humus according to DSTU 4732:2007 [16]. The pH of the water extract was determined by the

potentiometric method. All analyses were performed in triplicate. According to the method of M. Z. Stankov, the root system in the soil profile of the ordinary chernozem on arable land and virgin plots was washed out.

Results and Discussion. Our research has confirmed the large and multifaceted role of humus in the soil formation process, as humus availability is the main indicator of natural soil fertility.

During the vital activity of plants and microorganisms, we observed changes in soil composition under the influence of their exudates and secreted enzymes, such as humus mineralisation and mobilisation of mineral nutrients, which are converted into available forms for plants and accumulate in topsoil. The sharp decline in organic fertiliser application, and in particular semi-rotted manure, has led to intensive dehumidification in this soil. The stability of soil fertility is highly dependent on the dynamic balance between the humification and mineralisation of organic matter. In virgin soil formation, humification prevails over mineralisation, and over time, there is a gradual accumulation of soil organic matter, the content of which stabilises under certain conditions. Excess mineralisation over humus formation results in dehumidification of the soil profile. Under herbaceous vegetation, the main source of humus formation is roots, the root biomass in the one-metre layer in steppe phytocoenoses reaches 13–14 t/ha, therefore, there is no problem with dehumidification on virgin soil.

According to our research, the above-ground vegetation mass in the virgin land is unstable and varies in a wide range from 1.8 to 5.2 t/ha. The average indicator of dry matter is 3.3 t/ha. Above-ground biomass accounts for 20 % of the total plant biomass, and underground biomass for 80 %. The total biomass reserves of the virgin soil are 15.0–16.6 t/ha. The rapid decomposition of the litter results in the formation of a significant amount of humus, which is not washed away but accumulates in the soil.

It is worth noting the sharp difference in the amount of organic matter reaching the soil between virgin and arable land. Virgin and arable ordinary chernozems differ significantly

in terms of annual phytomass production. If ordinary chernozem is used in a grain-row crop rotation, against the background of average fertiliser rates, the total annual growth of phytomass decreases to 13 t/ha, of which 10 t/ha is aboveground and 3.0 t/ha is underground biomass. Thus, with agricultural utilisation of soils, the annual increase in total biomass is reduced by more than 2.0 t/ha compared to virgin soils. In virgin soils, these processes are balanced and the humus content is quite stable.

The deficit of organic matter occurs after the involvement of soils in agricultural production. The main reasons for this phenomenon are as follows: alienation of a significant part of the phytomass of crops, resulting in a lower level of humification (with the current structure of sown areas, 65–70 % of organic matter is taken from the field with the

main and by-products); intensification of mineralisation processes and other losses of organic matter due to erosion caused by soil loosening, when the field surface is left without vegetation cover for a long time. The second reason is the saturation of crop rotation with row crops, especially sunflower and maize, which negatively affects the cycle of organic matter and leads to an imbalance in the processes of synthesis and decomposition towards the latter.

This fact was confirmed by a comparative assessment of the humus content in soil samples taken in soil cut on virgin land and arable land, which convincingly showed that the most significant changes in humus content were observed in the 0–5 cm layer – 8.25 % in virgin soil and 4.2 % in arable soil, i.e. the difference was 4.05 % (Fig. 1).

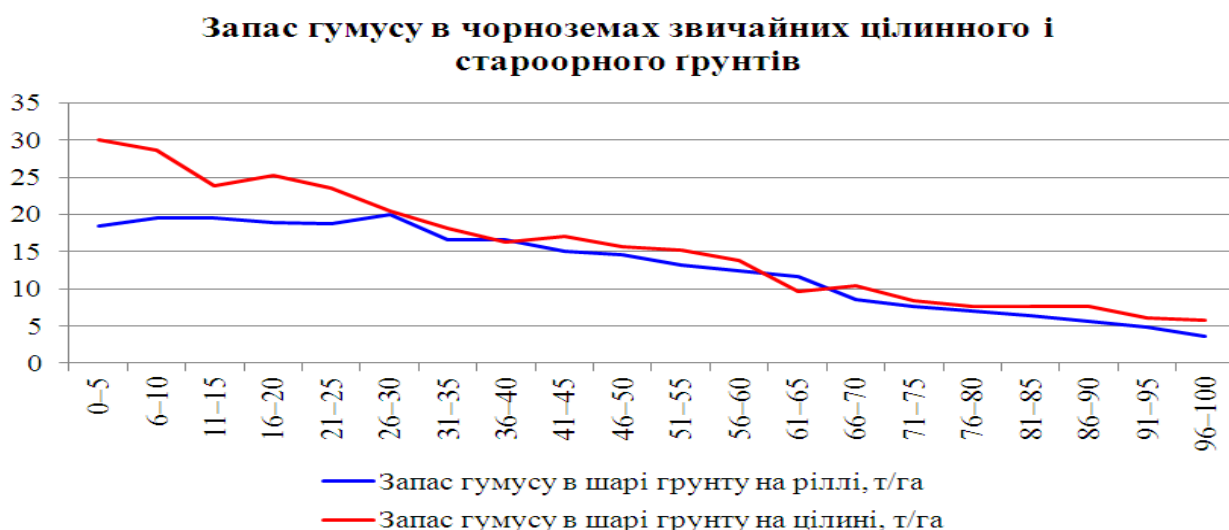


Fig. 1. Humus reserves in the ordinary chernozems of the virgin and arable lands

Humus content in the virgin soil up to a depth of 0–60 cm significantly exceeded the arable land, and only from a depth of 60–65 cm and deeper, humus content in the arable land begin to exceed the virgin soil. The increase in soil humus content on arable land starting from a depth of 60 cm can be explained by the formation of labile humus.

The labile component of the soil undoubtedly plays an important role in plant nutrition, being the primary source of nitrogen nutrition. However, on arable land, labile humus migrates from the upper layers to the lower layers with atmospheric precipitation moisture, where it remains preserved for a long time, as

the activity of aerobic microorganisms is minimised in its deeper layers, so there is no humus mineralisation at this depth.

Layer-by-layer determination of humus reserves (t/ha) on virgin land and arable land showed a significant difference (Fig. 2) in advantage of virgin land. Since humus is formed from plant decomposition products, its reproduction should be carried out by replenishing it with sufficient organic matter and preventing further decline in its content. The forecast of the humus balance shows that in order to fully compensate for the humus losses due to mineralisation under the current structure of sown areas in the Steppe zone of Ukraine, an

annual introduction of semi-rotted cattle manure at a dose of 8.0 t/ha is required.

The topsoil of ordinary chernozems is negatively affected not only by dehumification, but also by global climate warming. The rise in atmospheric temperature against the background of insignificant precipitation results in increased aridity and moisture evaporation from the soil surface, which causes the migration of calcium and magnesium hydrocarbons from the lower soil layers to the upper ones. The consequence of these processes is an increase in alkalinisation of topsoil of arable soil in relation to virgin soil. The higher humus content and greater soil absorption capacity of virgin soil contributes to insignificant moisture evaporation, and therefore,

there is no significant transfer of two alkaline earth hydrocarbons from the lower layers to the upper layers, as is the case on arable land. A comparative assessment of the soil solution reaction on virgin and arable soil showed alkalinisation of topsoil on arable land compared to virgin soil due to hydrocarbonates from the lower layers (Fig. 2). Calcium and magnesium hydrocarbonates removed from the lower layers and concentrated in the topsoil of arable land interact chemically with dihydrogen phosphates $H_2PO_4^-$ and trace metals Cu^{2+} , Zn^{2+} cations, etc., chemically binding them into poorly soluble compounds and reducing the availability of these nutrients for plants.

In this case, the alkalinisation of the topsoil

Порівняльна оцінка реакції ґрунтового розчину в чорноземах звичайних цілинного і староорного ґрунтів

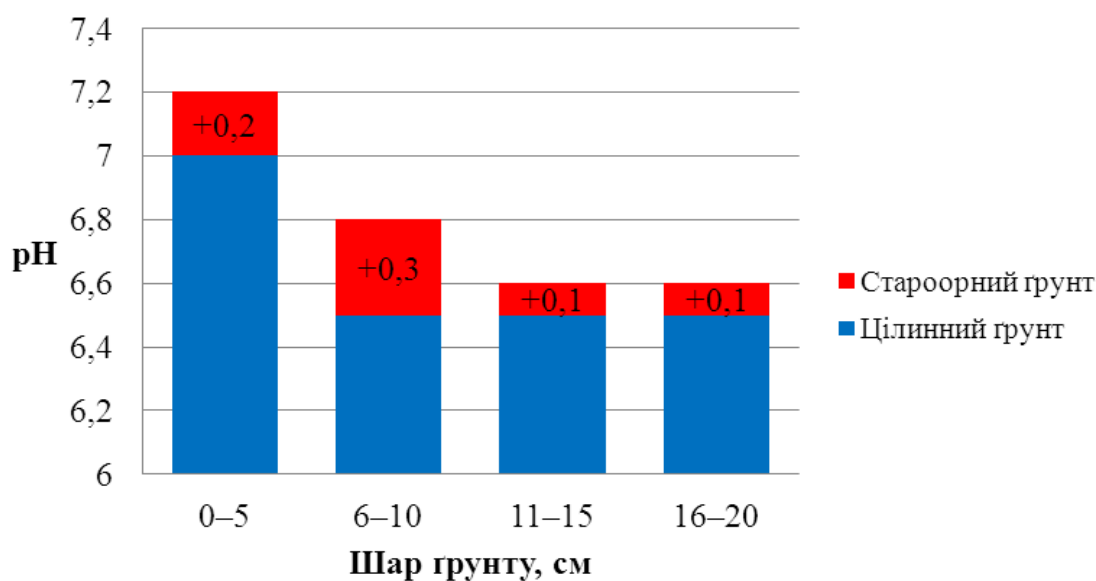


Fig. 2. Comparative diagram of alkalinisation of the topsoil of ordinary chernozem on arable land and virgin land.

on arable land compared to virgin land is a consequence of the intensive development of dehumification processes, which result in the intensity of productive moisture evaporation from the soil and the removal of calcium and magnesium hydrocarbons from the lower to the upper soil layers.

Conclusions. Thus, our research has shown that long-term ploughing of chernozem soils and their intensive exploitation in agricul-

tural production not only leads to the development of dehumification processes, but also contributes to the alkalinisation of the topsoil. The calculation of the humus balance shows that to fully compensate for its losses from mineralisation under the current structure of sown areas in the Steppe zone of Ukraine, the annual application of 8.0 t/ha of semi-rotted cattle manure is required.

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Крамарьов С. М.¹, Бандура Л. П.¹, Зайцева І. О.¹, Крамарьов О. С.² Дегуміфікація чорнозему звичайного в умовах степової зони України. Зернові культури 2023.7 (2). 322–328.

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Актуальність обумовлена необхідністю вирішення проблеми активізації негативного впливу у результаті інтенсивної виробничої діяльності у аграрній сфері на зональний підтип ґрунту чорнозем звичайний. У північній підзоні Степу України у чорноземі звичайному під впливом тривалої дії на

нього антропогенного чинника спостерігаються суттєві зміни за всіма агрохімічними показниками, особливо за вмістом в ньому гумусу. **Мета.** Узагальнити дослідження вивчення чорноземів у історичному розвитку, надати оцінку змін вмісту гумусу, які відбулися в чорноземі звичайному під дією тривалого впливу антропогенного чинника, шляхом порівняння його вмісту в ґрунті порівняно з цілиними ділянками та розробка наукових рекомендацій щодо проведення агрохімічних заходів збереження родючості ґрунту і призупинення втрати гумусу. **Матеріали та методи.** Багаторічні дослідження проводили на експериментальній базі ДУ Інституту зернових культур НААН України – Ерастівській дослідній станції і навчально-науковому центрі Дніпровського державного аграрно-економічного університету. Аналітичні дослідження відібраних зразків ґрунту виконувались за стандартизованими методиками в Дніпровській філії ДУ Інститут охорони ґрунтів України. Дослідження по визначенню якості ґрунту та вмісту органічних речовин проводилися згідно з ДСТУ 4289:2004. **Результати.** Виконані дослідження переконливо показали: найсуттєвіші зміни вмісту гумусу спостерігалися в шарі 0–5 см – 8,25 % на цілині і 4,2 % – на ріллі, тобто різниця між ними становила 4,05 %. До глибини 0–60 см за вмістом гумусу цілинна ділянка суттєво переважала ріллю і лише розпочинаючи з глибини 60–65 см і глибше вміст гумусу в ґрунті ріллі почав переважати цілинну ділянку. Зростання вмісту гумусу на ріллі розпочинаючи з глибини 60 см пояснюється формуванням в ній лабільного гумусу, який разом з атмосферними опадами мігрував в нижній підорний шар ґрунту. **Висновки.** Встановлено, що тривале розорювання чорноземних ґрунтів і інтенсивне їх використання в сільськогосподарському виробництві призводить не тільки до розвитку в них дегуміфікаційних процесів, а й сприяє підлугуванню орного шару ґрунту, викликаного підняттям і концентрацією в них гідрокарбонатів кальцію та магнію. Розрахунок прогнозу балансу гумусу свідчать, що для повного відшкодування його втрат від мінералізації, при сучасній структурі посівних площ в степовій зоні України необхідне щорічне внесення напівперепрілого гною дозою 8,0 т/га.

Ключові слова: дегуміфікація, гумус, міграція поживних речовин, баланс гумусу, цілина, рілля