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Labile organic matter and fertility of chernozems

Abstract. Soil organic matter can be divided into stable and labile, with the latter directly supporting plant growth and development during the growing season. To restore soil fertility and ensure high productivity of agrocenoses, a certain ratio between the labile and stable parts of humus must be maintained. The purpose of this study was to determine the content of labile organic matter under different tillage and fertilisation options and to establish the optimal ratio between their content and the content of total carbon, based on which to develop measures to restore and improve the fertility of chernozem soils. In stationary experiments, the study investigated the impact of the intensity of chernozem use, its cultivation and fertilisation systems on the humus state of the amount of labile organic matter and its ratio to humus carbon. Field research, laboratory method of soil sample analysis, systematisation, analysis, and generalisation were used in the study. The soil

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samples were analysed for humus content according to DSTU 4289:2004 and labile organic matter content according to DSTU 4732:2007. When chernozems are ploughed up, labile organic matter is mineralised the most and their share in humus decreases, while when arable land is converted to fallow land, it is restored the fastest. Minimising tillage systems and applying organic and mineral fertilisers increases the amount of labile organic matter in the humus of chernozems. The use of no-till for sixteen years resulted in a 0.13% increase in humus content, and a 0.53% increase over forty-two years compared to ploughing. The application of organo-mineral fertiliser increased the ratio of labile organic matter carbon content to total carbon content compared to the unfertilised variants. A strong correlation was found between the content of labile organic matter in chernozems and the yield of winter wheat and maize. The practical significance of the research results is to minimise the fertiliser rate and the C:N ratio to ensure gross crop yields and restore soil fertility

Keywords: humus; mineralisation; humification; winter wheat; maize

INTRODUCTION

Understanding the essence of fertility and the factors that have the greatest impact on crop yields and cenosis productivity will help determine land quality more accurately and allow developing measures to restore and improve fertility. One of these factors will be the content and reserves of humus in the root or half-metre layer of soil, which provides 80-85% of crop yields (Zabaluev *et al.*, 2020). Humus is called an integral indicator of fertility because it affects most soil properties, especially chernozems, regulates and coordinates the processes on which their fertility depends, and determines the level of crop productivity for a long period (Volkogon *et al.*, 2019; Oldfield *et al.*, 2019; Rattan, 2020).

Many authors note the ongoing dehumification of agricultural land and provide evidence of a decline in the humus content of Ukrainian soils, especially chernozem (Litvinova *et al.*, 2019; Balyuk *et al.*, 2023). According to S. Balyuk *et al.* (2023), humus losses are observed on 43% of arable land at an average rate of 620 kg/ha, and this process has been ongoing for decades. M. Mayer *et al.* (2022) indicate that agricultural use has led to substantial losses of soil organic matter, accompanied by increased CO_2 emissions and reduced soil fertility. That is why, in view of global warming, it is necessary to ensure the sustainable development of agroecosystems.

Humus is a multicomponent organic substance that includes dozens of soil-specific and non-specific compounds that have different transformation capacities during the growing season, including resistance to mineralisation. Humus substances are divided into stable and labile on this basis. Some authors (Volkogon *et al.*, 2018) believe that labile organic matter is associated with the microbiological regime of the soil and due to their mineralisation, plants can consume macro- and microelements released from them. Furthermore, they contain enzymes and plant growth stimulants, which also contribute to crop productivity.

Labile organic matter acts as the closest reserve of micronutrient nutrition, determining the content and dynamics of mobile forms of trace elements. Co, Cu, Fe can be actively released from them and transferred to the soil solution, while Mn and Zn are subject to fixation. The positive effect of fertilisation on the humus state of organic systems is reported in M. Chen *et al.* (2022). The issues of regulating the content of labile organic matter and humus have been investigated and discussed in scientific sources by Ukrainian and foreign researchers (Volkogon *et al.*, 2019; Yang *et al.*, 2019).

Stable organic matter provides soils with such characteristics as structural and water-physical properties, indicators of the soil-absorbing complex, buffering capacity, humus group composition, carbon, nitrogen, phosphorus, and sulphur reserves (Demydenko, 2019; Rattan, 2020). Therewith, J. Zhou *et al.* (2021) point out that the supply of labile carbon to the soil can accelerate the decomposition of soil organic matter, as well as cause changes in the dynamics of soil organic matter, changing the direction and intensity of humus formation. Therefore, the carbon balance depends on both the amount and frequency of labile carbon input. They conclude that the supply of labile organic matter in large quantities can lead to intensive decomposition of soil organic matter.

Potentially mineralised C represented the largest labile C pool, while microbial N biomass was the largest labile N pool. As for the rate of carbon and nitrogen mineralisation, they were oppositely distributed over the seasons. The authors also conclude that it is important to achieve zero soil degradation based on a detailed investigation of organic matter (Koković *et al*., 2021)

The purpose of this study was to investigate labile organic substances, establish their relationship and optimal correlation with total soil carbon and crop productivity, and develop methods for regulating their amount in the soil to restore and improve the fertility of chernozems.

MATERIALS AND METHODS

The study was conducted in long-term stationary experiments in 2017-2022, which investigated the impact of the intensity of use of chernozem soils, different tillage systems and fertilisation on the content of humus and labile organic matter, their correlation and relationship with crop productivity. The virgin chernozem of the Mykhailivska Tsilyna Reserve was chosen as a reference, where organic matter transformation processes contribute to maintaining a high level of soil humus with an optimal content of labile organic matter. The amount of labile substances and their share in chernozem humus were investigated on virgin plots and fallow land, which served as models of natural self-regulation of humus formation and humus accumulation.

In a stationary experiment at the Separate Subdivision of the National University of Life and Environmental Sciences of Ukraine "O.V. Muzychenko Velykosnitynske Educational and Research Farm" in Fastiv district, Kyiv region, the study investigated the impact of 16 years of use of different tillage and fertilisation systems on the humus and labile organic matter content, their correlation and relationship with crop productivity at the Drabivske Experimental Field of the Cherkasy Experimental Station of the Educational and Research Centre "Institute of Agriculture of the National Academy of Agrarian Sciences" over 42 years of use of different tillage and fertilisation systems. The fallow land options were taken as natural models of organic matter transformation and restoration of chernozem fertility. The experimental variants were replicated three times and randomised across replications. Short rotation crop rotations were used in the experiments.

A 16-year experiment in the Kyiv region at the Separate Subdivision of the National University of Life and Environmental Sciences of Ukraine "O.V. Muzychenko Velykosnitynske Educational and Research Farm" had the following crop rotation: soybeans, winter wheat, grain maize, barley, and at the Drabivske experimental field of the Cherkasy Experimental Station of the Educational and Research Centre "Institute of Agriculture of the National Academy of Agrarian Sciences" – perennial grasses, winter wheat, sugar beet, grain maize, barley with grasses.

Soil of the stationary experiment at the SS of the NULES of Ukraine "O.V. Muzychenko Velykosnitynske ERF" – a typical coarse-grained and light-loamy in the forest – was characterised by the following indicators: soil sericulture reaction was neutral, the amount of extracted cations was 35.4 mg-eq/100 g of soil, and the degree of saturation of cations was 93.4%.

In the multifactorial stationary experiment of the Cherkasy State Research Station of the ERC "Institute of Agriculture of NAAS" at the Drabivske experimental field, the soil of the experimental plot was typical low-humus light loamy chernozem.

Laboratory tests were carried out according to standardised methods. The humus content was determined according to DSTU 4289:2004 "Soil quality. Methods for determining organic matter" (2005); the content of labile organic matter (LOM) was determined according to DSTU 4732:2007 "Soil quality. Methods of determining available (labile) organic matter" (2008). The study was conducted per the requirements of the International Convention on Biological Diversity (1992).

RESULTS AND DISCUSSION

Soil functioning and fertility depend on environmental conditions, soil use, and crop cultivation techniques. They determine the intensity of soil formation processes, their focus on preserving and restoring soil fertility or on increasing degradation processes and loss of fertility. These factors also affect the integral indicator of chernozem fertility – the humus content of its upper layers. According to researchers (Dmytruk & Demid, 2019), it is the top 0-50 cm layer of soil that is crucial for the productive function of chernozems. This layer accounted for 80-85% of crop yields in the author's research. Bagherifam *et al*. (2023) emphasise that soil organic matter plays a key role in the environmental chemistry of macro- and micronutrients.

Table 1 shows the results of a study of the impact of different uses of typical chernozem in the Mykhailivska Tsilyna Reserve on the indicators of their humus state, namely the content of humus and labile organic matter.

Table 1. Content of humus and labile organic matter in typical chernozem under different uses in the Mykhailivska Tsilyna Reserve, %

Land	Layers of soil, cm	Organic substances					C_{lom}:C_{hum}
		Humus	C_{humus}	%, of absolute virgin soil	C_{los}	%, of absolute virgin soil	
Absolute virgin soil	0-20	8.79	5.36	100	0.63	100	11.7
	20-40	6.25	3.62	100	0.34	100	9.4
Mown virgin soil	0-20	7.79	4.51	84.1	0.51	81.0	11.3
	20-40	5.33	3.09	85.4	0.21	67.7	6.7
Fallow	0-20	7.29	4.23	79.0	0.33	52.4	7.8
	20-40	5.79	3.36	92.8	0.20	64.5	5.9
Arable land	0-20	5.62	3.25	60.6	0.15	17.5	4.6
	20-40	5.40	3.13	86.5	0.11	25.8	3.5

Note: C_{humus} – carbon content of humus, %; C_{lom} – carbon content of labile organic matter
Source: compiled by the authors of this study

The table shows that the more intensively the soil is used, the more humus mineralisation processes are manifested. Therewith, the components of humus that are more easily accessible to microorganisms mineralise faster. Thus, while the humus content of mown virgin soil, fallow land, and arable land compared to absolute virgin soil in the upper 0-20 cm soil layer decreased by 15.9%, 21.0%, 39.4%, respectively, the labile organic matter content decreased by 19.0%, 47.6%, and 82.5%, respectively. Given that these compounds can be an affordable source of macro- and microelements for plant growth and development during the growing season, the findings suggest a substantial decrease in potential soil fertility and, consequently, crop productivity. On all variants with natural vegetation, they are much more numerous in the upper 0-20 cm layer, which is saturated with plant roots and their secretions are part of labile organic matter. Thus, while in the variant of absolute virgin soil in the 0-40 cm layer their share was on average 10.6, in mown virgin soil, fallow land, and arable land, respectively, it was 8.5, 6.9, 4.1. On arable land their number in the upper layer is 4.2 times less than in absolute virgin soil. The high ratio (S_{lom}:C_{hum})/100 against the background of significant humus content of the upper layers of virgin chernozem indicates the stability of the humus state of this soil and its large reserves of available macro- and microelements for microorganisms and plants, and thus high potential productivity. A decrease in this ratio indicates a deterioration in the conditions for humus formation and a possible deficit in the balance of organic matter in the soil and a decrease in its potential fertility.

The natural humus-accumulative process takes place in chernozems under natural vegetation on fallow land, which helps restore the content of humus and labile organic matter. Therewith, comparing arable land and fallow land, the share of labile organic matter in humus increases faster on the latter. Thus, their content on fallow land increased from 17.5% to 52.4%, i.e., by 34.9%, and humus by only 18.4%, from 60.6% to 79.0%. Notably, both on virgin soil and on fallow land, relative changes in the amount of LOM are 2 times faster than humus.

In the modern period, there are three primary areas of achieving a neutral level of degradation while restoring the fertility of chernozems, including minimising tillage, biologising fertiliser systems, and ensuring a deficit-free balance of basic nutrients in crop rotation (Balyuk *et al.*, 2023). These factors were studied in a stationary experiment at the SS of the NULES of Ukraine "O.V. Muzychenko Velykosnitynske ERF", which investigated the effect of different tillage and fertilisation systems on the humus status of typical chernozem (Table 2). The table data shows that minimising tillage helped preserve the organic matter of chernozems and, when organic and mineral fertiliser was applied, increased the humus content.

Table 2. Humus and labile organic matter content and their ratio for 16 years of using different tillage and fertilisation systems in typical chernozem in the SS of the NULES of Ukraine "O.V. Muzychenko Velykosnitynske ERF", %

Soil cultivation system	Layers of soil, cm	Fertilizer variants								
		Control (no fertiliser)			Straw 1.2t/ha+ $N_{12}+N_{78}P_{68}K_{68}$			Straw 1.2t/ha+ green manure+ $N_{12}+N_{78}P_{68}K_{68}$		
		humus / C_{humus}	C_{los}	C_{los}: C_{hum}	humus / C_{humus}	C_{los}	C_{los}: C_{hum}	humus / C_{humus}	C_{los}	C_{los}: C_{hum}
Different depth ploughing	0-20	3.18 / 1.84	0.09	4.8	3.58 / 2.07	0.14	6.7	3.72 / 2.16	0.20	9.2
	20-40	3.05 / 1.77	0.11	6.2	3.48 / 2.02	0.16	7.9	3.69 / 2.14	0.23	10.7
Different depth non-ploughing tillage	0-20	3.26 / 1.89	0.12	6.3	3.64 / 2.11	0.16	7.6	3.85 / 2.23	0.28	12.5
	20-40	3.01 / 1.75	0.10	5.7	3.53 / 2.05	0.18	8.7	3.68 / 2.14	0.23	10.7
Mimimum non-ploughing tillage	0-20	3.28 / 1.90	0.11	5.8	3.59 / 2.08	0.16	7.7	3.79 / 2.19	0.24	10.9
	20-40	2.97 / 1.72	0.09	5.2	3.50 / 2.03	0.11	5.4	3.58 / 2.02	0.19	9.3
Fallow	0-20	3.98 / 2.31	0.30	12.9						
	20-40	3.92 / 2.27	0.24	10.5						

Source: compiled by the authors of this study

Without fertilisation, there was a tendency to increase the humus content only in the top 0-20 cm of the soil layer. The same pattern was observed in the content of labile organic matter, where in the non-ploughing variant their content was higher than in ploughing.

Fertiliser application contributed to the enhancement of the humus-accumulative process, the accumulation of humus and labile organic matter in both soil layers under study. The growth in the upper layer of 0-20 cm was 0.40-0.53% in the variants with straw and mineral fertilisers and increased to 0.54-0.59% when green manure was also used. In the lower layer of 20-40 cm, the growth from fertilisation and green manure use was significant and amounted to 0.43-0.67%. The effect of fertilisers on labile organic matter was even more significant, with the content of LOM increasing by 1.5-2.0 times or more compared to the unfertilised variant. The best results, especially in the topsoil, were observed in the variants with non-ploughing and amounted to 0.24-0.28%. The best indicators of the humus state of typical chernozem were observed on the fallow land variant, which served as a benchmark for comparing the effectiveness of soil fertility restoration measures, and where the humus content was 3.98% and labile organic matter was 0.30%.

Comparable patterns were observed in the typical chernozem of the Drabivske experimental field, where the content of humus and labile organic matter in the soil decreased without fertilisation (Table 3). Minimal tillage, even without fertilisers, substantially reduces humus mineralisation, as its content is much higher in the variant of different depth non-ploughing tillage than in different depth ploughing.

Table 3. Humus and labile organic matter content and their ratio under different tillage and fertilisation systems in typical chernozem at the Drabivska Experimental Station, %, average for 2017-2019

Soil cultivation system	Layers of soil, cm	Fertilizer variants					
		Control (no fertiliser)			$N_{130}P_{110}K_{110}$/ha of crop rotation		
		humus / C_{humus}	C_{los}	C_{los}: C_{hum}	humus / C_{humus}	C_{los}	C_{los}: C_{hum}
Different depth ploughing	0-20	2.97 / 1.73	0.041	2.36	3.02 / 1.75	0.142	8.11
	20-40	2.54 / 1.47	0.035	2.38	2.95 / 1.71	0.085	4.80
Different depth non-ploughing tillage	0-20	3.29 / 1.90	0.152	8.08	3.55 / 2.06	0.211	10.3
	20-40	3.00 / 1.80	0.079	4.38	3.14 / 1.82	0.078	4.29
Fallow	0-20	4.02 / 2.33	0.113	4.85			
	20-40	3.22 / 1.87	0.061	3.26			

Source: compiled by the authors of this study

The content of labile organic matter varied in proportion to the total humus. Notably, it was high – 0.152% in the upper 0-20 cm layer in the variant with different depths of non-ploughing tillage, which may be caused by more than 40 years of incorporating plant residues in this layer. In addition, very low values of the C_{lom}:C_{hum} ratio (2.36-2.38) were observed in the ploughed variant, indicating an unfavourable humus regime, namely, increased mineralisation of organic matter caused by intensive tillage and insignificant new formation of humus substances due to the lack of fresh organic matter. On the fallow land variant, the humus content was the highest, and an increased amount of labile organic matter was observed in the upper 0-20 cm sod layer saturated with plant roots. The absence of tillage and excessive loosening contributes to the formation of more formed and stable humus substances, which increase humus accumulation.

Figure 1 shows the dependence of winter wheat and grain maize yields on the content of LOM in typical chernozem.

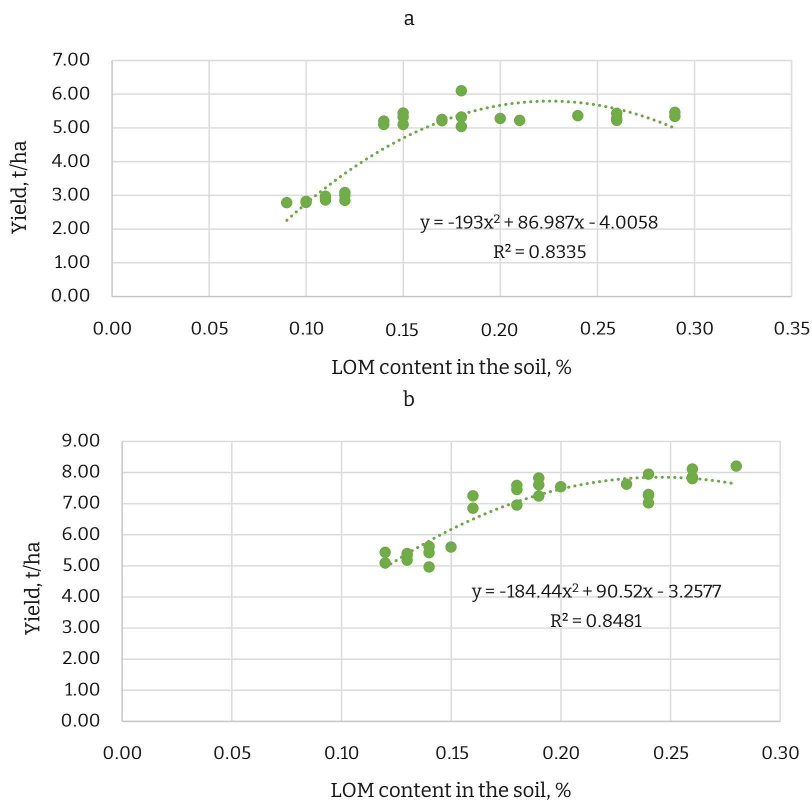

Figure 1. Influence of LOM content on the yield of winter wheat and grain maize (polynomial dependence)

Note: a – winter wheat, b – grain maize

The lowest yields of winter wheat and grain maize are dependent on the content of LOM in typical chernozem. The lowest crop yields and LOM content were recorded without fertilisation and amounted to 2.78-3.08 t/ha and 0.09-0.12% for winter wheat, respectively, and 5.43-5.62 t/ha and 0.12-0.15% for grain maize. When organo-mineral fertilisers were applied, the yields increased for winter wheat by 5.10-5.44 t/ha and 0.14-0.18%, and for grain maize by 6.85-7.82 t/ha and 0.16-0.19%. When green manure was used in this fertilisation system, the content of LOM and the yield of grain maize increased to 0.20-0.29% and 7.29-8.20 t/ha and were the highest, while the productivity of winter wheat stayed at the same level.

The intensification of mineralisation processes in chernozems under agricultural use reduces the proportion of labile organic matter in the fractional composition of humus. The application of fresh organic matter to the soil in combination with mineral fertilisers restores soil humus content, increases the amount of labile organic matter, and helps optimise the formation of soil microorganisms, enhances biological processes in the soil, which has a positive impact on potato yields. From an environmental standpoint, it is undesirable to use mineral fertilisers when there is a deficit of organic matter in the soil, as this increases gaseous nitrogen losses and intensifies mineralisation processes (Volkogon *et al.*, 2018). According to the authors (Balyuk *et al.*, 2016), a decrease in the humus content in the 0-20 cm layer of typical chernozem from 4.70% in the virgin variant to 3.60-4.00% under different fertilisation systems led to a significant reduction in labile humus substances. Therewith, in the organic-mineral fertilisation system, they accounted for 0.38%, 0.22% – upon mineral fertilisation, 0.15% – upon organic fertilisation, and 0.14% – no fertilisation.

It is safe to say that there is a connection between total soil carbon and labile organic matter, and it is logical to assume a correlation between them and plant productivity. This is noted in the studies of several authors (Balaev *et al.*, 2019). Land productivity is associated with labile organic matter as an easily accessible and balanced source of macro- and microelements for agricultural plants and microorganisms, which are released during its mineralisation, and it also contributes to the release of hard-to-reach compounds into solution. The authors (Rattan, 2020) note a prominent correlation between the content of LOM and the yield, and a closer correlation between the yield and the content of total carbon in the soil.

In modern conditions, it is necessary to consider not only the crops grown and soil fertility indicators, but climate aridisation. Studies by G. Wu *et al.* (2023) revealed the impact of global warming on changes in soil organic matter. The multifunctionality of the soil, caused by enzyme activity, was lower when warming due to lower soil moisture, nutrient availability and the supply of labile organic matter. The close relationship between microbial diversity and functional genes and soil multifunctionality has highlighted the importance of soil biodiversity in maintaining the functioning of agroecosystems, which is linked to nutrient cycling. With increasing soil and air temperatures, leaving the straw on the field resulted in higher bacterial diversity (by 3.6%) and the number of microbial functional genes of the C, N, and P cycle compared to removing the straw from the field. The straw reduced the amplitude of soil temperature fluctuations. Overall, the return of straw created a favourable habitat for microorganisms and thus mitigated the adverse effects of warming on microbial communities and soil functionality. Comparable results were obtained from the study of the microbiological state of meadow chernozem soil (Motruk *et al.*, 2021)

In soils where the humus-accumulative process is manifested and soil fertility is restored, the proportion of labile organic matter in the humus composition increases. In the experiment at the SS of the NULES of Ukraine "O.V. Muzychenko Velykosnitynske ERF", the ratio of C_{lom}:C_{hum} was the lowest in the variants without fertilisation and increased with the improvement of the humus state of the chernozems, which is typical for the application of different fertiliser rates or the use of minimised tillage. The highest indicators were observed in multi-depth no-till cultivation and on fallow land, where they were 10.7-12.5 and 10.5-12.9, respectively. Studies by E. Litvinova *et al.* (2019) found that the use of no-till variant created conditions for increasing the content of labile organic matter in the arable layer of typical chernozem by 4-7% compared to ploughing.

Notably, there is a direct correlation between stable and labile organic substances and a certain ratio between them should be maintained for the soil to effectively perform its productive function over a long period of time, as well as its ecological function in the biosphere (Lukas & Weil, 2012; Gamkalo & Bedernyk, 2014; Balyuk *et al.*, 2016).

Due to the high humus content, the C_{lom}:C_{hum} ratio averaged 4.85-3.26, and was highest in the top layer upon multi-depth no-till cultivation – 8.08.

Correlation analysis of the data for the 0-20 cm soil layer showed that soil organic matter stock was positively related to labile compounds, the proportion of large macroaggregates, and negatively related to small macroaggregates, aromatic compounds, and the aromaticity index. The accumulation of soil organic matter in the topsoil under no-till was influenced by the accumulation of labile organic compounds (Briedis *et al.*, 2023).

S.T. Lukas & R.R. Weil (2012) found that the content of labile organic matter is closely related to total organic carbon in the soil (r=94). The results of the study show that labile organic matter can serve as a test in soils where agronomic practices are used to increase their productivity.

When fertilising the Drabivske experimental field, an increase in the humus content of the soil layers was observed under both tillage systems. The highest results were observed in the variant of different depth non-ploughing tillage, where the humus content in the layers 0-20 and 20-40 cm was 3.55% and 3.14%, which is 0.25% and 0.14% higher than upon ploughing, respectively. The content of labile organic matter was also better here, especially in the top 0-20 cm of soil. Fertiliser application increased their share in the humus composition, indicating favourable conditions for the formation of humus substances, the predominance of humification over humus mineralisation and the focus of soil processes on restoring the fertility of typical chernozems.

In the studies of V.V. Volkogon *et al.* (2018), the authors pointed out that it is not possible to improve the microbiological and nutrient regimes of the soil under the influence of LOM, although there is little evidence of a direct link between their content and crop yields. The paper by T. Yang *et al.* (2019) notes that grain yields are correlated with both LOM and soil organic matter content. The maximum yield was achieved at an organic matter content of about 4.0% and a high LOM value. J. Shen *et al.* (2023) found that water-soluble organic matter stability is not an intrinsic trait during initial pedogenesis: stable water-soluble organic matter compounds stay after bacteria rapidly utilise its labile compounds, while fungi slowly decompose the remaining pools.

The dependence of winter wheat and grain maize yields on the content of LOM was strong, with correlation coefficients of r=0.83 and r=0.85, respectively. E. Oldfield *et al.* (2019), using data from 240 experiments from 29 countries at the global level, established a link between organic carbon content from 0.1% to 2.0% and maize and wheat yields. Thus, the yield of these crops was 1.2 times higher with an organic carbon content of 1.0% compared to 0.5%. The yield increase stabilises at a concentration of about 2.0%, and this value is proposed as a critical limit for temperate soils. An analogous opinion is shared by L. Rattan (2020), who suggests that the critical threshold for reducing the organic carbon content in temperate soils is 2.0%, and for tropical soils 1.1%. The author notes the relationship between the content of organic carbon in the soil and crop yields due to its ability to improve the water regime of the soil, especially in arid conditions, and provide plants with nutrients, primarily nitrogen, phosphorus, and sulphur.

Thus, the content of LOM can be considered not only as an indicator of the humus state of the soil and a favourable regime of humus formation in chernozems, but as an indicator of potential soil fertility and crop productivity.

CONCLUSIONS

The intensity of mineralisation of the organic matter of chernozems depends on the methods and period of their agricultural use. Increased anthropogenic pressure, intensification of soil cultivation, and a decrease in the supply of fresh organic matter to the soil under arable conditions lead to losses in the content of humus reserves. When virgin chernozems are ploughed up, labile organic matter in the humus is mineralised more rapidly, and when arable land is converted to fallow, it is restored more quickly. Relative changes in the amount of labile organic matter under the influence of agricultural practices are twice as fast as humus. Thus, labile organic matter can be an indicator of changes in the humus state of chernozems under the influence of agricultural practices and crop cultivation technologies.

Minimising soil tillage and applying organic and mineral fertilisers enhances the humus-accumulative process, increases the amount of humus and LOM, and increases their ratio in typical chernozem. The long-term use of non-ploughing tillage and fertilisation significantly increases the humus content, especially in the top layer, compared to ploughing. During the 16-year period of their use, the increase in humus was 0.13%, and during the 42-year period – 0.53%. Without fertilisation, the ratio of labile organic matter carbon to humus carbon was 2.36-6.3, with fertilisation it was 4.8-12.5. The highest ratio was in the case of non-ploughing tillage and fertilisation and was 10.9-12.5.

The content of labile organic matter and the ratio of labile organic matter carbon to humus carbon in chernozems can indicate potential soil fertility and favourable conditions for the growth and development of crops during the growing season. The prominent ratio of LOM to humus carbon indicates a favourable humus condition and the predominance of humification processes over the mineralisation of organic matter. A strong correlation was found between the content of LOM in typical chernozems and the yield of winter wheat and grain maize with correlation coefficients of 0.83 and 0.85, respectively. Studies on changes in the content of LOM in other soil types are considered promising.

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CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

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Лабільні органічні речовини і родючість чорноземів

Анотація. Органічні речовини ґрунту умовно можна розділити на стабільні і лабільні, причому останні безпосередньо забезпечують ріст і розвиток рослин впродовж вегетаційного періоду. Для відновлення родючості ґрунтів і високої продуктивності агроценозів у них повинно витримуватись певне співвідношення між лабільною і стабільною частиною гумусу. Мета дослідження – визначити вміст лабільних органічних речовин за різних варіантів обробітку ґрунту та удобрення, а також встановити оптимальне співвідношення між їх вмістом та вмістом загального вуглецю, на основі якого розробити заходи з відновлення та підвищення родючості чорноземних ґрунтів. У стаціонарних дослідах вивчався вплив інтенсивності використання чорноземів, їх систем обробітку і удобрення на гумусний стан кількості лабільних органічних речовин і їх співвідношення з вуглецем гумусу. У роботі використовували польові дослідження, лабораторний метод аналізу зразків ґрунту, систематизацію, аналіз та узагальнення. У зразках ґрунту визначали вміст гумусу згідно ДСТУ 4289:2004 і вміст лабільних органічних речовин за ДСТУ 4732:2007. За розорювання чорноземів найбільше мінералізуються лабільні органічні речовини і їх частка в складі гумусу зменшується, а за переведення ріллі в перелоги вони відновлюються найшвидше. Мінімізація систем обробітку ґрунту і внесення органо-мінерального удобрення збільшує кількість лабільних органічних речовин в складі гумусу чорноземів. Застосування безполицевого обробітку ґрунту протягом шістнадцяти років зумовила підвищення вмісту гумусу на 0,13 %, протягом сорока двох років – на 0,53 % відносно оранки. Внесення органо-мінерального удобрення підвищувало співвідношення вмісту вуглецю лабільних органічних речовин до вмісту загального вуглецю порівняно з варіантами без удобрення. Встановлена сильна кореляційна залежність між вмістом лабільних органічних речовин в чорноземах і врожайністю озимої пшениці і кукурудзи на зерно. Практичне значення результатів досліджень полягає в мінімізації норми удобрення та співвідношення в ній C:N для забезпечення валової врожайності культур і відновлення родючості ґрунтів

Ключові слова: гумус; мінералізація; гуміфікація; пшениця озима; кукурудза