UDC 631.417.1: 631.417.2

Seasonal sequestration capacity of chernozem under different agrotechnological influences in agrocenosis

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The purpose of the study. To assess the sequestration capacity of C-CO_2 humus in soil formation and fertility of typical chernozem, to identify the causes, rates, existing limits of the sequestration capacity decrease, it is important to study the seasonal dynamics of qualitative and quantitative indicators of humus state in time depending on the method of tillage and fertilization in agrocenoses of short rotation crop rotations in the central part of the Forest-Steppe of Ukraine. Methods. **Field** - to establish and conduct a field stationary experiment to study the influence of tillage and fertilization methods on the sequestration capacity of chernozem; laboratory - to determine the humus content; calculation and statistical - to calculate seasonal stocks of sequestered carbon and phosphorus and to model the sequestration capacity of chernozem. **Results of the study.** Under no-till cultivation with fertilizer application, the increase in C-CO_2 stocks in the period April - July was +21 t/ha (0-20 cm) and +36 t/ha (0-30 cm). Under plowing, the growth tended to increase by 1.52 times (0-20 cm) and 1.25 times (0-30 cm), but occurred at a lower quantitative level, and in the period July - September, the change in the humus C-CO_2 stock was insignificant, indicating the predominance of C-CO_2 sequestration processes in the summer - autumn period under no-till cultivation. Under no-till tillage, the stock of SOC in April exceeded the stock for plowing in the thickness of 0-30 cm by 4.34-7.67 times (without fertilizers), 1.5-2.76 times (with fertilizers); in July - by 4.59-8.90 times (without fertilizers) and 1.32-3.16 times (with fertilizers); in September - by 4.52-4.04 times (without fertilizers) and by 1.11-1.93 times (with fertilizers), and the C-CO_2 stock of the ENT compared to fallow land under no-till cultivation without fertilizers in April, July, and September was 1.59-1.78 times, 2.31-3.29 times, and 1.4-1.78 times higher, and under fertilization - by 1.99-2.0, 1.86-4.50, and 1.7-2.6 times, respectively, depending on the seasons. Under fallow land maintenance, the seasonal dynamics of the C-CO_2 stock of the SOC is subject to the seasonal dynamics of Rorg(SOC). A direct strong correlation was found at the level of $R=+0.89\pm0.02$; R2=79. In the period April - July, the decrease of Porg(ENT) stock in the thickness of 0-20 cm was found to be 1.15 times, and in the thickness of 0-30 cm - 1.1 times. From summer to autumn, the stock of Rorg (ENT) was restored, and the stock in the thickness of 0-30 cm increased by 1.10 times. Conclusions. Trends in C-CO_2 stocks of humus and SOC indicate that in the series plowing-no-till-swidden land, the cyclicality index under no-till tillage was closer to the value of the seasonal cyclicality of fallow land than the seasonal cyclicality under plowing, which indicates the restoration of the CI. **Conclusions.** Trends in C-CO_2 stocks of humus and SOC indicate that in the series plowing-no-till-subsidence, the index of cyclicality under no-till cultivation was closer to the value of the seasonal cyclicality of fallow land than the seasonal cyclicality of plowing, which indicates the restoration of the IC. However, the timing of changes in the Rorg ENT stock indicates that in the series plowing-no-till-subsidence, no-till tillage is directed to fallow land by its seasonal cyclicality. The general regularity of seasonal cyclicality for all parameters of humus condition lies in the fact that a decrease in the values of Iц , as in fallow land or under moldboardless tillage, indicates the ordering of Iц , and an increase in the index of cyclicality to destruction, as under plowing.

Keywords: *organic carbon and phosphorus stocks, plowing, moldboardless tillage, trends in stock changes, lightly hydrolyzed organic matter*

The conclusion of academician V.V. Medvedev [1] on the degradation of arable chernozems of Ukraine under modern management conditions, as well as the opinion that '...the soil formation process can develop in two directions - natural, forming a typical genetically determined soil and anthropogenic, forming degraded soil (due to a constantly deficient balance of biogenic elements and abnormal, almost uncontrolled pressure) with parameters other than natural...' are fair. Chornozems in agrocenoses, as a 4-dimensional polygenic formation [2], are becoming anthropogenically transformed degraded formations, and the total anthropogenic and anthropogenic load exceeds the capacity of chornozems for self-reproduction and self-regulation of soil fertility.

In nature, ecosystems form a self-regulating mechanism, the main link of which is plants and soils that accumulate solar energy in the form of living matter (biomass) and soil humus, and the integrating indicator of these processes is the system of soil humus substances [V.A. Kovda (1974)]. Chernozems are characterised by a transformational and migratory type of humus profile, which is a self-regulating system with an upper (about 20 cm) part that has the transport function of the upper zone of the humus profile of chernozem soils [M.I. Dergachova (1984)]. The humus horizon of chernozems is a prerequisite for the formation and evolution of chernozems, and therefore the processes of functioning of the humus horizon determine the direction and intensity of the elementary typogenetic processes of chernozem soil formation [L.I. Prasolov (1939)].

Nature has developed a complex, organically expedient device for the extraction of mineral nutrition by plants - the process of humus formation, and in a broader sense - the process of soil formation. In the process of ploughing, the biochemical 'pulsation' of the humus horizon of chernozems almost stops, and the soil loses its chemical and physical properties and turns into a more or less inert substrate, on which it is impossible to obtain a high yield under conditions of high doses of fertilisers and intensive cultivation [Ponomareva V.V., 1980].

In arable agroecosystems, compared to natural biogeocenoses, irregular fluctuations increase dramatically and the amplitude of seasonal cycling of soil solution is clearly reduced, which is explained primarily by the lack of a necessary supply of dead organic matter in the form of a thick layer of steppe litter in the upper layer of arable chernozems [T.L. Bystrytska and co-authors (1981)]. The role of crop residues and by-products is especially important in modern management conditions [3-9]. Only the restoration of the appropriate seasonal cycling of chernozem humus can bring chernozem soils to a certain stable state, and biologisation of agriculture is the most promising direction that ensures the preservation of chernozem fertility and increased profitability of crops. An important role is played by saturating crop rotations with crops that are designed to enrich the soil with organic matter and nitrogen, mobilise hard-to-reach forms of phosphorus and potassium, and improve the water and physical properties of the soil [M.I. Dergacheva (1984)].

The content of total humus on both virgin and arable chernozem decreases from spring to summer, and by autumn it increases again, tending to an ascending value, and even exceeds it in November, when the chernozem is covered with snow, and the reducing processes in it sharply prevail over the oxidising ones or completely suppress them. The idea of organic matter as a conservative formation seems to be erroneous, as many researchers have established [10-15].

The noticeable decrease in humus content from spring to summer is due to the intensification of its oxidation processes under optimal moisture and temperature conditions. In summer, oxidation processes are sharply dominant in the soil, and as it becomes wetter in autumn and spring, reduction processes prevail. A decrease in pH in the summer can weaken the bonds between humus and the mineral part and thus worsen the aggregation capacity of soils, but at the same time it increases the mobility of nutrients and improves the nutritional regime of chernozem. There are periods during spring, summer, and autumn, or even in some years, when there is a predominant loss or increase in the humus content of soils. The separation in time of the processes of its formation or decomposition is associated with hydrothermal conditions and the intensity of microflora activity, which causes these processes and is changed by the influence of the cultivation method [16-17].

The studies of B.S. Nosko [18-21] established that organic phosphates are one of the main reserve parts of phosphorus, and their content should be considered as a ratio of mineralisation and synthesis of organic matter of humus and SOC, which indicates the importance of organic phosphates in the soil formation of chernozems. The content of organic phosphates is closely related to the amount of humus and its quality. Under natural conditions of soil formation, the release of organic phosphorus and its sequestration follows a natural cycle, while in agrocenoses, humus depletion by organic phosphates and disruption of seasonal cycles of consumption and reproduction prevail. It is relevant to assess the impact of tillage and fertilisation methods on the reproduction of the C-CO2 sequestration capacity of humus and labile organic matter, to identify the nature of sequestration enrichment of chernozem with organic phosphorus in agrocenoses and to establish the patterns of POM deposition in humus during C-CO2 sequestration by agrocenoses in a seasonal cycle, which is not studied. The analysis of scientific sources shows that this issue has not been studied in this area.

The aim of the study. To assess the impact of humus C-CO2 stocks on soil formation and fertility of chernozem, to identify the causes, rates, and existing limits of soil sequestration capacity reduction, the aim is to study the seasonal dynamics of humus carbon monoxide and labile organic matter stocks depending on the method of cultivation and fertilisation in the agrocenosis of short rotation crop rotation in the central part of the Forest-Steppe of Ukraine.

Research methods. The research was carried out in the central part of the left-bank Forest-Steppe of Ukraine in a long-term (over 35 years) stationary experiment of the Drabivske experimental field of the Cherkasy State Agricultural Research Station ‘NSC “Institute of Agriculture of NAAS”. Soil - typical low-humus coarse-dusty light loamy chernozem with humus content of 3.8-4.2%, mobile phosphorus content of 120-140 mg per 1000 g of soil, mobile potassium content of 80-100 mg per 1000 g of soil, pHH2O = 6.8-7.0. The size of the sowing plot is 162 m2 and the accounting plot is 100 m2 .

The research was carried out in 1976-2022 (46 years) in a multifactorial stationary experiment of the Cherkasy State Research Station of the National Research Centre ‘Institute of Agriculture of the National Academy of Sciences of Ukraine’. The experiment studied 5-field crop rotation: A: perennial grasses - winter wheat - sugar beet - corn - barley + perennial grasses (cereals - up to 60%, industrial - up to 20%; perennial grasses - up to 20%);

Fertilisation system: 6.0 t/ha of by-products; N31-62P33-66K41-82 per 1 ha of crop rotation area, or NPK - Σ250-350 kg.d.m. Until 1999, 6 t/ha of manure was applied, and from 2000 to 2022, 6-7 t/ha of by-products were applied.

Methods of main tillage: different depth ploughing (22-25 cm) for all crops; no-till tillage (22-25 cm) for all crops. Both experiments were replicated three times.

In laboratory conditions, soil samples were examined in triplicate, in which the humus content was determined by I. V. Tyurin in the modification of V. M. Simakov (DSTU 4289:2004); labile organic matter (DSTU 4732:2007).

The content of organic phosphates (POM) in humus was determined by B.S. Nosko [18-19]. It was found that the correlation coefficient between the content of total humus and POM is $R=+0.98\pm0.02$, $R2=0.96$ for the entire genetic zonal range of chernozems (podzolised - typical - ordinary - southern). The dependence is described by a straight line according to Eq: $Y=15.5+17.2x - 1.47x2$, where Y is the POM content, mg/100g of soil, and x is the humus content, %. According to the established relationship between the content of total humus and the content of POM, the content of POM in labile organic matter was determined. Subsequently, the content of humus, LOC and POC was converted into stocks (t/ha), which is the basis for writing this report. The generalisation of crop rotation productivity, soil moisture regime indicators, climatic parameters and calculations of research results were carried out by the 'Method of analysis of variance' using the STATISTICA-10 software and the application of non-parametric statistical methods, correlation, factor and cluster analysis.

Research results. The change in the C-CO2 stock of humus in chernozem under fallow land is associated with the manifestation of natural cyclicality from spring to autumn, as well as the content of total humus [Hertsyk V.V., 1959, Kuprychenkov M.T., 2013 [23]]. The C-CO2 stock in the 0-20 cm layer of chernozem in April was 195 t/ha, and in the 20-30 cm soil layer - 79 t/ha. In the 0-30 cm layer, the stock is 275 t/ha. In July, the C-CO2 stock decreased by -15 t/ha, -3 t/ha and -18 t/ha in the soil layers, respectively. In September, the C-CO2 stock was restored, which increased by +27 t/ha, +12 t/ha and +39 t/ha. The period from April to July is a consumption period, and July to September is a restoration or sequestration period. Under natural conditions, the sequestration period is more intensive than the reproductive period by 1.8 times, 4 times and 2.2 times, respectively, for soil layers 0-20 cm, 20-30 cm and 0-30 cm. The Porg stock changed cyclically with the change in the C-CO2 stock.

During the reproductive period, the consumption of POM in humus was -0.058 t/ha (0-20 cm), -0.078 t/ha (20-30 cm) and -0.136 t/ha (0-30 cm), and the reproduction of POM in the sequestration period was +0.146 t/ha, +0.145 t/ha and +0.295 t/ha, which is 2.5, 1.85 and 2.17 times more intensive than the consumption of soil layers, respectively. The ratio of C-CO2 stock to POM by periods ranged from 140 to 1 to 151 to 1 or 38-42 to 1 in terms of POM, which indicates high resistance of C-CO2 and POM stocks to mineralisation and ensures POM accumulation under conditions of long-term fallow land. The intensity of C-CO2 and Pg stock reproduction under conditions of fallow land maintenance and the positivity of the balance contributes to the high sequestration capacity of fallow land (Fig. 1).

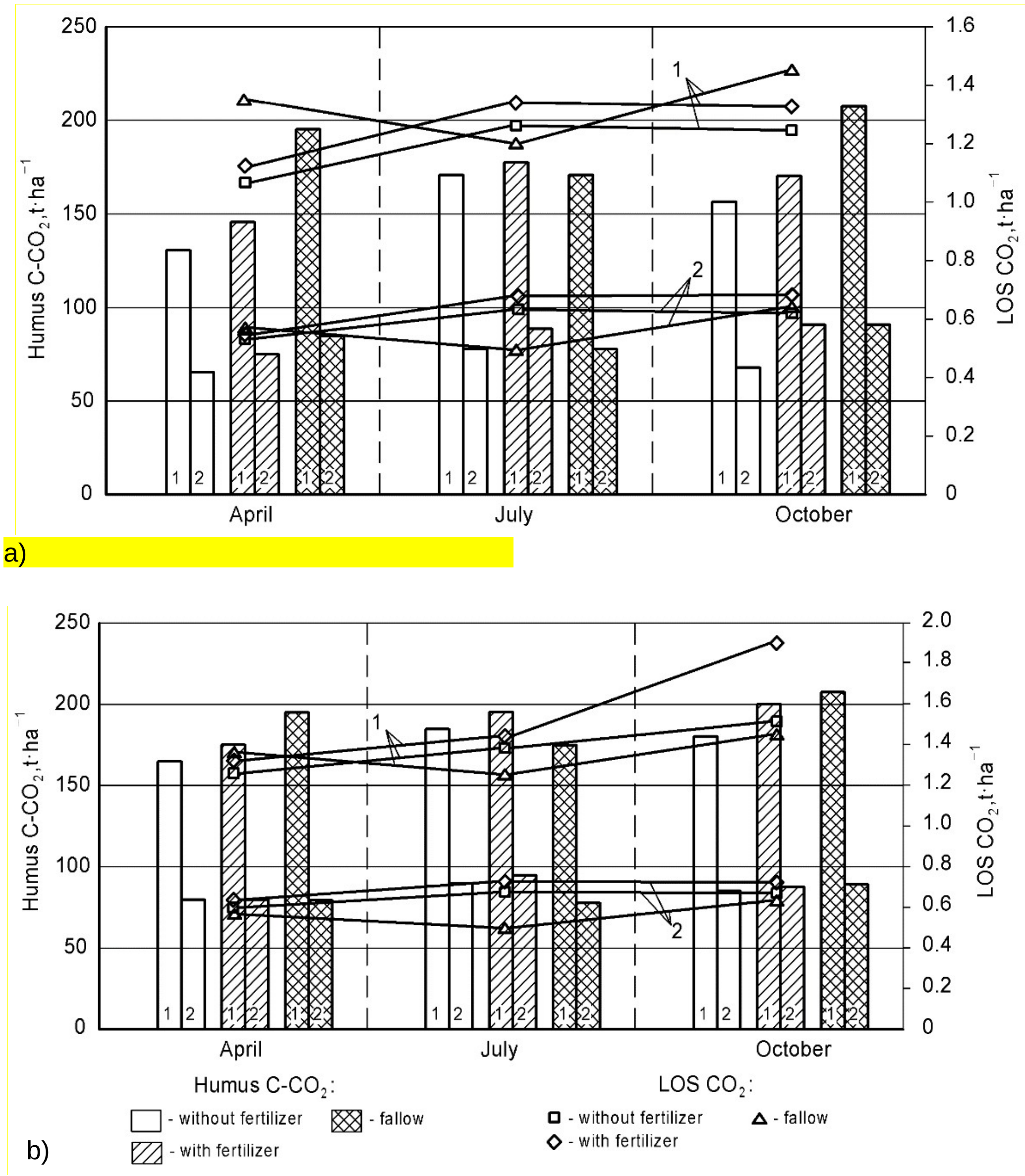


Fig. 1. Seasonal dynamics of humus C-CO2 and SOC stock depending on the method of cultivation and fertilisation in the wheat-sugar beet-maize crop rotation chain at 45 years after the beginning of the experiment.

The systematic implementation of ploughing leads to a change in the order of seasonal changes in C-CO2 and POC stocks. Thus, the C-CO2 stock in April without fertilisers in the 0-20 cm layer was 1.5 times lower, and in the 20-30 cm and 0-30 cm layers of soil it was 1.3 and 1.4 times lower compared to fallow. Similarly, in July, the C-CO2 stock was 1.1 times lower than the fallow land (0-20 cm) and 1.2 times lower (0-30 cm), which is -20 t/ha (0-20 cm) and -15 t/ha (0-30 cm). In September, the C-CO2 stock under ploughing decreased and was lower compared to fallow by 1.34 times (0-20 cm), 1.33 times (20-30 cm) and 1.35 times (0-30 cm), or -102 t/ha, -22 t/ha and -76 t/ha for the soil layers, respectively.

Under no-till cultivation without fertilisers, the C-CO2 stock in April-September was higher than under ploughing by +40 t/ha (0-20 cm), +90 t/ha (20-30 cm) and +55 t/ha (0-30 cm). In July, the stock was higher by +25 t/ha (0-20 cm), +13 t/ha (20-30 cm) and +38 t/ha (0-30 cm). In September, the C-CO2 stock was higher compared to ploughing by +30 t/ha (0-20 cm) and +54 t/ha (0-30 cm). Under no-till cultivation, the C-CO2 stocks were closest to fallow land in the periods of determination. With the application of fertilizers, the C-CO2 stock of humus in April in the thickness of 0-20 cm under no-till cultivation increased by 15 t/ha, and in the thickness of 0-30 cm - by 25 t/ha. A similar increase in the C-CO2 stock was observed in July: +12 t/ha, +10 t/ha and +22 t/ha in the black soil layers respectively. A similar increase in humus C-CO2 stock was observed in September. The cyclical nature of the seasonal change in the humus C-CO2 stock under fertilisation was of a regular nature, as in the control without fertilisation, but at a higher quantitative level.

Under no-till cultivation with fertiliser application, the increase in humus C-CO2 stocks was lower compared to ploughing. The growth of C-CO2 stock in the period April - July was: +21 t/ha (0-20 cm), +15 t/ha (20-30 cm) and +36 t/ha (0-30 cm). During ploughing, the growth tended to increase by 1.52 times (0-20 cm) and 1.25 times (0-30 cm), but at a lower quantitative level. In the period July - September, the change in the humus C-CO2 stock was insignificant, which indicates the predominance of C-CO2 sequestration processes in the summer and autumn period under no-till cultivation.

However, the generalisation of the consumption and growth of C-CO2 humus stock showed that the consumption of C-CO2 humus stock in April - July was: -15 t/ha (0-20 cm), -3 t/ha (20-30 cm) and -18 t/ha (0-30 cm), while in the period July - September there is an increase in the sequestration of C-CO2 of humus and an increase in the carbon monoxide stock by +27 t/ha, +12 t/ha and 39 t/ha, respectively, in soil layers.

During ploughing on the control without fertilizers in the period April - July, the growth of C-CO2 humus stock was found to be +35 t/ha, +12 t/ha and +47 t/ha, and in July - September, the consumption was found to be: -10 t/ha, -10 t/ha and -20 t/ha. With fertilisation, the increase in C-CO2 stock was at the level of the control without fertilisation, and the consumption was 1.42 times, 3.3 times and 5 times lower.

Under no-till cultivation, the growth of humus C-CO2 stock in April - July in the control without fertilizers was +21 t/ha, +15 t/ha and +36 t/ha, and with fertilizers it tended to increase: +20 t/ha, +10 t/ha and +30 t/ha. However, the consumption in the control without fertiliser was significantly lower compared to ploughing: -3 t/ha, -6 t/ha and -9 t/ha. The consumption was 2.2 times lower for the 0-30 cm layer. The decrease in the C-CO2 stock of humus had a weak tendency to decrease compared to ploughing.

Seasonal changes in the C-CO2 stock of labile humus due to fallow land maintenance were cyclical, similar to the changes in the C-CO2 stock of total humus. The consumption of C-CO2 stock of labile humus for the period April - July was: -3.7 t/ha (0-20 cm), - and -3.8 t/ha (0-30 cm), and the reproduction of the C-CO2 stock of labile humus in July - September: +1.15 t/ha, +0.62 t/ha and +0.71 t/ha, respectively, by depth. The stock of C-CO2 of labile humus for ploughing in April without fertilisation was 4.8 times lower (0-20 cm) and 4.1 times lower (0-30 cm) compared to the fallow. In July - by 2.56 times, 1.99 times and 2.38 times, and in September - by 2.3 times, 2.5 times and 2.16 times, respectively, for the soil layers. The seasonal cyclicality of the LOR was different from that of fallow land in that there was an increase in the LOR from spring to autumn, which is associated with seasonal increasing activation of humus due to aged, more stable humus C-CO2 reserves (Table 1).

1. Seasonal dynamics of labile organic matter and organic phosphates depending on tillage, fertilisation and fallow land

<table>
<tr><th rowspan="2">Depth, cm</th><th colspan="3">Ploughing</th><th colspan="3">Ploughless cultivation</th></tr>
<tr><th>April</th><th>July</th><th>September</th><th>April</th><th>July</th><th>September</th></tr>
<tr><td colspan="7">C-CO_2 LOR to $P_{орг}$</td></tr>
<tr><td colspan="7">without fertiliser</td></tr>
<tr><td>0-20</td><td>2,28</td><td>2,85</td><td>2,67</td><td>18,0</td><td>24,0</td><td>15,0</td></tr>
<tr><td>0-30</td><td>3,41</td><td>4,21</td><td>3,95</td><td>23,0</td><td>30,0</td><td>20,0</td></tr>
<tr><td colspan="7">NPK - Σ250-350 кг д,р,</td></tr>
<tr><td>0-20</td><td>14,1</td><td>25,0</td><td>11,4</td><td>22,0</td><td>33,0</td><td>24,0</td></tr>
<tr><td>0-30</td><td>16,0</td><td>26,6</td><td>12,8</td><td>28,0</td><td>38,0</td><td>30,0</td></tr>
<tr><td colspan="7">Rogue LOR, t/ha</td></tr>
<tr><td colspan="7">without fertiliser</td></tr>
<tr><td>0-20</td><td>0,052</td><td>0,026</td><td>0,029</td><td>0,130</td><td>0,180</td><td>0,110</td></tr>
<tr><td>0-30</td><td>0,071</td><td>0,037</td><td>0,044</td><td>0,180</td><td>0,230</td><td>0,151</td></tr>
<tr><td colspan="7">NPK - Σ250-350 кг д,р,</td></tr>
<tr><td>0-20</td><td>0,111</td><td>0,191</td><td>0,150</td><td>0,160</td><td>0,250</td><td>0,170</td></tr>
<tr><td>0-30</td><td>0,126</td><td>0,236</td><td>0,195</td><td>0,211</td><td>0,291</td><td>0,222</td></tr>
<tr><td colspan="7">Listing</td></tr>
<tr><td></td><td colspan="2">April</td><td colspan="2">July</td><td colspan="2">September</td></tr>
<tr><td colspan="7">C-CO_2 LOR, t/ha</td></tr>
<tr><td>0-20</td><td colspan="2">11,0</td><td colspan="2">7,31</td><td colspan="2">8,45</td></tr>
<tr><td>0-30</td><td colspan="2">13,8</td><td colspan="2">9,76</td><td colspan="2">11,66</td></tr>
<tr><td colspan="7">Rogue LOR, t/ha</td></tr>
<tr><td>0-20</td><td colspan="2">0,075</td><td colspan="2">0,064</td><td colspan="2">0,081</td></tr>
<tr><td>0-30см</td><td colspan="2">0,096</td><td colspan="2">0,083</td><td colspan="2">0,106</td></tr>
</table>

When fertilising with ploughing, the stock of SOC increased compared to the control without fertiliser in April by 6.2 times (0-20 cm), 1.76 times (20-30 cm) and 4.7 times (0-30 cm); in July - by 8.8 times (0-20 cm), 1.2 times (20-30 cm) and 6.3 times (0-30 cm); in September - by 3.18 times (0-20 cm), 4.8 times (20-30 cm) and 3.44 times (0-30 cm). However, the C-CO2 stock of the ENT under fertilisation for ploughing was significantly higher than under fallow: 1.16-1.28 times (April), 2.6-3.4 times (July) and 1.34-1.5 times (September). In the control without fertilisers in the period from April to September, the stock of LOR in the thickness of 0-30 cm was 2.43-4.83 times less (April), 1.99-2.38 times less (July) and 2.3-2.5 times less (September).

Under no-till tillage, the stock of SOC in April exceeded the stock under ploughing in the 0-30 cm layer by 4.34-7.67 times (without fertilizers), 1.5-2.76 times (with fertilizers); in July - by 4.59-8.90 times (without fertilizers) and 1.32-3.16 times (with fertilizers); in September - by 4.52-4.04 times (without fertilizers) and 1.11-

1.93 times (with fertilizers). The C-CO2 stock of the ENT compared to the fallow land under no-till cultivation without fertilizers in April, July, and September was 1.59-1.78 times, 2.31-3.29 times, and 1.4-1.78 times higher, and under fertilizers - 1.99-2.0, 1.86-4.50, and 1.7-2.6 times, respectively, depending on the seasons.

2. Seasonal dynamics of the ratio of humus C-CO2 stock and LOR to POR under different methods of cultivation and fertilisation

Depth, cm	Ploughing			Ploughless cultivation		
	April	July	September	April	July	September
$C\text{-}CO_2$ LOR to P_{opr}						
without fertiliser						
0-20	61 to 1	130 to 1	125 to 1	137 to 1	140 to 1	136 to 1
0-30	58 to 1	133 to 1	110 to 1	133 to	136 to 1	134 to 1
NPK						
0-20	127 to 1	132 to 1	95 to 1	147 to 1	132 to 1	133 to 1
0-30	130 to 1	85 to 1	116 to 1	131 to 1	140 to 1	134 to 1
$C\text{-}CO_2$ humus to P_{opr}						
without fertiliser						
0-20	121 to 1	130 to 1	124 to 1	134 to 1	135 to 1	132 to 1
0-30	121 to 1	126 to 1	117 to 1	134 to 1	134 to 1	133 to 1
NPK						
0-20	130 to 1	133 to 1	128 to 1	136 to 1	135 to 1	132 to 1
0-30	134 to 1	133 to 1	131 to 1	134 to 1	134 to 1	133 to 1

Listing			
	April	July	September
$C\text{-}CO_2$ LOR to P_{opr}			
0-20	149 to 1	115 to 1	120 to 1
0-30	144 to 1	122 to 1	130 to 1
$C\text{-}CO_2$ humus to P_{opr}			
0-20	147 to 1	142 to 1	147 to 1
0-30	144 to 1	150 to 1	144 to 1

In contrast to the biochemistry of C-CO2, for which the gas form of the compound is an obligatory chain in biosphere flows, the biochemistry of phosphorus (P) is associated with living organic matter [21-22], i.e. organic phosphorus is a biophilic element, and its content in chernozems depends on the stock of organic matter (C-CO2) of humus and the labile form of humus. The correlation coefficient between the content of organic phosphorus and humus according to the calculations of B.S. Nosko [18] is R = +0.994 (R2 = 0.98), and the dependence is expressed by a straight line.

Under fallow land, the seasonal dynamics of C-CO2 stock in the ENV is subordinated to the seasonal dynamics of Rorg(ENV). A direct strong correlation was found at the level of R=+0.89±0.02; R2=79. In the period from April to July, the decrease of Porg(ENT) stock in the 0-20 cm thickness was found to be 1.15 times, and in the 0-30 cm thickness - 1.1 times. From summer to autumn, the stock of

Rorg(ENT) was restored, and the stock in the 0-30 cm layer increased by 1.10 times. The assessment of the ratio of the C-CO2 stock of the LOM to the POM stock showed that in spring a wide ratio of 138-149 to 1 was formed, indicating the 'concatenation' of organic phosphates, and in summer the ratio expanded to 115-128 to 1 (31-35 to 1), which is associated with the release of POM due to the mineralisation of the LOM humus. In autumn, when the C-CO2 stock of the LOR is replenished, the POR of the LOR becomes more concentrated and accumulates in the humus. The positivity of the Porg stock in relation to the expenditure period indicates an extended reproduction of Porg(ENV) as the C-CO2 stock of ENV (Table 2).

Under systematic ploughing without fertilisers, the cyclicality of POM was found to be similar to that of fallow land, but at a lower quantitative level. Thus, in April, in the control without fertilisers, the Porg(LOR) stock was 1.69-1.85 times lower compared to fallow land, and when fertilisers were applied in the 0-30 cm layer, it was 1.29 times higher. In the soil layer, on the contrary, it was 6 times lower compared to the fallow period.

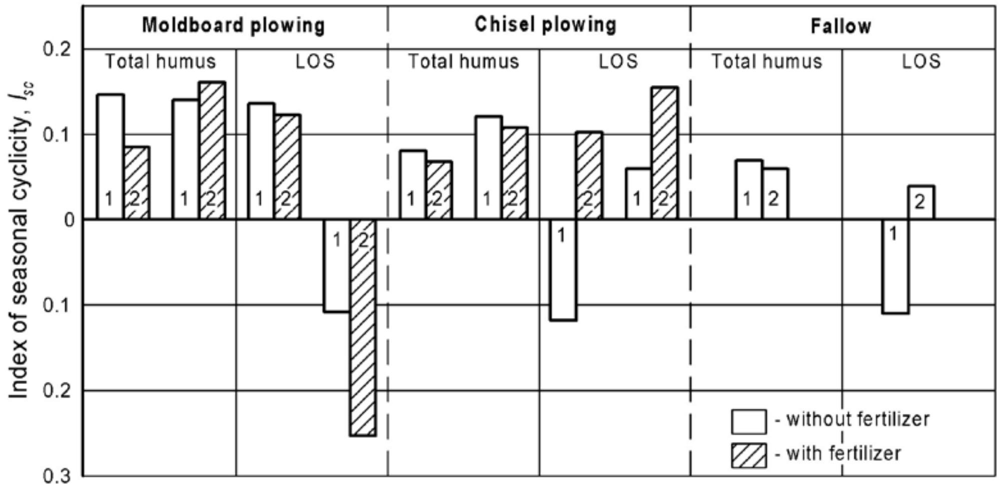
In July, the pattern was similar. In the control without fertilisers, the Porg(LOR) reserve was 2.1-2.5 times lower, and with fertilisers it was 2-3 times higher compared to the fallow. In September, without fertilisers, the POR stock for ploughing without fertilisers was 1.5-2.4 times lower, and for fertilisation it was 1.70-1.96 times higher than the stock on fallow land. The ratio of C-CO2 stocks of the soil to POC in the control without fertilizers was wide: 58-70 to 1 in April, 130-136 to 1 in July and 85-125 to 1 in September, indicating high rates of mineralisation and POC release. After fertilisation, the C-CO2 reserves of the ENT increased by 6.2 times (0-20 cm) and 4.7 times (0-30 cm) in April. In July - 8.8 times and 6.4 times, and in September - 3.1 and 3.54 times, respectively, for the soil layers.

At the same time, the ratio of C-CO2 stock of the ENV to Porg(ENV) on the fertilised background was wider: 127-132 to 1 in April, 38-132 to 1 in July and 95-136 to 1 in September, which indicates a more restrained mineralisation of the LOR and release of Porg(LOR) compared to the control without fertilisation. After fertilisation in September, the POM stock of ploughed soil had a steady upward trend in the 0-20 cm, 20-30 cm and 0-30 cm soil layers, but the organic phosphorus stock did not reach the level of April.

Under no-till cultivation, an increase in POM was found, which exceeded the increase under ploughing: in the 0-20 cm soil layer - by 3.7 times; in the 0-20 cm soil layer - by 2.7 times and in the 0-30 cm soil layer - by 3.4 times. With fertilisation, the stock of Rorg LOR increased 5 times (0-20 cm), 3 times (20-30 cm) and 4.3 times (0-30 cm).

Under no-till cultivation, the POM reserve was 1.13-1.16 times higher than under ploughing. With fertilisation, the PPG reserve in September exceeded the reserve in April by 1.10-1.55 times, but the enrichment was higher in no-till cultivation. The POM reserve relative to the control without fertiliser was 2.1-3.2 times higher in April, 4.7-7.8 times higher in July, and 2.3-3.7 times higher in September. With the application of fertilizers, the POM reserve in April increased by 1.27 times (0-20 cm) and by 1.16 times (0-30 cm). In July, the POM reserve increased by 1.45 times and 1.30 times, and in September - by 1.5 times and 1.44 times, respectively, for the soil layers. Relative to fallow land, the POR stock under no-till tillage was 2.1-2.4 times higher in April, 1.61-3.90 times higher in July, and 1.78-2.36 times higher in September.

The ratio of the C-CO2 stock of the LOR to the Rorg(LOR) in the thickness of 0-30 cm in April was: 115-147 to 1, in July 132-147 to 1, and in September 1.31-1.34 to 1. A higher ratio of C-CO2 stock to POM under no-till tillage compared to ploughing with fertilisation indicates lower mineralisation of C-CO2 in the soil and release of POM.



a)

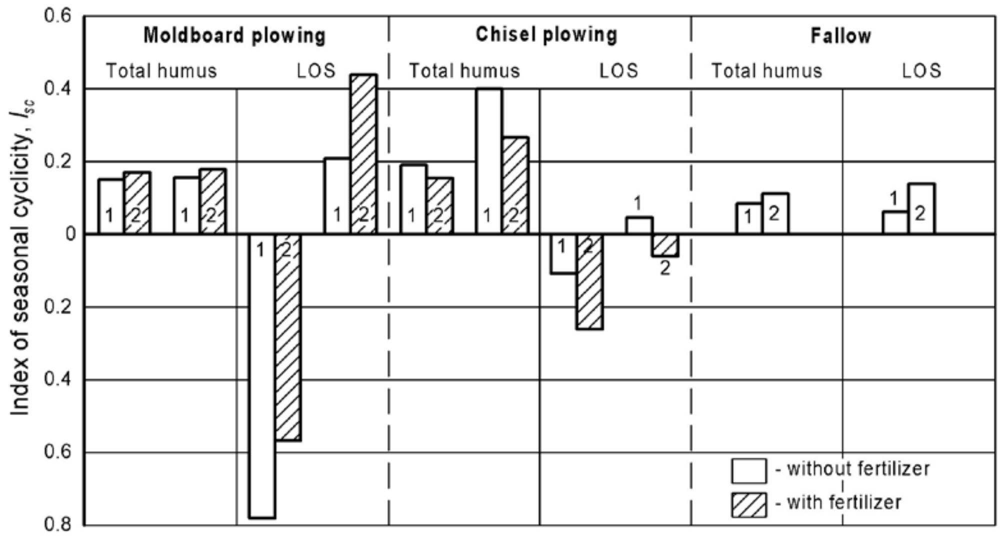


Fig. 2. Changes in the seasonal cyclicality index depending on fertiliser and cultivation method

To determine the index of seasonal cyclicality (Iц) of the humus state parameters, we propose to calculate it by the following expression:

Iц = Δk / Qmin, where Iц is the cyclicity index; Δk is the difference between the final (Lk - autumn) value of the parameter and the initial (Lp - spring); Qmin is the minimum value of the parameter (summer). It was found that under fallow land Iц the humus C-CO2 stock in the soil layers 0-20 cm and 0-30 cm was: Iц = 0.06 - 0.07, while under ploughing without fertilisation Iц increased by 2.15 times, and under moldboardless tillage it approached the value for fallow land. With fertilisation, Iц increased by 2.0-2.70 times and 1.74-1.80 times for both ploughing and no-till cultivation, respectively. The index of seasonal cyclicality of the C-CO2 stock of the

ENT under fallow in the 0-20 cm soil layers acquired a negative value, while in the 0-30 cm soil layer Iц=0.039 (Fig. 2).

Under ploughing without fertilisation, Iц acquired positive values, and with fertilisation, Iц values were negative: Iц=-0.108-0.25. Under moldboardless tillage without fertilisation, in the 0-20 cm soil layer, Iц was at the level of fallow land (Iц=-0.117), and in the 0-30 cm layer it reached the value of Iц=0.10. After fertilisation, the CI under no-till tillage had a positive value in the 0-20 cm and 0-30 cm layers: Iц = 0.06 and Iц = 0.16, respectively, while under ploughing, the values of Iц were negative, indicating a violation of seasonal cyclicality, and under moldboardless tillage, the process of restoring Iц in the direction of cyclicality when maintaining fallow land.

Trends in C-CO2 stocks of humus and SOC indicate that in the row ploughing-no-till-slash fallow, the CI under no-till tillage is closer to the value of the seasonal cyclicality of fallow than the seasonal cyclicality under ploughing, which indicates the recovery of CI in the latter case.

The index of seasonal cyclicality of the humus stock Rorg for keeping fallow in the soil layer 0-30 cm was Iц=-0.083-0.11, while under ploughing without fertilisation Iц was 1.75 times higher, and under moldboardless tillage - 2.24 times higher in the soil layer 0-20 cm, and in the thickness of 0-20 cm were at the level of fallow. After fertilisation, the CI for ploughing in the 0-30 cm layer increased by 1.63-185 times compared to fallow land, and under no-till tillage in the 0-20 cm layer was 5 times higher, and 2.6 times higher compared to ploughing. In the 0-30 cm layer, the CI increased by 2.4 times in comparison with fallow land and by 1.44 times in comparison with ploughing.

The index of seasonal cyclicality Rorg ENT under fallow land in the soil layer of 0-20 cm and 0-30 cm was Iц=0.065-0.14, while under ploughing without fertilizers Iц= -0.58-0.79, under moldboardless tillage Iц= -0.11-0.27. With fertilisation, Iц increased relative to fallow land by 3.10-3.15 times, and with no-tillage, Iц approached the values of fallow land.

However, the trends of changes in the stock of POR indicate that in the series of ploughing - no-till - fallow, no-till tends to be more seasonally cyclical. The general regularity of seasonal cyclicality for all parameters of humus state is that a decrease in the values of Iц , as in fallow land or under moldboardless tillage, indicates the ordering of Iц , and an increase in the index of cyclicality to destruction, as under ploughing.

Conclusions.

1. Under fallow land, the seasonal dynamics of humus C-CO2 and SOC stocks is subject to the seasonal dynamics of POC with a strong correlation at the level of R=+0.89±0.02; R2=79. In the period April - July, the decrease of Porg(ENT) stock in the thickness of 0-20 cm was 1.15 times, and in the thickness of 0-30 cm - 1.1 times. From summer to autumn, the stock of Rorg(LOR) was restored, and the stock of Rorg(LOR). in the thickness of 0-30 cm increased by 1.10 times.

2. Under no-till cultivation with fertiliser application, the increase in C-CO2 stock in the period April - July was: +21 t/ha (0-20 cm), and +36 t/ha (0-30 cm), and under ploughing, the growth tended to increase by 1.52 times (0-20 cm) and 1.25 times (0-30 cm), but occurred at a lower quantitative level, and in the period July -

September, the change in the humus C-CO2 stock was insignificant, indicating the predominance of C-CO2 sequestration processes in the summer - autumn period.

3. In April, under no-till tillage, the stock of LOR exceeded the stock under ploughing in the 0-30 cm thickness by 4.34-7.67 times (without fertilisers), 1.5-2.76 times (with fertilisers); in July - by 4.59-8.90 times (without fertilisers) and 1.32-3.16 times (with fertilisers); in September - by 4.52-4.04 times (without fertilisers) and by 1.11-1.93 times (with fertilisers), and the C-CO2 stock of the ENT compared to the fallow under no-till cultivation without fertilisers in April, July, September was 1.59-1.78 times, 2.31-3.29 times and 1.4-1.78 times higher, and with fertilisers - by 1.99-2.0, 1.86-4.50 and 1.7-2.6 times, respectively, depending on the seasons.

4. Trends in C-CO2 stocks of humus and SOC indicate that in the series ploughing-no-till-slow cropping, the cyclicality index in no-till cropping decreases and approaches the seasonal cyclicality of fallow land. However, the trends of changes in the RorgLOR stock indicate that in the series ploughing-less ploughing-slow cropping, the less ploughed ploughing also tends to fallow land in its seasonal cyclicality. The general regularity of seasonal cyclicality for all parameters of humus condition lies in the fact that a decrease in the values of Iц, as in fallow land or under no-till cultivation, indicates the ordering of Iц, and an increase in the index of cyclicality to the destruction of the natural order, as in ploughing.

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UDC 631.417.1: 631.417.2

Sequestration of seasonal change of organic carbon and humus phosphate stock under different tillage and fertilization

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The purpose of the study. To assess the sequestration capacity of C-CO_2 humus in soil formation and fertility of typical chernozem, to identify the causes, rates, existing limits of the sequestration capacity decrease, it is important to study the seasonal dynamics of qualitative and quantitative indicators of humus state in time depending on the method of tillage and fertilization in agrocenoses of short rotation crop rotations in the central part of the Forest-Steppe of Ukraine. Methods. **Field** - to establish and conduct a field stationary experiment to study the influence of tillage and fertilization methods on the sequestration capacity of chernozem; laboratory - to determine the humus content; calculation and statistical - to calculate seasonal stocks of sequestered carbon and phosphorus and to model the sequestration capacity of chernozem. **Results of the study.** Under no-till cultivation with fertilizer application, the increase in C-CO_2 stocks in the period April - July was +21 t/ha (0-20 cm) and +36 t/ha (0-30 cm). Under plowing, the growth tended to increase by 1.52 times (0-20 cm) and 1.25 times (0-30 cm), but occurred at a lower quantitative level, and in the period July - September, the change in the humus C-CO_2 stock was insignificant, indicating the predominance of C-CO_2 sequestration processes in the summer - autumn period under no-till cultivation. Under no-till tillage, the stock of SOC in April exceeded the stock for plowing in the thickness of 0-30 cm by 4.34-7.67 times (without fertilizers), 1.5-2.76 times (with fertilizers); in July - by 4.59-8.90 times (without fertilizers) and 1.32-3.16 times (with fertilizers); in September - by 4.52-4.04 times (without fertilizers) and by 1.11-1.93 times (with fertilizers), and the C-CO_2 stock of the ENT compared to fallow land under no-till cultivation without fertilizers in April, July, and September was 1.59-1.78 times, 2.31-3.29 times, and 1.4-1.78 times higher, and under fertilization - by 1.99-2.0, 1.86-4.50, and 1.7-2.6 times, respectively, depending on the seasons. Under fallow land maintenance, the seasonal dynamics of the C-CO_2 stock of the SOC is subject to the seasonal dynamics of Rorg(SOC). A direct strong correlation was found at the level of $R=+0.89\pm0.02$; R2=79. In the period April - July, the decrease of Porg(ENT) stock in the thickness of 0-20 cm was found to be 1.15 times, and in the thickness of 0-30 cm - 1.1 times. From summer to autumn, the stock of Rorg (ENT) was restored, and the stock in the thickness of 0-30 cm increased by 1.10 times. Conclusions. Trends in C-CO_2 stocks of humus and SOC indicate that in the series plowing-no-till-swidden land, the cyclicality index under no-till tillage was closer to the value of the seasonal cyclicality of fallow land than the seasonal cyclicality under plowing, which indicates the restoration of the CI. **Conclusions.** Trends in C-CO_2 stocks of humus and SOC indicate that in the series plowing-no-till-subsidence, the index of cyclicality under no-till cultivation was closer to the value of the seasonal cyclicality of fallow land than the seasonal cyclicality of plowing, which indicates the restoration of the IC. However, the timing of changes in the Rorg ENT stock indicates that in the series plowing-no-till-subsidence, no-till tillage is directed to fallow land by its seasonal cyclicality. The general regularity of seasonal cyclicality for all parameters of humus condition lies in the fact that a decrease in the values of Iц , as in fallow land or under moldboardless tillage, indicates the ordering of Iц , and an increase in the index of cyclicality to destruction, as under plowing.

Keywords: *organic carbon and phosphorus stocks, plowing, moldboardless tillage, trends in stock changes, lightly hydrolyzed organic matter*