ЗЕМЛЕРОБСТВО І РОСЛИННИЦТВО

DOI: 10.32636/01308521.2022-(72)-2-1
UDC 631.582:633.1:631.81

O. Y. KACHMAR[1], A. O. DUBYTSKA[1], candidates of agricultural sciences
M. M. SHCHERBA[1], I. V. SAVERYN[1], researchers
O. V. TARAVSKA[1], senior specialist
A. I. VOVK[2], Z. O. KOTYK[2], candidates of technical sciences
[1]Institute of Agriculture of Carpathian Region of NAAS
Hrushevskoho street, 5, v. Obroshyne, Lviv district, Lviv region,
81115, e-mail: oksanaostrowska@ukr.net
[2]Lviv Polytechnic National University
Karpinskoho street, 6, Lviv, 79013, e-mail: andrii.i.vovk@lpnu.ua

REDISTRIBUTION OF NUTRIENT ELEMENTS OF GRAY FORESTAL SOIL UNDER GRAIN CROPS IN SHORT-ROTATION CROP ROTATIONS UNDER DIFFERENT FERTILIZATION SYSTEMS

In the conditions of short-rotation crop rotations, the influence of fertilization systems and precursors on the nutrient regime of grey forestal soil under winter wheat and spring barley was investigated.

It was established that the highest content of nutrients under winter wheat and spring barley is formed in the conditions of the traditional fertilization system. During the direct application of 40 t/ha of manure to winter wheat in combination with mineral fertilizers in a dose of $N_{60}P_{90}K_{90}$ in the phase of vegetation recovery of the crop in the arable layer of the grain crop rotation, the concentration of alkaline hydrolyzable nitrogen compounds was 13.51 mg kg^{-1} of soil, mobile forms of phosphorus and potassium were 14.20 and 12.00 mg kg^{-1} of soil. By the application under spring barley of the complex $N_{60}P_{60}K_{60}$ + byproducts of the precursor of winter wheat in the grain-forage and $N_{60}P_{60}K_{60}$ in the crop rotation in the seedling phase, 12.34-12.40 mg kg^{-1} of soil alkaline hydrolysis nitrogen was formed, 12.72-12.81 and 11 .28-11.44 mg kg^{-1} of the soil of mobile forms of phosphorus and potassium

Higher values of mobile compounds of the main nutrients of plants under winter wheat are formed after the precursors meadow clover and peas. The lowest values are observed in repeated sowings: in the phase of recovery of crop vegetation on unfertilized variants in crop rotation with the predecessor of meadow clover the content of mobile forms of nitrogen, phosphorus and potassium amounted to 10.81, 10.93 and 9.71 mg kg^{-1} of soil, in grain with a predecessor of peas it was 10.72, 11.11 and 10.19 mg kg^{-1} of soil, in repeated sowings of winter wheat in grain rotation 10.19, 10.86 and 9.79 mg kg^{-1} of soil.

Before the end of the vegetation season of winter wheat and spring barley, the content of nutrients decreased and equalized by the absolute intervariant values due to their use by plants for growth, development and crop formation.

The use of organo-mineral fertilization systems ensured an increase in the level of provision of the soil environment with organic substances. Under the alternative fertilization system, the amount of by-products after meadow clover was 8.20-9.00 t/ha, corn for grain – 6.74 t/ha, winter wheat – 4.63-5.25 t/ha, and with growing it in repeated crops – 5.06-5.27 t/ha. Potatoes grown under an alternative fertilization system in crop rotation formed 2.43-2.56 t/ha, and buckwheat – 2.86 t/ha of by-products. Under the traditional fertilization system, this indicator was the highest among all cultivated crops.

Keywords: short-rotation crop rotations, winter wheat, spring barley, fertilization systems, nutrients, plant residues.

Качмар О. Й.[1], Дубицька А. О.[1], Щерба М. М.[1], Саверин І. В.[1], Таравська О. В.[1], Вовк А. І.[2], Котик З. О.[2]

[1]Інститут сільського господарства Карпатського регіону НААН

[2]Національний університет «Львівська політехніка»

Перерозподіл елементів живлення сірого лісового ґрунту під зерновими культурами в короткоротаційних сівозмінах за різних систем удобрення

В умовах короткоротаційних сівозмін досліджено вплив систем удобрення та попередників на поживний режим сірого лісового ґрунту під пшеницею озимою та ячменем ярим.

Встановлено, що найвищий вміст елементів живлення під пшеницею озимою та ячменем ярим формується в умовах традиційної системи удобрення. За безпосереднього внесення під пшеницю озиму 40 т/га гною в поєднанні мінеральними добривами в дозі $N_{60}P_{90}K_{90}$ у фазі відновлення вегетації культури в орному шарі зернової сівозміни концентрація сполук легкогідролізного азоту становила 13,51 мг кг$^{-1}$ ґрунту, рухомих форм фосфору й калію – 14,20 й 12,00 мг кг$^{-1}$ ґрунту; від застосування під ячмінь ярий комплексу $N_{60}P_{60}K_{60}$ + побічна продукція попередника пшениці озимої в зерно-кормовій та $N_{60}P_{60}K_{60}$ у плодозмінній сівозмінах у фазі сходів формувалося 12,34–12,40 мг кг$^{-1}$ ґрунту легкогідролізного азоту, 12,72–12,81 й 11,28–11,44 мг кг$^{-1}$ ґрунту рухомих форм фосфору й калію.

Вищі значення рухомих сполук основних елементів живлення рослин під пшеницею озимою формуються після попередників конюшина лучна й горох, найнижчі показники спостерігаються в повторних посівах: у фазі відновлення вегетації культури на неудобрених варіантах у плодозмінній сівозміні з попередником культури конюшина лучна вміст рухомих форм азоту, фосфору й калію становив 10,81; 10,93 й 9,71 мг кг$^{-1}$ ґрунту, у зерновій з попередником горох – 10,72; 11,11 й 10,19 мг кг$^{-1}$ ґрунту, у повторних посівах пшениці озимої в зерновій сівозміні – 10,19; 10,86 й 9,79 мг кг$^{-1}$ ґрунту.

До закінчення вегетації пшениці озимої та ячменю ярого вміст елементів живлення знижувався і вирівнювався за абсолютними міжваріантними значеннями внаслідок використання їх рослинами для росту, розвитку й формування врожаю.

Застосування органо-мінеральних систем удобрення збільшувало рівень забезпеченості ґрунтового середовища органічними речовинами. За альтернативної системи удобрення кількість побічної продукції після конюшини лучної була 8,20–9,00 т/га, кукурудзи на зерно – 6,74 т/га, пшениці озимої – 4,63–5,25 т/га, а при її вирощуванні в повторних посівах – 5,06–5,27 т/га. Картопля, вирощена за альтернативної системи удобрення у сівозміні, формувала 2,43–2,56 т/га, а гречка – 2,86 т/га побічної продукції. За традиційної системи удобрення цей показник був найвищим за всіма вирощуваними культурами.

Ключові слова: короткоротаційні сівозміни, пшениця озима, ячмінь ярий, системи удобрення, елементи живлення, рослинні рештки.

Introduction. An important condition for the efficient management of agricultural production, the achievement of the highest possible level of realization of the productive potential of agricultural crops and the obtaining of significant values of ecologically and economically reasonable yields is the provision of high soil fertility during the entire vegetation period of plants, which is determined by a complex of water-physical, agrochemical and microbiological properties [2, 8, 17, 18, 26]. Agrochemical characteristics depend on the intensity of the soil processes of accumulation, destruction, synthesis and transformation of substances and determine the nutrient regime of the soil environment, the main management measures of which are the implementation of scientifically based crop rotations and the use of organo-mineral fertilization systems [3, 10, 14, 30, 33].

In crop rotation, the genetically determined productive capacity of soils and the yield potential of agricultural plants are most fully implemented, it determines the systems of fertilization, mechanical tillage and protection of crops from weeds, pests and pathogens, ensures the natural supply of plant residues, which contribute to the return to the soil environment of significant parts of macro- and microelements, serve as energy material for soil microflora, determine the biogenicity of soils and their humus content [1, 6, 13, 15, 16, 25, 36].

Organo-mineral fertilizer complexes based on both traditional (cattle manure) and alternative (plant by-products, post-harvest siderates) components have the highest effect on optimizing the nutrient regime of soils, the accumulation of water-soluble and exchangeable forms of the main nutrients, and the transformation of the biological substrate [4, 5, 7, 28, 37].

With their use, a special trophic environment is formed in the soil, which stabilizes the organic colloidal complex, and increases the proportion of its saturation with exchangeable forms of nutrients. Mineralization of organic matter introduced into the soil environment by microbial cenosis, and involvement of its decay products in the biological cycles of the circulation of substances contributes to the improvement of agrochemical indicators, as well as a higher level of supply of plants with nutrients [12, 24, 29, 31, 34, 35].

This is extremely important in the development of fertilization systems, since in conditions of high anthropogenic loads on the soil, with the harvest occurs a significant alienation of part of the created organic matter, and therefore of the nutrients and energy contained in it, which, in turn, leads to less bioproductivity of agrocenosis [27, 32].

Therefore, the management of the nutritional regime of plants involves the introduction of rational, balanced fertilization systems that would meet the needs of crops in nutrients throughout the growing season, contribute to their return to the soil with plant residues, restore soil reserves and ecological balance in agricultural landscapes [9, 11, 18, 19].

Materials and methods. The research was conducted during 2016-2020 at the experimental ground of the Institute of Agriculture of the Carpathian Region, which is located in the village Stavchany of Lviv district, Lviv region. The study was carried out in the conditions of a two-factor stationary experiment, which has the status of long-term and entered into the Register of stationary experiments of Ukraine (certificate number – 053). The experiment was established in 2001 on grey forestal surface-gleyed soil. The number of researched factors is 2 (areas of the first order – systems of short-rotation crop rotations, second – fertilization systems).

The experiment studies 9 different field crop rotations (3-4-5-field) with saturation with grain crops (s.g.c.) from 50% to 100%, on the options of using traditional (combination of mineral fertilizers and manure) and alternative (combination of mineral fertilizers, straw, harvest siderates) organo-mineral fertilization systems and without fertilization (control). The experimental data covered in this article were obtained from seven crop rotations of the experiment: 1) peas – winter wheat – winter wheat – oats (four-field grain, 100% s.g.c.); 2) peas – winter wheat – corn (grain) – oats (four-field grain, 100% s.g.c.); 3) meadow clover – winter wheat – winter wheat – spring barley + meadow clover (four-field grass-grain, 75% s.g.c.); 4) meadow clover – winter wheat – potato – spring barley + meadow clover (four-field crop rotation, 50% s.g.c.); 5) buckwheat – winter wheat – potato – spring barley (four-field grain-weed removing, 75% s.g.c.); 6) corn (green mass) – winter wheat – buckwheat – soybean – winter wheat (five-field grain-weed removing, 80% s.g.c.); 9) winter wheat – winter wheat – fodder beans (triple-field, 66% s.g.c.). In the traditional system of fertilization on the background of manure (40 tons once per crop rotation under weed removing crops, and in the 1st and 3rd crop rotations – under winter wheat in repeated sowings), mineral fertilizers were applied in the dose: under winter wheat $N_{60}P_{90}K_{90}$, spring barley – $N_{60}P_{60}K_{60}$, oats – $N_{40}P_{40}K_{40}$, buckwheat – $N_{60}P_{60}K_{60}$, peas – $N_{45}P_{45}K_{45}$, soy – $N_{45}P_{45}K_{45}$, potatoes – $N_{90}P_{90}K_{90}$, corn – $N_{120}P_{100}K_{100}$. In an alternative system with half doses of mineral fertilizers on the background of ploughing all the by-products (bp.) of the cultivated crops once per rotation, oil radish was sown post-harvest as siderate (under the same crops where manure was applied in the traditional system, at the same time, full doses of mineral nutrition were applied). In the three-field crop rotation, one (mineral) fertilizer system was applied with $N_{60}P_{90}K_{90}$for winter wheat, and $N_{45}P_{45}K_{45}$ for fodder beans. The options were repeated three times, the location was consecutive. The total area of the site according to the crop rotation factor was 864 m^2 (72 m x 12 m), by fertilizer: total area 96 m^2 (12 m x 8 m), accounting area – 60 m^2 (10 m x 6 m). The introduction of crops into the crop rotation was carried out simultaneously on all fields.

The influence of fertilization systems on changes in the nutritional regime was studied under winter wheat of the Poliska 90 variety, spring barley of the Kniazhyi variety.

The soil of the experimental plots – gray forestal surface-gleyed coarse dusty light-loamy with the following agrochemical properties (before the experiment): humus content 1.67-1.71%, the number of absorbed bases 4.4-5.0 mg-eq kg^{-1} of soil, easily hydrolyzable nitrogen 9.2-9.9, mobile phosphorus and exchangeable potassium 10.8-11.13 and 9.3-9.5 mg kg^{-1} soil, respectively. The reaction of the soil solution is pH_{KCl} 4.70-4.84, hydrolytic acidity 2.26 mg-eq kg^{-1} of soil.

The selection of soil samples of experimental variants and their preparation for laboratory and analytical work was carried out in accordance with DSTU 4287:2004 [22] and DSTU ISO 11464-2001 [23]. The following soil samples were determined: easily hydrolyzable nitrogen – according to Kornfield (DSTU 7863:2015) [20]; mobile phosphorus and exchangeable potassium according to Kirsanov (DSTU 4405:2005) [21].

The values of the listed indicators were determined from the arable (0-20 cm) and sub-arable (20-40 cm) layers for five years (2016-2020) in 3 repetitions and in 2 analytical parallels (in general for each of the layers, n = 30).

In the conducted research, general scientific and special research methods were used. With the help of a field experiment, data on the variability of nutrients under the influence of agrotechnological factors were obtained; by the laboratory-analytical methods – quantitative characteristics of the redistribution of mobile compounds of nitrogen, phosphorus and potassium in the soil environment were established; by the calculation-comparative methods – the number of changes in the studied indicators was substantiated.

Results and discussion. The nutritional regime is an important factor in increasing the production process of agricultural crops and an ecological indicator of maintaining soil fertility [3, 8, 25]. In order to ensure high yields of agricultural crops, it is extremely important to provide them with a sufficient amount of nutrients during the entire growing season. In different periods of life and development, plants need different amounts of them. Conditionally, this need can be represented parabolically: in the initial phenological phases and during ripening, it is smaller, and during the time interval of active growth and development of the plant, it gradually increases, approaching the peak during the formation of fruits, and then gradually decreases as they ripen.

Therefore, it is important to study the impact of agrotechnological factors on the dynamics of mobile compounds of nitrogen, phosphorus and potassium as the main elements of plant nutrition.

The studies conducted under the conditions of a stationary experiment under winter wheat established (Table 1) that at the time of sowing the crop in the arable layer on the control variants, the highest values of easily hydrolyzable nitrogen were in the crop rotation with the predecessor meadow clover (10.38 mg kg^{-1} soil) and in grain rotation after the predecessor of peas (10.31 mg kg^{-1} soil). The maximum availability of mobile forms of phosphorus on unfertilized variants was observed in grain-weed removing crop rotations: after buckwheat (10.89 mg kg^{-1} of soil) and after soybeans (10.72 mg kg^{-1} of soil). Without the use of fertilizers, a higher level of plant-available forms of potassium was noted in the grain-weed removing rotation after the predecessor of soybeans (9.88 mg kg^{-1} of soil) and in the grain rotation after peas (9.80 mg kg^{-1} of soil). In the phase of recovery of winter wheat vegetation on the background (unfertilized) variants, the best nutritional regime was formed in the crop rotation with the precursor of meadow clover culture (the content of mobile forms of nitrogen, phosphorus and potassium was 10.81, 10.93 and 9.71 mg kg^{-1} of soil) and in grain rotation with a predecessor of peas (by the nutrients, 10.72, 11.11 and 10.19 mg kg^{-1} of soil). The lowest values of the nutritional regime (10.19, 10.86 and 9.79 mg kg^{-1} of soil) were in grain rotation in repeated sowings of winter wheat.

1. Dynamics of the nutrient regime of the soil under winter wheat by the phases of vegetation, mg/100 g of soil, 2016-2020.

Winter wheat fertilizer	Soil layer, cm	Time of soil sampling								
		Before sowing			Vegetation recovery			Complete maturity		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1	2	3	4	5	6	7	8	9	10	11
Grains, the predecessor – peas *(100 % s.g.c.)*										
control	0-20	10.31	10.65	9.80	10.72	11.11	10.19	9.47	10.25	9.22
	20-40	9.23	9.90	8.72	9.60	10.29	8.98	8.44	9.54	8.22
$N_{60}P_{90}K_{90}$	0-20	11.81	12.49	11.31	12.79	13.42	11.71	10.76	11.55	10.13
	20-40	10.16	11.41	9.93	11.01	11.95	10.36	9.27	10.54	8.97
$N_{30}P_{45}K_{45}$ + bp.	0-20	11.05	11.45	10.49	11.87	12.37	10.72	9.90	10.51	9.46
	20-40	9.89	10.41	9.64	10.61	11.04	10.06	9.05	9.67	8.72
Grains, the predecessor – winter wheat *(100 % s.g.c.)*										
control	0-20	9.67	10.56	9.51	10.19	10.86	9.79	8.88	10.12	8.92
	20-40	8.56	9.80	8.36	9.30	10.22	8.60	7.76	9.44	7.85
Manure, 40 t/ha + $N_{60}P_{90}K_{90}$	0-20	12.58	13.09	11.73	13.51	14.20	12.00	11.25	12.29	10.58
	20-40	10.69	11.74	10.36	11.49	12.73	10.60	9.52	11.13	9.38
Siderate + $N_{60}P_{90}K_{90}$ + bp.	0-20	11.87	12.04	11.30	12.96	13.28	11.65	10.59	11.27	10.31
	20-40	10.41	11.22	10.24	11.28	12.20	10.41	9.45	10.58	9.30
Crop rotation, the predecessor – clover *(50 % s.g.c.)*										
control	0-20	10.38	10.49	9.38	10.81	10.93	9.71	9.74	10.05	8.78
	20-40	9.27	9.76	8.27	9.67	10.15	8.47	8.48	9.39	7.77
$N_{60}P_{90}K_{90}$	0-20	11.93	12.39	11.12	13.09	13.31	11.34	10.88	11.45	9.90
	20-40	10.25	11.26	9.74	11.12	11.87	10.11	9.34	10.47	8.79
$N_{30}P_{45}K_{45}$	0-20	11.09	11.38	10.40	12.13	12.29	10.55	10.00	10.43	9.33
	20-40	9.95	10.33	9.50	10.66	11.00	9.71	9.07	9.58	8.61

Continuation of table 1

1	2	3	4	5	6	7	8	9	10	11
Grain-weed removing, the predecessor – buckwheat *(75 % s.g.c.)*										
control	0-20	9.95	10.89	9.67	10.51	11.40	9.98	9.18	10.42	9.13
	20-40	8.83	10.08	8.55	9.43	10.47	8.79	8.09	9.76	8.07
$N_{60}P_{90}K_{90}$	0-20	11.27	12.71	11.21	12.27	13.70	11.51	10.29	11.84	10.06
	20-40	9.89	11.45	9.85	10.68	12.10	10.19	9.12	10.77	8.90
$N_{30}P_{45}K_{45}$ + bp.	0-20	10.51	11.62	10.46	11.44	12.58	10.62	9.52	10.77	9.42
	20-40	9.60	10.53	9.56	10.39	11.25	9.80	8.83	9.91	8.70
Grain-weed removing, the predecessor – corn *(80 % s.g.c.)*										
control	0-20	9.83	10.38	9.28	10.40	10.92	9.63	9.06	10.05	8.67
	20-40	8.69	9.64	8.19	9.36	10.15	8.40	7.97	9.43	7.70
$N_{60}P_{90}K_{90}$	0-20	11.26	12.30	10.97	12.17	13.17	11.25	10.16	11.47	9.80
	20-40	9.91	11.15	9.63	10.57	11.83	10.00	9.01	10.49	8.70
$N_{30}P_{45}K_{45}$	0-20	10.59	11.28	10.30	11.35	12.25	10.45	9.42	10.44	9.26
	20-40	9.64	10.29	9.40	10.30	10.89	9.64	8.73	9.58	8.48
Grain-weed removing, the predecessor – soy *(80 % s.g.c.)*										
control	0-20	10.18	10.72	9.88	10.60	11.25	10.34	9.35	10.32	9.36
	20-40	9.15	9.90	9.10	9.53	10.38	9.30	8.36	9.64	8.63
$N_{60}P_{90}K_{90}$	0-20	11.51	12.58	11.35	12.47	13.51	11.78	10.46	11.71	10.25
	20-40	10.01	11.37	10.00	10.79	11.98	10.44	9.19	10.68	9.06
$N_{30}P_{45}K_{45}$ + bp.	0-20	10.67	11.54	10.58	11.72	12.48	10.83	9.77	10.67	9.54
	20-40	9.69	10.47	9.69	10.49	11.17	10.15	8.94	9.82	8.80
Grains, the predecessor – winter wheat *(100 % s.g.c.)*										
$N_{60}P_{90}K_{90}$	0-20	11.17	12.38	11.11	12.07	13.32	11.71	9.76	11.31	9.65
	20-40	9.73	11.20	9.76	10.42	11.86	10.23	8.65	10.39	8.48

Thus, without the imposition of fertilization systems, the highest values of the main indicators of effective fertility are provided by the predecessor of meadow clover in the crop rotation and peas in the grain crop rotation.

The use of fertilization systems ensured a significant increase in the values of the nutritional regime. The highest content of nutrients in the phase of crop vegetation recovery was observed under the conditions of the traditional system when 40 t/ha of manure and mineral fertilizers in a dose of $N_{60}P_{90}K_{90}$ were directly applied under winter wheat. In the arable layer in the grain crop rotation, the concentration of easily hydrolyzable nitrogen compounds was 13.51 mg kg^{-1} of soil, mobile forms of phosphorus and potassium – 14.20 and 12.00 mg kg^{-1} of soil. When combining a complex alternative organic component (green mass of oil radish on the background of by-products of winter wheat) and $N_{60}P_{90}K_{90}$, the content of nutrients available to plants in the soil environment was lower and amounted to 12.96, 13.28 and 11.65 mg kg^{-1} of the soil, respectively, mobile compounds of nitrogen, phosphorus and potassium (alternative fertilization system).

Applying mineral fertilizers directly under winter wheat, and the organic component under another crop of the crop rotation, i. e. at a distance in time, formed a nutritional regime at a lower concentration level in all studied crop rotations. The range of variability of the content of easily hydrolyzable nitrogen was 12.17-13.09 mg kg^{-1} of soil, mobile forms of phosphorus and potassium – 13.17-13.70 and 11.25-11.78 mg kg^{-1} of soil, respectively.

Before the end of the vegetation season of winter wheat, the content of nutrients decreased and leveled off in terms of absolute intervariant values due to their use by plants for growth, development and crop formation, and in the phase of full maturity of the crop in the control variants of crop rotation, it was 8.88-9.74 mg kg^{-1} of easily hydrolyzable soil of nitrogen, 10.05-10.42 and 8.67-9.36 mg kg^{-1} of soil mobile compounds of phosphorus and potassium, respectively 10.16-11.25, 11.45-12.29 and 9.80 on fertilized – 10.58 mg kg^{-1} soil (traditional fertilization system) and 9.42-10.59, 10.43-11.27 and 9.26-10.31 mg kg^{-1} soil (alternative fertilization system).

Observations of the dynamics of the nutritional regime during the growing season of spring barley grown in two crop rotations showed that the highest content of plant nutrients was at the time of crop emergence (Table 2). On unfertilized variants, the following concentration levels were observed: 9.70 mg kg^{-1} soil of easily hydrolyzable nitrogen, 10.79 mg kg^{-1} mobile forms of phosphorus and 9.81 mg kg^{-1} soil mobile compounds of potassium in the grain-forage crop rotation and, respectively, 9.76, 10.63

and 9.64 mg kg^{-1} of soil in the crop rotation. On variants of the traditional fertilization system, when $N_{60}P_{60}K_{60}$ was applied to the crop during two crop rotations, 12.34-12.40 mg kg^{-1} of easily hydrolyzable nitrogen was formed, 12.72-12.81 and 11.28-11.44 mg kg^{-1} of mobile soil forms of phosphorus and potassium. Under the conditions of an alternative fertilization system, when $N_{30}P_{30}K_{30}$ was applied on the background of by-products of winter wheat in the grain-forage crop rotation and $N_{30}P_{30}K_{30}$ in the crop rotation, 11.27-11.31 mg kg^{-1} of easily hydrolyzable nitrogen accumulated in the soil, 11.47-11.64 and 10, 86-11.03 mg kg^{-1} of the soil of mobile compounds of phosphorus and potassium.

During the vegetation season of spring barley, the content of nutrients in the soil decreased as a result of their use by plants for growth, development and crop formation. The lowest values of plant nutrients were observed in the phase of full maturity of the crop and amounted to 8.83-8.89 mg kg^{-1} of easily hydrolyzable nitrogen soil, 9.65-9.78 and 8.96-9.06 mg kg^{-1} of phosphorus and potassium compounds available to plants in the soil on unfertilized backgrounds. In the variants of application of organo-mineral fertilization systems, their amount was 10.04-10.7 mg kg^{-1}, 11.16-11.25 mg kg^{-1} and 9.59-9.70 mg kg^{-1} and 9.27-9.40, 10.10-10.18 and 9.27-9.38 mg kg^{-1} of soil.

Scientific studies have proven that plant residues of agricultural crops are an important factor influencing the nutrient regime and redistribution of organic substances in the soil [29, 27]. During their mineralization, a significant part of nitrogen, phosphorus and potassium, used by plants from fertilizers and soil, is returned to the soil. The amount of plant residues that accumulate in the soil depends on the range of crops grown in crop rotations, their productivity, biological and morphological features, weather conditions and nutrition levels.

As the results of our research showed (Table 3), in the variants without fertilizer application, the highest amount of plant residues accumulated in the soil after meadow clover (7.60-8.00 t/ha), corn for grain (5.15 t/ha) and winter wheat (3.97-4.45 t/ha). When sowing winter wheat in repeated sowings, this indicator was lower – 3.82-3.91 t/ha. The least amount of organic matter entered the soil after potatoes (1.41-1.46 t/ha) and buckwheat (2.55 t/ha).

The use of organo-mineral fertilization systems ensured an increase in the provision of the soil environment with organic substances. Under the alternative fertilization system, the number of by-products after meadow clover was 8.20-9.00 t/ha, corn for grain – 6.74 t/ha, winter wheat – 4.63-5.25 t/ha, and with growing it in repeated crops – 5.06-5.27 t/ha.

2. Dynamics of the nutritional regime under spring barley by the phases of vegetation, mg/100 g of soil, average for 2016–2020.

Spring barley fertilizer	Soil layer, cm	Time of soil sampling								
		Shoots			Earing			Full ripeness		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Grain-fodder, the predecessor – winter wheat *(75% s.g.c.)*										
control	0-20	9.70	10.79	9.81	9.18	10.14	9.29	8.89	9.78	9.06
	20-40	8.76	9.77	8.64	8.20	9.45	8.13	7.72	9.10	7.77
$N_{60}P_{60}K_{60}$	0-20	12.34	12.81	11.44	10.81	11.64	10.21	10.04	11.25	9.70
	20-40	11.38	11.66	10.47	9.65	10.68	9.24	8.96	10.31	8.65
$N_{30}P_{30}K_{30}$ + bp.	0-20	11.27	11.64	11.03	9.77	10.42	9.73	9.40	10.18	9.38
	20-40	10.60	10.80	10.19	8.93	9.65	9.02	8.77	9.34	8.54
Crop rotation, the predecessor – potato *(50% s.g.c.)*										
control	0-20	9.76	10.63	9.64	9.27	10.00	9.22	8.83	9.65	8.96
	20-40	8.81	9.69	8.54	8.05	9.38	8.07	7.58	8.09	7.64
$N_{60}P_{60}K_{60}$	0-20	12.40	12.72	11.28	10.90	11.55	10.07	10.07	11.16	9.59
	20-40	11.42	11.50	10.36	9.61	10.59	9.10	8.91	10.24	8.56
$N_{30}P_{30}K_{30}$	0-20	11.31	11.47	10.86	9.94	10.33	9.60	9.27	10.10	9.27
	20-40	10.65	10.67	10.07	9.18	9.57	8.90	8.64	9.24	8.42

3. Accumulation of crop residues by crop rotation, t/ha

Crop rotation/fertilizer per 1 ha of crop rotation area	Cultures				Total per rotation, c/ha	Per 1 ha of arable crop rotation
Grains, 100% s.g.c.	Peas	Winter wheat	Winter wheat	Oat		
-	2.81	4.25	3.82	3.66	14.54	3.64
$N_{51.2}P_{66.2}K_{66.2}$ + manure	3.14	5.71	5.90	4.41	19.15	4.80
$N_{33.1}P_{44.4}K_{44.4}$ + bp.+ siderate	2.80	4.70	5.06	3.92	16.47	4.12
Grains, 100 % s.g.c.	Peas	Winter wheat	Corn for grain	Oat	Total per rotation, c/ha	Per 1 ha of crop rotation
-	2.58	4.10	5.15	3.61	15.44	3.86
$N_{66.2}P_{68.7}K_{68.7}$ + manure	3.12	5.78	7.77	4.60	21.30	5.33
$N_{48.1}P_{46.9}K_{46.9}$ + bp.+ siderate	2.80	4.90	6.74	4.14	18.58	4.64
Grain-fodder 75 % s.g.c.	Clover	Winter wheat	Winter wheat	Spring barley	Total per rotation, c/ha	Per 1 ha of crop rotation
-	7.60	4.45	3.91	3.40	19.36	4.84
$N_{45.0}P_{60.0}K_{60.0}$ + manure	9.85	5.80	6.27	5.50	27.41	6.85
$N_{30.0}P_{41.2}K_{41.2}$ + bp.+ siderate	8.20	4.90	5.27	4.15	22.52	5.63
Crop rotation, 50 % s.g.c.	Clover	Winter wheat	Potatoes	Spring barley	Total per rotation, c/ha	Per 1 ha of crop rotation
-	8.00	4.34	1.46	3.51	17.31	4.33
$N_{52.5}P_{60.0}K_{60.0}$ + manure	11.34	5.97	3.00	4.74	25.05	6.26
$N_{37.5}P_{41.2}K_{41.2}$ + bp.+ siderate	9.00	5.25	2.56	4.30	21.11	5.30
Grain-weed removing, 75 % s.g.c.	Buckwheat	Winter wheat	Potatoes	Spring barley	Total per rotation, c/ha	Per 1 ha of crop rotation
-	2.55	3.97	1.41	3.88	11.81	2.95
$N_{67.5}P_{75.0}K_{75.0}$ + manure	3.40	5.65	2.88	5.07	17.00	4.25
$N_{45.0}P_{48.7}K_{48.7}$ + bp + siderate	2.86	4.63	2.43	4.60	14.52	3.63

Potatoes grown under an alternative fertilization system in crop rotation formed 2.43-2.56 t/ha, and buckwheat – 2.86 t/ha of by-products. Under the traditional fertilization system, this indicator was the highest among all cultivated crops. In particular, after meadow clover remained 9.85-11.34 t/ha, corn for grain – 7.77 t/ha, winter wheat – 5.65-5.97 t/ha, winter wheat in repeated sowings – 5.90-6.27 t/ha of organic substances. On the background of this fertilization system, the number of by-products in potatoes and buckwheat increased to 2.88-3.00 t/ha and 3.40 t/ha.

The analysis of the accumulation of plant residues by crop rotation showed that, in general, during the rotation, the largest amount of them entered the soil environment in the grain-forage (19.36-27.41 t/ha) and crop (17.31-25.05 t/ha) rotations, the smallest – in grain-weed removing with 75% saturation with grain crops (11.81-17.00 t/ha). Accordingly, based on the calculation per hectare of crop rotation, this indicator was: 4.84-6.85, 4.33-6.26 and 2.95-4.25 t/ha. The amount of accumulation of plant residues in other crop rotations acquired intermediate values.

Conclusions

The formation of the nutrient regime of the soil under grain crops in short-rotation crop rotations is influenced by the fertilization system and precursors.

Without the introduction of fertilizers during the recovery of winter wheat vegetation, the higher values of the indicators of the nutritional regime are formed in the crop rotation with the precursor of the meadow clover culture (the content of mobile forms of nitrogen, phosphorus and potassium was 10.81, 10.93 and 9.71 mg kg^{-1} of soil) and in grain with a predecessor of peas (according by nutrients, 10.72, 11.11 and 10.19 mg kg^{-1} of soil); the lowest (10.19, 10.86 and 9.79 mg kg^{-1} soil) – in grain rotation in repeated sowings of winter wheat.

Accumulation of the highest content of nutrients in the soil takes place on variants of the traditional fertilization system with the application of a fertilized complex with 40 t/ha of manure and mineral fertilizers in a dose of $N_{60}P_{90}K_{90}$ directly under winter wheat, and $N_{60}P_{60}K_{60}$ under spring barley.

The largest amount of plant residues accumulate in the soil under the traditional fertilization system after meadow clover (9.85-11.34 t/ha), corn for grain (7.77 t/ha), winter wheat – (5.65-5.97 t/ha), the lowest – after potatoes (2.88-3.00 t/ha) and buckwheat (3.40 t/ha).

The highest level of accumulation of plant residues by crop rotations in the soil environment occurs in grain-fodder (19.36-27.41 t/ha) and crop

(17.31-25.05 t/ha) rotations, the lowest – in grain-weed removing crop with 75% saturation with grain crops (11.81-17.00 t/ha).

Список використаної літератури

1. Бойко П. І. Ефективні різноротаційні сівозміни у сучасному землеробстві. *Вісник Полтавської державної аграрної академії.* 2014. № 3. С. 20–32.

2. Гамаюнова В. В., Касаткіна Т. О. Вплив оптимізації живлення ячменю ярого на формування якості зерна в умовах Південного Степу України. *Наукові горизонти.* 2019. № 10 (83). С. 3–12. URL: https://dspace.mnau.edu.ua/jspui/bitstream/123456789/9345/1/3-12.pdf (дата звернення: 04.05.2022).

3. Екологічні аспекти удобрення сільськогосподарських культур / за ред. В. В. Волкогона. Київ : Аграр. наука, 2019. 264 с.

4. Господаренко Г. М. Система застосування добрив. Київ : ТОВ «СІК ГРУП УКРАЇНА», 2018. 376 с.

5. Ефективність застосування побічної продукції зернових культур на добриво за різних способів обробітку сірого лісового ґрунту / Н. М. Тараріко та ін. *Землеробство.* 2012. Вип. 84. С. 56–62.

6. Єщенко В. О. Роль сівозмін у сучасному землеробстві. *Землеробство.* 2015. Вип. 1. С. 23–27.

7. Заришняк А. С., Цвей Я. П., Іваніна В. В. Оптимізація удобрення та родючості ґрунту в сівозмінах. Київ : Аграрна наука, 2015. 208 с.

8. Камінський В. Ф. Наукові основи оптимізації живлення рослин в сучасних системах землеробства. *Землеробство.* 2018. Вип. 2 (95). С. 3–6.

9. Кірілеско О. Л., Корнійчук О. В. Вплив насичення сівозмін багаторічними травами, заорювання соломи та сидератів на баланс гумусу в ґрунтах. *Землеробство.* 2015. Вип. 1. С. 77–81.

10. Літвінов Д. В., Борис Н. Є. Зміна органічної речовини та біогенних елементів під культурами у сівозмінах. *Землеробство.* 2018. Вип. 2 (95). С. 14–19.

References

1. Boiko P. I. Effective multi-rotation crop rotations in modern agriculture. *Visnyk poltavskoi derzhavnoi akademii*. 2014. No. 3. P. 20–32.

2. Gamaiunova V. V., Kasatkina T. O. The effect of optimization of spring barley nutrition on the formation of grain quality in the conditions of the Southern Steppe of Ukraine. *Scientific horizons*. 2019. No. 10 (83). P. 3–12. URL: https://dspace.mnau.edu.ua/jspui/bitstream/123456789/9345/1/3-12.pdf. (date of application: 04.05.2022).

3. Ecological aspects of fertilization of agricultural crops / under the editorship V. V. Volkogon. K.: Agrarian. Science. 2019. 264 p.

4. Hospodarenko H.M. Fertilizer application system. Kyiv: LLC "SIK GRUP UKRAINA". 2018. 376 p.

5. Effectiveness of the use of by-products of grain crops as fertilizer by different methods of processing gray forestal soil / N. M. Tarariko., et al. *«Zemlerobstvo»*. 2012. Issue 84. P. 56–62.

6. Yeshchenko V.O. The role of crop rotation in modern agriculture. *Zemlerobstvo*. 2015. Issue 1. P. 23–27.

7. Zaryshniak A. S., Tsvei Y. P., Ivanina V. V. Optimization of fertilization and soil fertility in crop rotations. K.: Agrarian science. 2015. 208 p.

8. Kaminskyi V. F. Scientific basis of optimization of plant nutrition in modern agricultural systems. *Zemlerobstvo*. 2018. Issue 2 (95). P. 3–6.

9. Kirilesko O. L., Korniichuk O. V. The influence of saturation of crop rotations with perennial grasses, plowing of straw and siderates on the balance of humus in soils. *Zemlerobstvo*. 2015. Issue 1. P. 77–81.

10. Litvinov D. V., Borys N. E. Changes in organic matter and biogenic elements under crops in crop rotations. *Zemlerobstvo*. 2018. Issue 2 (95). P. 14–19.

11. Мирошниченко М. С. Продуктивність короткоротаційних сівозмін за системи удобрення та обробітку ґрунту. *Збірник наукових праць ННЦ «Інститут землеробства НААН»*. 2019. Вип. 3/4. С. 3–14.

12. Надточій П. П., Ратошнюк В. І., Ратошнюк Т. М. Вплив добрив і обробітку на якісний стан дерново-підзолистого ґрунту та продуктивність польових культур сівозміни в умовах Житомирського Полісся. *Вісник аграрної науки.* 2021. № 5 (818). С. 5–15. DOI: 10.31073/ agrovisnyk202105-01.

13. Польовий В. М. Оптимізація систем удобрення у сучасному землеробстві. Рівне : Волинські обереги, 2007. 320 с.

14. Потапенко Л. В., Горбаченко Н. І. Вплив систем удобрення та мікробних препаратів на формування поживного режиму дерново-підзолистого ґрунту. *Сільськогосподарська мікробіо-логія.* 2021. Т. 34. С. 53–60. DOI: https://doi.org/10.35868/1997-3004.34.53-60.

15. Продуктивність пшениці озимої в короткоротаційній сівозміні Лівобережного Лісостепу на різних рівнях інтенсифікації / Я. С. Цимбал та ін. *Збірник наукових праць ННЦ «Інститут землеробства НААН».* 2020. Вип. 1/2. С. 32–41.

16. Продуктивність агрофітоценозів різноротаційних сівозмін у Лівобережному Лісостепу / П. І. Бойко та ін. *Землеробство.* 2015. Вип. 1. С. 32–37.

17. Системи удобрення сільськогосподарських культур у землеробстві початку XXI століття / за ред. С. А. Балюка і М. М. Мірошниченка. Київ : Альфа-стевія, 2016. 400 с.

18. Тараріко О. Г. Охорона родючості ґрунтів у контексті продовольчої безпеки. *Вісник аграрної науки.* 2003. № 2. С. 5–9.

19. Цвей Я. П. Родючість ґрунтів і продуктивність сівозмін. Київ : КОМПРИНТ, 2014. 416 с.

20. Якість ґрунту. Визначення легкогідролізного азоту методом Корнфілда: ДСТУ 7863:2015. [Чинний від 2016-07-01]. Київ : УкрНДНЦ, 2016. 9 с.

21. Якість ґрунту. Визначання

11. Myroshnychenko M. S. Productivity of short-rotational crop rotations under fertilization and tillage systems. *Collection of scientific works of the NSC "Institute of Agriculture of the National Academy of Sciences*". 2019. Issue 3-4. P. 32–14.

12. Nadtochiy V.R., Ratoshnyuk V.I., Ratoshnyuk T.M. The influence of fertilizers and tillage on the quality of sod-podzolic soil and the productivity of field crops of crop rotation in the conditions of Zhytomyr Polissia. *Visnyk ahrarnoi nauky*. 2021. No 5 (818). P. 5–15. DOI: 10.31073/agro visnyk202105-01

13. Polovyi V. M. Optimization of fertilization systems in modern agriculture. Rivne: Volynski oberehy. 2007. 320 p.

14. Potapenko L. V., Horbachenko N. I. (2021). The influence of fertilization systems and microbial preparations on the formation of the nutritional regime of sod-podzolic soil. *Silskohospodarska mikrobiolohiia*. 2021. T. 34, P. 53–60. https://doi.org/10.35868/1997-3004.34.53-60

15. Productivity of winter wheat in short-rotation crop rotation of the Left-Bank Forest-Steppe at different levels of intensification / Ya.S. Tsymbal, et al. *Zbirnyk naukovykh prats NNTs «Instytut zemlerobstva NAAN».* 2020. Issue 1/2. P. 32–41.

16. Productivity of agrophytocenoses of different rotational crop rotations in the Left-Bank Forest-Steppe / P. I. Boiko et al.. *Zemlerobstvo*. 2015. Issue 1. P. 32-37.

17. Fertilization systems of agricultural crops in agriculture at the beginning of the 21st century / Ed. S. A. Baliuk and M. M. Miroshnychenko. K.: Alpha-stevia, 2016.400 p.

18. Tarariko O. H. Protection of soil fertility in the context of food security. *Visnyk ahrarnoi nauky*. No. 2. 2003. P. 5–9.

19. Tsvei Ya.P. Soil fertility and crop rotation productivity. K.: "COMPRYNT". 2014. 416 p.

20. Soil quality. Determination of easily hydrolyzable nitrogen by the Kornfield method: DSTU 7863:2015. [Valid from 2016-07-01]. Kyiv: UkrNDNC, 2016. 9 p.

21. Soil quality. Determination of mobile compounds of phosphorus and potassium by the Kirsanov method in the modification of

рухомих сполук фосфору і калію за методом Кірсанова в модифікації ННЦ ІГА: ДСТУ 4405:2005. [Чинний від 2005-05-30]. Київ : Держспоживстандарт України, 2006. 18 с.

22. Якість ґрунту. Відбирання проб: ДСТУ 4287:2004. [Чинний від 2005-07-01]. Київ : Держспоживстандарт України, 2005. 9 с. (Національні стандарти України).

23. Якість ґрунту. Попереднє обробляння зразків: ДСТУ ISO 11464-2001. [Чинний від 2002-04-02]. Київ : Держспоживстандарт України, 2003. 19 с. (Національні стандарти України).

24. Do cover crops benefit soil microbiome? A meta-analysis of current research / Kim N. et al. *Soil. Biol. Biochem*. 2020. № 142. P. 1–14. https://doi.org/10.1016/j.soilbio.2019.107701

25. Effect of fertiliser on changes in labile and water-soluble forms of humus in short-term rotations / Stasiv, O. et al. *Scientific Horizons*. 2022. 25(4). P. 9-17.

26. Effects of long-term organic fertilization on soil microbiologic characteristics, yield and sustainable production of winter wheat / Li, C.X. et al. *Journal of Integrative Agriculture*. 2018. 17. P. 210-219. doi: 10.17221/60/2020-PSE

27. Gura, I.; Mnkeni, P.N.S. Crop rotation and residue management effects under no till on the soil quality of a Haplic Cambisol in Alice, Eastern Cape, South Africa. *Geoderma.* 2019. 337. P. 927–934. https://doi.org/10.1016/j.geoderma.2018.10.042

28. Long-Term Effects of the Use of Organic Amendments and Crop Rotation on Soil Properties in Southeast Spain / Sánchez-Navarro, A. et al. *Agronomy*. 2021. 11. P. 2363. https://doi.org/10.3390/ agronomy11112363

29. Performance of an optimized nutrient management system for double-cropped wheat-maize rotations in North-Central China. / He, P. et al. *Agron. J.* 2009. 101. P. 1489–1496. doi.org/10.2134/agronj2009.0099

30. Rotation and Fertilization Effects on Soil Quality and Yields in a Long Term Field Experiment. / Giacometti, C. *Agronomy.*

the National Center of IGA: DSTU 4405: 2005. [Valid from 2005-05-30]. Kyiv: Derzhspozhyvstandart of Ukraine. 2006. 18 p.

22. Soil quality. Sampling: DSTU 4287:2004. - [Valid from 2005-07-01]. K.: Derzhspozhyvstandart of Ukraine, 2005. 9 p. (National standards of Ukraine).

23. Soil quality. Preliminary processing of samples: DSTU ISO 11464-2001. [Valid from 2002-04-02]. K.: Derzhspozhyvstandart of Ukraine, 2003. 19 p. (National standards of Ukraine).

24. Do cover crops benefit soil microbiome? A meta-analysis of current research / Kim N. et al. *Soil. Biol. Biochem*. 2020. № 142. P. 1–14. https://doi.org/10.1016/j.soilbio.2019.107701

25. Effect of fertiliser on changes in labile and water-soluble forms of humus in short-term rotations / Stasiv, O. et al. *Scientific Horizons*. 2022. 25(4). P. 9-17.

26. Effects of long-term organic fertilization on soil microbiologic characteristics, yield and sustainable production of winter wheat / Li, C.X. et al. *Journal of Integrative Agriculture*. 2018. 17. P. 210-219. doi: 10.17221/60/2020-PSE

27. Gura, I.; Mnkeni, P.N.S. Crop rotation and residue management effects under no till on the soil quality of a Haplic Cambisol in Alice, Eastern Cape, South Africa. *Geoderma.* 2019. 337. P. 927–934. https://doi.org/10.1016/j.geoderma.2018.10.042

28. Long-Term Effects of the Use of Organic Amendments and Crop Rotation on Soil Properties in Southeast Spain / Sánchez-Navarro, A. et al. *Agronomy.* 2021. 11. P. 2363. https://doi.org/10.3390/ agronomy11112363

29. Performance of an optimized nutrient management system for double-cropped wheat-maize rotations in North-Central China. / He, P. et al. *Agron. J.* 2009. 101. P. 1489–1496. doi.org/10.2134/agronj2009.0099

30. Rotation and Fertilization Effects on Soil Quality and Yields in a Long Term Field Experiment. / Giacometti, C. *Agronomy.* 2021. 11. P. 636. https://doi.org/10.3390/

2021. 11. P. 636. https://doi.org/10.3390/ agronomy11040636

31. The benefits of crop rotation including cereals and green manures on potato yield and nitrogen nutrition and soil properties / N'Dayegamiye, A. et al. *Adv. Crop Sci. Technol*. 2017. 5. P. 279.

32. The effect of mineral fertilisers and farmyard manure on grain and straw yield, quality and economical parameters of winter wheat / Hlisnikovský L. et al. *Plant, Soil and Environment.* 2020. 66. P. 249–256. doi: 10.17221/60/2020-PSE.

33. The inffluence of AKM Growth Regulator on Photosynthetic Activity of Oilseed Flax Plants in the Conditions of Insufficient Humidification of the Southern Steppe of Ukraine / Eremenko O. et al. *Modern Development Paths of agricultural production*. Ed. V. Nadykto. 2019. P. 703–807. https://doi.org/ 10.1007/978–3–030–14918–5_78

34. The influence of ecologised fertiliser systems on the elements of fertility and productivity of winter wheat. / Dubytska, A. *Scientific Horizons*. 2021. 24(9). P. 44-54.

35. Triberti, L.; Nastri, A.; Baldoni, G. Long-term effects of crop rotation, manure and mineral fertilisation on carbon sequestration and soil fertility. *Eur. J. Agron*. 2016. 74. P. 47–55. https://doi.org/10.1016/j.eja.2015.11.024

36. Wozniak, A. Chemical properties and enzyme activity of soil as affected by tillage system and previous crop. *Agriculture.* 2019. 9. P. 262. https://doi.org/10.3390/ agriculture9120262

37. Yield and quality of winter durum wheat grain depending on the fertiliser system / Hospodarenko, H. et al. *Scientific Horizons.* 2022. 25(3). P. 16-25. https: //doi.org/10.48077/scihor.25(3).2022.16-25

agronomy11040636

31. The benefits of crop rotation including cereals and green manures on potato yield and nitrogen nutrition and soil properties / N'Dayegamiye, A. et al. *Adv. Crop Sci. Technol*. 2017. 5. P. 279.

32. The effect of mineral fertilisers and farmyard manure on grain and straw yield, quality and economical parameters of winter wheat / Hlisnikovský L. et al. *Plant, Soil and Environment.* 2020. 66. P. 249–256. doi: 10.17221/60/2020-PSE.

33. The inffluence of AKM Growth Regulator on Photosynthetic Activity of Oilseed Flax Plants in the Conditions of Insufficient Humidification of the Southern Steppe of Ukraine / Eremenko O. et al. *Modern Development Paths of agricultural production*. Ed. V. Nadykto. 2019. P. 703–807. https://doi.org/ 10.1007/978–3–030–14918–5_78

34. The influence of ecologised fertiliser systems on the elements of fertility and productivity of winter wheat. / Dubytska, A. *Scientific Horizons*. 2021. 24(9). P. 44-54.

35. Triberti, L.; Nastri, A.; Baldoni, G. Long-term effects of crop rotation, manure and mineral fertilisation on carbon sequestration and soil fertility. *Eur. J. Agron*. 2016. 74. P. 47–55. https://doi.org/10.1016/j.eja.2015.11.024

36. Wozniak, A. Chemical properties and enzyme activity of soil as affected by tillage system and previous crop. *Agriculture.* 2019. 9. P. 262. https://doi.org/10.3390/ agriculture9120262

37. Yield and quality of winter durum wheat grain depending on the fertiliser system / Hospodarenko, H. et al. *Scientific Horizons.* 2022. 25(3). P. 16-25. https: //doi.org/10.48077/scihor.25(3).2022.16-25

Received: September 1, 2022
Accepted: November 4, 2022