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HUMUS BALANCE AND NUTRIENT REGIME OF IRRIGATED SOIL UNDER DIFFERENT SYSTEMS OF BASIC TILLAGE AND FERTILIZER

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Abstract

The article presents an analysis of the results of experimental research in a stationary field experiment to establish the peculiarities of the formation of humus reserves and nutrient regime in the arable layer of dark chestnut soil under the influence of different fertilizer systems and basic tillage. The purpose of research: to establish patterns of conversion of crop by-products of crop rotation into humus and the main elements of mineral nutrition of plants by organic and two organic-mineral fertilizer systems against the background of five systems of main cultivation in 4-field row crop rotation irrigation system in the area of the Ingulets irrigation system. The most favorable conditions for accumulation of leaf mass of crop rotation crops, the formation of a positive balance of humus with an average annual growth of 2.02 t/ha provided organic-mineral fertilizer system using by-products of crop rotations and doses of mineral fertilizers $N_{120}P_{60}$ *against the background of differentiated main cultivation with one slit to a depth of 38-40 cm per rotation.*

Key words: *row crop rotation, main tillage, fertilizers, humus, post-harvest residues.*

INTRODUCTION

The ability of the soil to create the necessary conditions for the development of crops and the formation of high yields is inextricably linked with the reserves of organic matter in it. It is known that humus determines favorable nutritional, water-air, thermal and biological regimes, soil structure, accumulation of physiologically active substances (Baliuk & Medvediev, 2012; Slepetiene & Slepetys, 2005).

In recent decades, the entry of organic matter into the soil is mainly due to post-harvest crop residues, which are energy material for microbiological processes, the formation of nutrients and the accumulation of humus. After all, each crop rotation, after fertilization, leaves in the irrigated soil a certain amount of roots, which becomes a source of humus - the most important indicator of fertility (Heitkamp et al., 2011).

As noted by GA Mazur, in recent years, due to the decline of the livestock industry, less than 1 t/ha of organic fertilizers have been applied annually, and humus losses have reached such proportions that 132 t/ha of litter manure is required to compensate for them without taking into account current humus mineralization processes (Mazur, 2013).

From one ton of the most nutrient-poor crop residues in the soil remains about 5 kg nitrogen, 1-1.5 - phosphorus, 8-10 - potassium and 3-4 kg - calcium. The remnants of green cereals contain the same amount of ash elements, but more nitrogen (10-15 kg/t). In general, it is 3-4 times less than required for a new harvest. Post-harvest residues of legumes enrich the soil the most (Kanivets, 2001).

Perennial grasses are able to leave behind 100 kg/ha or more of dry organic matter in the form of roots and aboveground post-harvest residues. Therefore, with the expansion of sown areas of these crops and especially alfalfa, the balance of humus will be positive, and a sharp deterioration of this balance will lead to an increase in the structure of sown areas of pure steam and row crops, in the fields of which and plant remains may be completely absent, as in the field of pure steam, or in most cases their

number may be insignificant (Yeshchenko et al., 2012).
Prolonged (26 years) agricultural use of typical chernozem without fertilizers has led to a decrease in humus content in the arable soil layer by 11% compared to baseline. The application of only mineral fertilizers to the soil was accompanied by a violation of the mineralization-immobilization balance in the direction of the predominance of mineralization and as a result the organic matter content decreased by 7.5% compared to the control. The use of manure in organic and organic-mineral fertilizer systems contributed to the maintenance of higher humus content (Skrylnyk et al., 2019).
According to a long experiment L Shedei on chernozem podzolic heavy loam application of mineral fertilizers together with cattle manure for a ten-year period did not ensure the accumulation of humus in the arable soil layer. Moreover, there was a tendency to reduce its content compared to baseline by 0.07% (Shedey, 2005).
The results of 27-year observations of changes in humus status in sod-podzolic sandy soil in the experimental 9-field crop rotation, depending on the use of different methods of basic tillage and fertilization systems proved that the use of by-products of grain and postharvest fertilizers in the background halved dose of fertilizers compared to conventional contributes to the accumulation of organic matter in the arable layer and can be a reserve for maintaining and reproducing soil fertility (Kochik, 2011).
Studies show that partial replacement of mineral fertilizers in crop rotation with alternative sources of nutrients allows you to create a resource-saving fertilizer system. Thus, reducing the dose of mineral fertilizers to 60% of the recommended against the background of plowing the post-harvest residues of previous crops crop rotation (straw of cereals, leaf mass of corn, soybeans, sunflowers) provides relatively high crop productivity and fertilizer yield (Maliarchuk et al., 2021).
Under the current conditions, the influence of methods and depth of basic cultivation, when using crop rotation by-products of crop rotation, on the direction of the processes of transformation, redistribution, mineralization and humification of fresh organic matter is insufficiently studied.
The influence of irrigation on the humus condition of soils is determined by the content and reserves of humus in the arable and 0-100 cm layer. The total balance of humus on irrigated and non-irrigated lands, judging by its reserves ranges from 100 tons on dark chestnut medium loamy soils to 230 and 520 t/ha on southern and ordinary chernozems, respectively (Saiko, 2006; Khruslova et al., 1991).
83% of its irrigated fund is concentrated in the southern region of Ukraine. However, in recent years the irrigation potential is not fully used and less efficiently (Vozhehova et al., 2014).
Under conditions of strong irrigation impact on soils, such forms of degradation as dehumi-dification, decalcification, compaction, reduction of water permeability and water content, increase of moisture loss due to runoff, reduction of soil biogenicity, crop quality and pollution of water sources with harmful elements and compounds (Tweeten & Thompson, 2002; Pavlichenko et al., 2014).
During irrigation with mineralized waters in the steppe agricultural zone of Ukraine, soil depletion of carbon dioxide and calcium is often observed, the content of exchangeable sodium increases and the leptization of soil colloids, compaction, formation of lumpy structure is revealed (Tarariko, 2011).
Irrigation water affects the soil, changes the rate and direction of chemical and microbiological processes, as well as the conditions of decomposition of organic matter (Pavlichenko et al., 2014).
According to scientific conclusions, many scientists irrigation with mineralized water, practiced on the Ingulets irrigation massif, has a negative effect on the soil, in connection with which its treatment under irrigated conditions plays an important role in improving the physical and chemical condition of the soil and related properties (Rusu et al., 2013).
Irrigation with a significant increase in water inflow into the geographical landscape, especially into the soil, leads to the formation of a number of new properties and reduce their potential fertility (Markovska et al., 2016; Matsko et al., 2002).
In connection with the above, the development of new and improvement of existing systems of

fertilizers and basic tillage when using crop by-products of crop rotations on irrigated lands is relevant and requires in-depth experimental research.

The aim of the research is to establish the regularities of crop by-products conversion of crop rotation to humus and basic elements of mineral nutrition of plants under organic and organic-mineral fertilizer systems against different main tillage systems in 4-field row crop rotation on irrigated lands in the Ingulets irrigation system.

MATERIALS AND METHODS

The research was conducted in a stationary experiment of the Institute of Irrigated Agriculture of NAAS of Ukraine during 2016-2020 in a 4-field row crop rotation on irrigation in the area of the Ingulets irrigation system.

The soil of the experimental field is dark chestnut medium loam; the arable layer contains humus 2.06%, total nitrogen content - 20.0, mobile phosphorus 30.0, potassium - 300.0 mg/kg of soil, the lowest moisture content - 21.2%, wilting moisture - 9.1%, the equilibrium density of the structure is 1.41 g/cm^3.

To characterize the nutrient regime (NPK content), soil samples were taken twice during the growing season – at the time of emergence and before harvest. The experiments determined the content of nitrates according to Kravkov, mobile phosphorus was determined according to Machigin, exchangeable potassium on the flame photometry, the humus content was determined by the method of IV Tyupin-Kononova (DSTU 4114-02, 2002; DSTU 4362: 2004, 2006).

The 4-field crop rotation included: corn for grain, winter wheat, grain sorghum and soybeans. In field experiments, soybean varieties and hybrids of agricultural crops, entered in the "State Register of Plant Varieties Suitable for Distribution in Ukraine", were sown (State Register of Plant Varieties Suitable for Distribution in Ukraine for 2021, 2021).

Crop rotation technologies are generally accepted for irrigated conditions, except for the factors studied. The irrigation regime ensured the maintenance of the pre- irrigation moisture threshold under the crops of all crop rotation crops at the level of 70% of the lowest soil moisture content in the soil layer 0-50 cm.

In crop rotation, five systems of basic tillage (Factor A) with different methods, techniques and depth of loosening on the background of organic and two organic-mineral fertilizer systems (Factor B) were studied.

Factor A - tillage:

1. Different-depth main tillage with a plow PLN-5-35 with rotation of the slice to a depth of 14-16 to 25-27 cm depending on the crop rotation - CONTROL;
2. Different-depth main tillage with the plow PCH-2,5 without rotation of the slice with chisel loosening of the soil to a depth of 14-16 to 25-27 cm, depending on the crop rotation;
3. Single-depth shallow tillage with a heavy disc harrow BDVP-4,2 without rotation of the slice with loosening to a depth of 12-14 cm for all crop rotations;
4. Differentiated-1 tillage with shallow disc loosening for corn for grain and winter wheat to a depth of 8-10 cm using a disc light harrow BDLP-4, soybean heavy disc harrow BDVP-4.2 to a depth of 14-16 cm, and for sorghum grain combined tillage with the use of disco-chisel harrow BDVP-3,0-0,1 with a depth of loosening of 12-14 + 38-40 cm;
5. Differentiated-2 tillage with plowing plow PLN-5-35 for corn to a depth of 18- 20 cm, chisel tillage for sorghum grain plow PCH-2.5 to a depth of 16-18 cm and shallow disc loosening BDLP-4 for wheat winter (10-12 cm) and BDVP-4.2 under soybeans (14-16 cm)

Factor B - fertilizer system:

- Organic - using only by-products of crops crop rotation (background) - CONTROL;
- Organic-mineral – mineral fertilizers with a dose of $N_{82.5}P_{60}$ + by-products;
- Organo-mineral – mineral fertilizers with a dose of $N_{120}P_{60}$ + by-products.

During the experiment, field, quantitative-weight, visual, laboratory, calculation-comparative, mathematical-statistical methods were used using generally accepted in Ukraine methods and methodological recommendations (Vozhegova et al., 2014).

To analyze the effectiveness of the combined use of fertilizer systems and basic tillage, the following indicators were used: the mass of post-harvest residues for each crop rotation; stocks of humus in the arable layer; humus balance; mass of nitrogen, phosphorus and potassium received in the soil with plant residues; ecological and economic effect (UAH/ha); energy increase (GJ/ha).

Receipts of plant residues, stem and root, were determined by the regression equation from the level of yield of the main product.

Changes in humus stock were calculated depending on the mass of by-products and mass of roots, their humification coefficient, humus mineralization coefficient.

The calculation of the supply of basic nutrients to the soil, depending on the fertilizer systems, was carried out taking into account the amount of nutrients received from mineral fertilizers and root and leaf residues.

The humus balance was calculated by the difference between the total weighted average of the newly created, due to the humification of postharvest residues (leaf and root) and mineralization of humus under crops of crop rotation.

Ecological and economic efficiency of organo-mineral fertilizer systems used in the cultivation of crops was determined taking into account production costs, the yield of fertilizers, the cost of their application and harvesting separately for each variant of the experiment, taking into account the growth of humus (Filip'ev I.D. et al., 2001).

RESULTS AND DISCUSSIONS

Organic and organic-mineral fertilizer systems using fertilizer for post-harvest crop residues in modern conditions have become the main source of organic matter in the soil. Due to the methods and depth of the main tillage, post-harvest residues fall into different hydrothermal conditions of the arable layer, which changes the nature and intensity of their decomposition.

According to the results of research it is established that on average for one year of crop rotation the inflow of postharvest residues (leaf-stem and root) under the organic fertilizer system per 1 hectare of crop rotation area in the variant of different depths of the main tillage system 4.8 t, with different depth tillage without rotation of the chip (2nd) - 4.5 t, single- depth shallow disk (3rd) - 3.9 t, differentiated-1 and differentiated-2 - 4.9 and 4.2 tons, respectively.

The organic-mineral fertilizer system with the application of mineral fertilizers with a dose of $N_{82.5}P_{60}$ in the soil earned an average of 7.4 to 8.6 tons of post-harvest residues per year, and the organic-mineral fertilizer system with a dose of mineral fertilizer $N_{120}P_{60}$ from 7.5 to 9.7 t/ha (Table 1).

Table 1. Receipt of post-harvest residues of agricultural crops in the soil under different systems of fertilization and cultivation in crop rotation under irrigation, on average for 2016-2020

Basic tillage system	Mass of postharvest residues, t/ha per year			
	grain corn	winter wheat	grain sorghum	soybeans
Organic fertilizer system (post-harvest residues - background) - control				
1- With the rotation of the slices, different depths	5.2	5.7	5.2	2.9
2- Without rotation of the slice, different depths	4.8	5.6	4.6	2.8
3- Without rotation of the slice, single- depth (12-14 cm)	3.8	5.2	4.1	2.3
4- Differentiated-1	5.4	5.8	5.4	3.0
5- Differentiated-2	4.0	5.4	4.6	2.8
Organic-mineral fertilizer system ($N_{82.5}P_{60}$ + background)				
1- With the rotation of the slices, different depths	13.4	8.1	8.2	3.5
2- Without rotation of the slice, different depths	12.5	7.8	8.0	3.3
3- Without rotation of the slice, single- depth (12-14 cm)	11.9	7.6	6.8	3.1
4- Differentiated-1	13.7	8.4	8.7	3.6
5- Differentiated-2	10.7	7.8	7.8	3.1
Organic-mineral fertilizer system ($N_{120}P_{60}$ + background)				
1- With the rotation of the slices, different depths	16.2	9.0	8.5	3.9
2- Without rotation of the slice, different depths	14.9	8.6	8.3	3.7
3- Without rotation of the slice, single- depth (12-14 cm)	11.6	8.1	6.9	3.3
4- Differentiated-1	16.7	9.2	9.0	3.7
5- Differentiated-2	12.3	7.9	8.1	3.4

Calculations of humus formation in the soil from wrapped post-harvest residues under different systems of basic tillage and fertilizer show that against the background of the organic fertilizer system a negative balance of humus is formed, while the largest deficit was found for single- depth shallow (12-14 cm) without rotation of the slice - 0.37 t/ha, and the smallest - 0.14 t/ha for differentiated-1 (Table 2).

Table 2. Estimated balance of humus for different fertilizer systems and basic tillage in crop rotation, average data for 2016-2020 in a layer of 0-40 cm

Components of the balance sheet	Variants of the main tillage system				
	with the rotation of the slices, different depths (control)	without rotation of the slice, different depths	without rotation of the slice, single- depth (12-14 cm)	differentiated-1	differentiated-2
Organic fertilizer system (post-harvest residues - background) - control					
Mass of residues, t/ha	4.8	4.5	3.9	4.9	4.2
Increase in humus, t/ha	1.0	0.94	0.81	1.02	0.88
Humus mineralization, t/ha	1.18	1.18	1.18	1.18	1.18
Humus balance, t/ha	-0.18	-0.24	-0.37	-0.16	-0.30
Organic-mineral fertilizer system ($N_{82.5}P_{60}$ + background)					
Mass of residues, t/ha	8.3	7.9	7.4	8.6	7.4
Increase in humus, t/ha	1.73	1.65	1.54	1.79	1.54
Humus mineralization, t/ha	1.18	1.18	1.18	1.18	1.18
Humus balance, t/ha	+0.55	+0.47	+0.36	+0.61	+0.36
Organic-mineral fertilizer system ($N_{120}P_{60}$ + background)					
Mass of residues, t/ha	9.4	8.9	7.5	9.7	7.9
Increase in humus, t/ha	1.96	1.85	1.56	2.02	1.65
Humus mineralization, t/ha	1.18	1.18	1.18	1.18	1.18
Humus balance, t/ha	+0.78	+0.67	+0.38	+0.84	+0.47

According to the organic-mineral fertilizer system with the introduction of $N_{82.5}P_{60}$ there is an increase in humus. In the variant of differentiated-1 cultivation, the increase in humus reserves compared to the control was 10.9%, while in different depths without rotation of the slice, it was lower by 14.5%. With the systems of single-depth shallow and differential-2, the increase in humus reserves was lower compared to the control by 34.5%.

Increasing the dose of mineral fertilizer to $N_{120}P_{60}$ against the background of by-products provided a further increase in the growth of humus reserves; at the same time, the regularity observed for the doses of mineral fertilizer $N_{82.5}P_{60}$ was preserved. It should be noted that at the increased dose of mineral nutrition in variants of different depths with rotation of the slice, and without and differentiated-1 cultivation, the average annual increase in humus reserves increased by 13.2; 12.0; 12.3%, and for differentiated-2 and single-depth without rotation shallow slices - only 7.1 and 1.2%, respectively.

Based on the mass of post-harvest residues, the inflow of nitrogen, phosphorus and potassium into the soil with root and leaf residues was calculated, which is a compensation for the removal of mineral nutrients from the crop yield. Thus, with the organic fertilizer system in the variant of differentiated-1 tillage with one slit by 38-40 cm per crop rotation there is an increase in the supply of mineral nutrients compared to the system of different depths of main tillage with rotation of the slice (control) on N and K_2O by 3.4%, and P_2O_5 at 3.7%.

A similar pattern, but with higher values, is noticeable in organo-mineral fertilizer systems.

Under the organic-mineral fertilizer system with the application of a dose of mineral fertilizers $N_{82.5}P_{60}$ with post-harvest residues in the soil received nitrogen, phosphorus and potassium by 68-80% more than organic.

The inflow of nitrogen, phosphorus and potassium into the soil under the organic-mineral fertilizer system with the application of mineral fertilizers $N_{120}P_{60}$ was the highest for differentiated-1 tillage and increased compared to different depths of plowing by 6.0-11.1%.

Only in the variant of single-depth shallow without rotation of the slice of the tillage system with its long-term use in crop rotation for organic and organic-mineral fertilizer systems there was a significant decrease in all mineral nutrients compared to different depth tillage with rotation of the slice (Table 3)

Table 3. Nutrient uptake into the soil with post-harvest crop residues of crop rotation under different fertilizer systems and basic tillage

Basic tillage system	Mass of nutrients in post-harvest residues, kg/ha per year		
	N	P_2O_5	K_2O
Organic fertilizer system (post-harvest residues - background) - control			
1- With the rotation of the slices, different depths	21.7	10.9	26.1
2- Without rotation of the slice, different depths	20.3	10.2	24.4
3- Without rotation of the slice, single-depth (12-14 cm)	17.6	8.8	21.1
4- Differentiated-1	22.5	11.3	27.0
5- Differentiated-2	19.3	9.6	23.1
Organic-mineral fertilizer system ($N_{82.5}P_{60}$ + background)			
1- With the rotation of the slices, different depths	38.7	19.4	46.4
2- Without rotation of the slice, different depths	37.1	18.6	44.5
3- Without rotation of the slice, single-depth (12-14 cm)	29.5	14.8	35.4
4- Differentiated-1	41.2	20.8	49.5
5- Differentiated-2	36.0	18.0	43.2
Organo-mineral fertilizer system ($N_{120}P_{60}$ + background)			
1- With the rotation of the slices, different depths	43.4	21.7	52.1
2- Without rotation of the slice, different depths	41.8	20.9	50.1
3- Without rotation of the slice, single-depth (12-14 cm)	33.0	16.5	39.2
4- Differentiated-1	46.1	24.1	55.2
5- Differentiated-2	41.3	20.7	49.6

In general, the application of mineral fertilizers and the use of post-harvest (leaf and root) residues on fertilizers contributed to the creation of different levels of available forms of mineral nutrients at the beginning of the spring winter vegetation and the emergence of spring cereals and industrial crops.

In order to assess the environmental and economic efficiency (EEE) of basic tillage systems, energy and monetary equivalents were assessed not only on the components of crop production technologies and material and technical means for their implementation, but also on crop and humus growth. The calculation is made on the variant of organic-mineral fertilizer system with doses of mineral fertilizers $N_{120}P_{60}$.

It was found that due to increased crop yields and increased humus reserves in the soil layer 0-40 cm energy increase compared to the system of different depths of main tillage with rotation of the slice (used as a control option), provided only differentiated-1 system of basic tillage, in which one splitting for crop rotation alternated with shallow loosening without rotation of the slice under the grain and soybeans. The increase in energy in this variant due to yield and humus was higher than in the control by 8.9% (Table 4).

Systems of different depth and single-depth main tillage without rotation of the chips on the contrary led to a reduction in energy growth compared to control primarily due to poor yields, and in the case of long-term use of shallow single-depth shelfless loosening also due to lower rates of humus accumulation. The decrease in the average annual increase in energy due to harvest and humus was 7.8 and 37.8%, respectively. The system of differentiated-2 main cultivation with one plowing per crop rotation also led to a reduction in energy growth due to yield and humus.

As a result of calculations it is established that the highest total ecological and economic effect was provided by the differentiated-1 system of the main cultivation with one crack on depth of 38-40 cm once for rotation and organo-mineral system of fertilizer with $N_{120}P_{60}$ and use of postharvest residues, which is higher than the control by 8.9%. In the variant of single-depth shallow (12-14 cm) cultivation without rotation of the chip, the reduction of the total ecological and economic effect reached 37.8%, and with different depth without rotation of the chip and differentiated-2 – 7.8 and 7.4% (Table 4).

Table 4. Ecological and economic efficiency of 4-field row crop rotation on irrigation under different systems of basic cultivation of dark chestnut soil, fertilizer dose $N_{120}P_{60}$

Basic tillage system	Energy increase, GJ/ha			EEE, UAH/ha	
	total	including due to:		total average	± to control
		harvest	humus		
1- With the rotation of the slices, different depths	132.0	120.6	11.4	63650.4	-
2- Without rotation of the slice, different depths	121.7	111.9	9.8	58683.7	- 4966.7
3- Without rotation of the slice, single-depth (12-14 cm)	82.1	77.4	4.7	39588.6	- 24061.8
4- Differentiated-1	143.8	130.7	13.1	69340.4	+ 5690.0
5- Differentiated-2	122.3	112.3	10.0	58973.1	- 4677.3
Note. EEE - environmental and economic effect					

Estimation of yield and humus growth in monetary terms made it possible to determine that the highest total ecological and economic effect is provided by differentiated-1 system of basic tillage against the background of organo-mineral fertilizer system using all by-products of crop rotation and application of mineral fertilizers $N_{120}P_{60}$

CONCLUSIONS

As a result of research, it was found that the most favorable conditions for the accumulation of leaf mass of crop rotation crops, the formation of a positive balance of humus with an average annual growth of 2.02 t/ha provided organic-mineral fertilizer system using by-products of crop rotation and fertilizer dose $N_{120}P_{60}$ background of differentiated main tillage with one for rotation slitting to a depth of 38-40 cm.

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