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Agrobiological and environmental measures to increase the yield of spring rapeseed on drained organogenic soils under climate change

Abstract. The article examined agrobiological and environmental protection methods for increasing the yield of spring rapeseed on drained organogenic soils under conditions of climate change, taking into account the characteristics of these soils and methodological approaches to determining mineral fertiliser doses in a field stationary experiment on drained organogenic soils of the floodplain of the Supii River. The aim of the research was to determine the effectiveness of the methodology for calculating the most appropriate fertiliser doses and the peculiarities of

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forming the optimal regime for spring rapeseed crops on drained organogenic soils by determining the reasonable rates of mineral fertiliser application depending on the methods that take into account the specifics of these soils. The study used methods such as field research with a complex of biometric, agrochemical and laboratory studies, as well as mathematical and statistical methods. The research focused on the development of optimal mineral fertilisation systems and effective methods of peatland use, taking into account environmental aspects. It was found that the application of mineral fertilisers leads to an intensification of mineralisation processes, which increase with higher fertiliser doses, resulting in the accumulation of nutrients that affect the yield of cultivated crops and their migration into drainage waters. Using field, laboratory and statistical methods, the authors determined that the highest mineralisation of peat and CO₂ emissions occur in crop rotations with annual crops, while perennial grasses reduce peat depletion. It was also found that the highest rapeseed yield was achieved in grass-field crop rotations with the application of mineral fertilisers (3.0-3.3 t/ha), which reduced energy costs and increased economic efficiency. Studies had revealed significant leaching of nitrate nitrogen and potassium into drained waters, especially in spring and autumn, which contributed to water pollution. The proposed methods also increased the stability of the agroecosystem, minimising degradation processes in organogenic soils and reducing the environmental impact on the surrounding environment. The results obtained were of practical value in improving organic fertilisation systems for binary crops and ensuring the sustainability of agroecosystems, and can be used by agricultural producers of various forms of ownership

Keywords: peat soils; decomposition of linen fabric; organic matter; fertilisation; soil cultivation; productivity; biogenic substances

INTRODUCTION

Modern farming systems in the context of climate warming on drained soils require a significant review of key aspects of crop cultivation technology and crop rotation structure. It is important to implement improved technological measures aimed at obtaining high and economically profitable yields, taking into account environmental protection principles. Peat soils, which are low in potassium, often deficient in phosphorus and high in nitrogen, are characterised by intensive mineralisation of organic matter and leaching of nutrients into groundwater. Therefore, sound calculations of mineral fertiliser application rates are extremely important. Such research should ensure the environmental and economic efficiency of the use of the reclamation fund in the context of climate warming, contribute to the restoration of soil fertility and reduce the energy costs of crop cultivation technologies, in particular agromeliorative measures characteristic of reclamation agriculture on drained soils. Addressing these issues will make it possible to maintain crop productivity and economic performance while reducing energy costs and lowering the environmental impact

in areas of drainage reclamation. In general, the development of effective and environmentally friendly technology for growing spring rapeseed on drained organogenic soils will significantly increase the productivity of reclaimed lands in the Polissya region, which will enable agricultural enterprises to allocate additional funds to improve the technical condition of reclamation systems, which is necessary for production.

The development of agrobiological and environmentally friendly measures contributes to the preservation of the fertility of drained organogenic soils and their effective cultivation in conditions of climate warming. These technologies are an important factor in the development of agricultural production in areas of excessive moisture (Tarariko *et al.*, 2025). However, as noted by I. Slyusar *et al.* (2023), farming on drained organogenic soils in Polissya is associated not only with weather conditions, but also with the operation of land reclamation networks, the selection of highly profitable crops, and the technology used to grow them. I. Malinovska & M. Tkachenko (2023), Yu. Tarariko *et al.* (2025) believe that when using drained organogenic soils, it

is essential to take into account environmental protection measures related to the prevention of excessive mineralisation of peatlands and contamination of soil and river waters with biogenic substances. An analysis of the literature by E. Jajor & M. Mrówczyński (2016) and M. Parkhomets *et al.* (2023) showed that by the beginning of the 21st century, rapeseed cultivation had become widespread in Ukraine and Europe. Spring rapeseed began to occupy a leading position in the world among oil crops, with gross oil production reaching 33-35 million tonnes, and in Ukraine it occupies about 1% of arable land (Ryzhuk *et al.*, 2022; Voropai *et al.*, 2024). At the same time, the main factor limiting the cultivation of rapeseed on drained organogenic soils is the lack of sound and environmentally friendly technology in these conditions as the climate warms. This primarily concerns the optimisation of mineral fertilisation, crop rotation, the impact of its cultivation on the intensity of peatland mineralisation and the leaching of biogenic substances into groundwater (Markova *et al.*, 2025).

This theory is also confirmed in the work of I. Slyusar *et al.* (2023), which is based on the theory of ecological and environmental aspects. For humid areas on drained organogenic soils, the introduction of spring rapeseed (annual crops) as a highly profitable crop into the structure of cultivated areas on old-ploughed carbonate peat soils provides a significant economic return from the use of reclaimed land. This contributes to increasing the profitability of agricultural production and provides a stable income from crop sales. The high economic benefits of rapeseed cultivation are due not only to market demand for rapeseed as a source of oil and feed protein, but also to its importance in biofuel production, which is particularly relevant in the context of energy crises and environmental challenges. These results can form the basis for further research aimed at improving agricultural technologies for growing spring rapeseed and other crops on drained organogenic soils.

The aim of the research was to provide a theoretical justification for agrobiological measures for growing spring rapeseed under different mineral fertilisation systems and methods of using drained carbonate organogenic soils in the context of climate change.

MATERIALS AND METHODS

The research was conducted during 2021-2023 in a stationary experiment of an 8-field grain crop rotation on drained old-ploughed organogenic soils of the Panfil Experimental Station of the National Scientific Centre "Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine" (floodplain of the Supii River, Boryspil District, Kyiv Region). The soil of the experimental plot (0-50 cm) is well-decomposed peat (50-55%), carbonate, of cattail-sedge origin, with a thickness of 2.4-2.5 m and a density of 0.215 g/cm³; ash content 40-43%, full moisture capacity (FMC) – 270-280%; gross nitrogen content – 2.33%, phosphorus – 0.76-0.90; potassium – 0.09-0.15, calcium – 20-26%; pH of aqueous solution – 7.3-7.5. The experiment was conducted in three replicates in time and space. Spring rapeseed was grown in a grass-crop rotation with two annual crops (maize and rapeseed) and six fields of perennial grass mixtures, and in a row-crop rotation with only three annual crops (sunflower, spring rapeseed, spring triticale) and, for comparison, a field with unchanging sowing of perennial grass mixtures to determine the most effective way to use organogenic soils for growing spring rapeseed. To determine the effectiveness of mineral fertilisers and compare different types, plots without fertiliser application and without fertiliser application + Opti Growth were added to the experimental design; The recommended fertiliser doses were determined based on the analysis of data from long-term studies in crop rotation on drained soils conducted by the National Scientific Centre "Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine", with the highest yield obtained.

The formation of mineral fertilisation options for spring rapeseed was carried out according to the following principle: based on the data obtained from the results of many years of field studies conducted on old-ploughed soils at the Panfil Research Station ($R_{45}K_{120}$); – balance – calculated for yield increase. The balance method is based on (two) methods of determining fertilisers for the planned yield increase:

$$D = (Y_p - Y_k) \times R \times 100 / C_u, \quad (1)$$

where Y_p – planned yield, t/ha; Y_k – long-term yield without fertilisers, t/ha; R – nutrient removal by plants, kg/t; C_u – coefficient of nutrient utilisation from fertilisers, %.

The coefficient of nutrient utilisation from fertilisers was calculated based on long-term data obtained on these soils (Slyusar, 2019). To study biochemical activity in the soil, experiments were conducted using the application method and assessment of total biological activity. In particular, to assess the activity of microorganisms, linen fabric stretched over glass was used, which was placed at a depth of 0-30 cm. The total area of the sowing plot was 20 m², and the accounting area was 15 m². Opti Growth is a biological product for stimulating plant growth and development and ensuring their balanced nutrition based on a concentrated suspension of live nitrogen-fixing, phosphorus- and potassium-mobilising cultures and microorganisms with fungicidal properties.

Soil moisture in the samples was determined by the thermostatic-weight method, nitrate nitrogen content – by the Granwald-Lazh method with disulphophenolic acid in accordance with (DSTU 4725-2007, 2008), the ammonium nitrogen content was determined using the potassium chloride solution extraction method according to (DSTU ISO/TS 14256-1:2005, 2006), the content of mobile phosphorus and potassium compounds – by flame photometry of carbon ammonium extract according to (DSTU 4114-2002, 2003). Soil respiration was

determined by CO₂ release, and the intensity of root system respiration was determined using the Boisen-Jensen method (Kolesnikov, 2019). To convert the intensity of soil organic matter mineralisation, a coefficient of 0.543 was used, which corresponds to 50.2% carbon in peat organic matter (Yevtushenko & Khyzhnyak, 2019). Weather conditions during the years of research at the Panfil Research Station (according to data from the Yahotyn Meteorological Station located 2 km from the research field) were characterised by increased average monthly values for April-September: the air temperature in 2021 was 16.6°C, in 2022 – 16.2°C, and in 2023 – 17.4°C (the long-term average is 15.2°C), and insufficient precipitation (298 mm in 2021, 27 mm more in 2022, and – 391.5 mm compared to the norm of 327 mm).

RESULTS AND DISCUSSION

Monitoring of soil water conditions showed that groundwater levels mostly fluctuated at levels close to the lower limit of optimality, which was particularly noticeable in 2021 (Fig. 1). During this period, higher air temperatures compared to long-term averages contributed to increased moisture evaporation. As a result, increased evaporation reduced the amount of moisture available to plants in the soil. However, this groundwater level, together with the shallow root system of spring rapeseed, ensured sufficient moisture in the root zone, thereby promoting optimal plant growth and development.

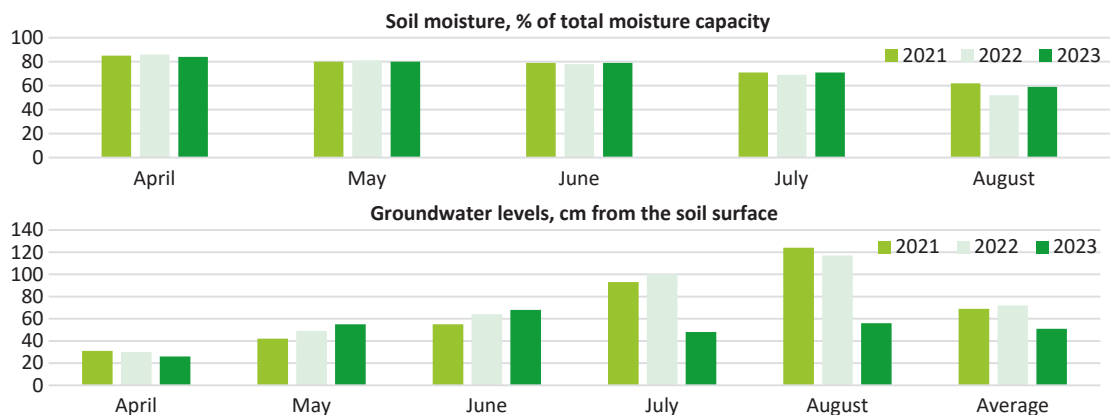


Figure 1. Soil water regime, average for 2021-2023

Source: developed by the authors

This water regime was particularly important because higher temperatures not only increase evaporation but also create additional challenges in maintaining plant access to moisture in the upper soil layers. Thus, the stable presence of groundwater at the specified depth is a key factor for the effective use of available water resources by plants, which had a positive overall effect on the development of rapeseed plants. Further research confirms that in the context of climate change, such as rising temperatures and uneven rainfall, the presence of groundwater at a certain depth is critical to crop productivity. These factors necessitate the adaptation of water management

and irrigation in modern conditions to ensure stable conditions for crop moisture supply. Accordingly, the moisture content of the active soil layer was within the optimal range during the rapeseed growing season (May-July) – 69-81% of full moisture capacity, with the lower optimal soil moisture content being 40% of full moisture capacity and the upper limit being 80% of full moisture capacity. An analysis of the nutrient content in the soil shows in Table 1 that it significantly depends on both the application of mineral fertilisers and the method of using drained soils, the structure of cropland in crop rotation and the place of rapeseed in it.

Table 1. Mobile nitrogen content in the 0-30 cm soil layer under spring rapeseed depending on the structure of sown areas in crop rotation, mg/kg of dry soil

Fertilisation	N-NO ₃				N-NH ₄			
	2021	2022	2023	average	2021	2022	2023	average
Row crop rotation with two annual crops (perennial grasses, maize, spring rapeseed)								
Without fertilisers (control)	159.0	78.0	23.0	86.7	38.5	42.0	43.5	41.3
Recommended fertiliser dose based on experiments	134.0	91.0	24.0	83.0	38.5	44.5	41.0	41.3
Calculated dose for yield increase	112.0	98.0	27.0	79.0	40.0	44.5	37.5	40.7
Recommended fertiliser dose based on experiments + Opti-Growth	135.0	102.0	68.0	101.7	33.5	44.5	35.8	37.9
Fertiliser: organic-mineral – Opti Growth	152.0	123.0	62.0	112.3	30.0	39.2	39.3	36.2
Crop rotation with three annual crops (sunflower, spring rapeseed, spring triticale)								
Without fertilisers (control)	107.0	69.0	135.0	103.7	36.5	46.5	48.5	43.8
Recommended fertiliser dose based on experiments	123.0	87.0	107.0	105.7	28.5	45.5	42.8	38.9
Calculated dose for yield increase	132.0	87.0	102.0	107.0	31.0	42.0	44.5	39.2
Recommended fertiliser dose based on experiments + Opti-Growth	129.0	100.0	95.0	108.0	28.5	44.5	42.8	38.6
Fertiliser: organic-mineral – Opti Growth	108.0	117.0	93.0	106.0	45.5	43.5	40.0	43.0
Perennial grasses 8 years								
Without fertilisers (control)	91.0	49.0	-	70.0	38.5	41.0	50.5	43.3
Recommended fertiliser dose based on experiments	87.0	79.0	-	83.0	36.5	43.5	49.5	44.8
Calculated dose for yield increase	81.0	91.0	-	96.0	33.5	44.5	54.5	44.2
Recommended fertiliser dose based on experiments + Opti-Growth	91.0	98.0	-	94.5	32.8	43.5	55.5	43.9
Fertiliser: organic-mineral – Opti Growth	94.0	32.2	-	63.1	36.5	42.0	60.5	46.3

Source: developed by the authors

Thanks to the stable groundwater level at the optimal depth, the moisture content of the active soil layer during the rapeseed growing season (May-July) was maintained within the range of 69-81% of full moisture capacity (FMC),

with the lower optimal soil moisture limit at 40% FMC and the upper limit at 80% FMC. Such moisture levels are optimal for the growth and development of rapeseed, as they provide sufficient water for the root system, especially in

conditions of climate change, which increase the risk of drought.

According to the results of soil nutrient analysis, their content is determined not only by the amount of mineral fertilisers applied, but also by a number of other factors, such as the method of drained soil cultivation, crop rotation composition, and the place of rapeseed in the crop structure (Table 2). Applying fertilisers

taking into account the specifics of each field and the needs of agricultural crops allows avoiding excessive or insufficient saturation of the soil with nutrients, in particular nitrogen, potassium and phosphorus. This is especially important for rapeseed, which has specific phosphorus and potassium requirements but, at the same time, avoids excess nitrogen, which can lead to leaching into groundwater.

Table 2. Content of mobile P₂O₅ and K₂O in the 0-30 cm soil layer on spring rapeseed crops, depending on the structure of cultivated areas in crop rotation, mg/kg of dry soil

Fertilisation	P ₂ O ₅				K ₂ O			
	2021	2022	2023	average	2021	2022	2023	average
Grass-based crop rotation with two annual crops (perennial grasses, sunflower, spring rapeseed)								
Without fertilisers (control)	61.1	36.0	22.5	39.9	105.0	102.0	88.0	98.0
Recommended fertiliser dose based on experiments	82.0	41.2	16.0	46.4	260.0	102.0	88.0	150.0
Calculated dose for yield increase	82.6	42.2	17.0	46.9	272.0	110.0	84.0	155.0
Recommended fertiliser dose based on experiments + Opti-Growth	82.0	40.0	22.5	48.2	269.0	123.0	132.0	175.0
Fertiliser: organic-mineral – Opti-Growth	76.0	41.4	27.0	48.5	104.0	88.0	126.0	106.0
Grass-based crop rotation with three annual crops (sunflower, spring rapeseed, spring triticale)								
Without fertilisers (control)	56.0	34.1	20.0	36.7	120.0	84.0	198.0	134.0
Recommended fertiliser dose based on experiments	66.0	32.0	21.2	39.7	162.0	86.0	216.0	155.0
Calculated dose for yield increase	69.0	45.0	19.4	44.5	170.0	88.0	263.0	174.0
Recommended fertiliser dose based on experiments + Opti-Growth	54.0	45.0	21.2	40.1	176.0	84.0	216.0	159.0
Fertiliser: organic-mineral – Opti-Growth	32.0	42.4	23.5	32.6	162.0	86.0	216.0	155.0
Perennial grasses 8 years								
Without fertilisers (control)	52.2	30.0	10.0	30.7	176.0	72.0	102.0	117.0
Recommended fertiliser dose based on experiments	77.2	36.0	12.0	41.7	126.0	84.0	216.0	142.0
Calculated dose for yield increase	79.0	38.0	20.0	45.7	120.0	98.0	298.0	172.0
Recommended fertiliser dose based on experiments + Opti-Growth	71.0	42.4	16.0	43.0	132.0	94.0	232.0	153.0
Fertiliser: organic-mineral – Opti-Growth	69.0	40.2	16.6	40.9	132.0	89.0	192.0	137.0

Source: developed by the authors

A particularly noticeable decrease in the level of nitrate nitrogen in the soil is observed under perennial grass mixtures, where the content ranges from 63.1 to 94.5 mg/ha of dry soil. This is because perennial grasses form a dense turf, which helps to reduce the mineralisation of

organic matter and the accumulation of nitrogen in mineralised form. In comparison, under annual crops such as rapeseed in grass-crop rotation, nitrate nitrogen levels are significantly higher (103.7-108.0 mg/ha). This indicates an intensive process of organic matter decomposition

in peat soil, which is greatly enhanced by annual crops that stimulate microbiological activity and, accordingly, peat decomposition processes.

In certain years, such as 2022, nitrate nitrogen content varied significantly, which may be due to climatic factors, in particular rising temperatures and changes in the water regime, which contribute to more intensive mineralisation of organic matter in peat soils. In general, regardless of how drained soils are used, all cultivated areas showed medium to high levels of mobile nitrogen, which is an important factor in planning mineral fertiliser application rates. This level of supply creates favourable conditions for high yields, but also requires control to avoid excess nitrogen, which can lead to its leaching into groundwater, increasing the risk of environmental pollution.

The content of mobile forms of phosphorus and potassium under rapeseed crops and perennial grass mixtures is usually associated with the application of mineral fertilisers, but on peaty carbonate soils, the dependence on fertilisers may vary. The vivianite layers in such soils create conditions under which phosphorus in a bound form, when interacting with air during ploughing, becomes available in a

mobile state. This provides an additional source of phosphorus for plants, which is important for maintaining an optimal phosphorus regime even with low fertiliser rates, such as P_{60} . Mobile phosphorus and potassium accumulate in the soil and provide rapeseed crops with nutrients, which has a positive effect on their yield. This is important in the context of maintaining soil fertility and the effective use of drained organogenic soils. The mineralisation of organic matter in peat soils not only enriches the soil with nutrients, but also stimulates the biological activity of microflora, which is one of the key factors in ensuring a nutritious regime. Depending on the composition and activity of microflora, mineralisation processes affect the intensity of accumulation of nutrients such as nitrogen, phosphorus and potassium, which determine crop yields on drained soils. During the growing season, the intensity of its decomposition (as a percentage of the initial mass) was an indicator of the biological activity of the soil. The faster the tissue decomposed, the higher the activity of microflora and the intensity of mineralisation processes, indicating the soil's high potential for converting organic matter into forms accessible to plants (Table 3).

Table 3. Effect of methods of use and fertilisation of drained organogenic soils under spring rapeseed crops on the decomposition of linen fabric, %

Fertilisation	Permanent crops of perennial grasses			Grass-based crop rotation			Crop rotation with annual crops		
	2021	2022	average	2021	2022	average	2021	2022	average
Without fertilisers (control)	30	41	35	54	63	58	70	57	63
Recommended fertiliser dose based on experiments	34	73	53	56	72	64	67	71	69
Calculated dose for yield increase	37	59	48	60	82	71	65	69	67

Note: soil layer 0-30 cm (exposure period 18.05-25.09)

Source: developed by the authors

It was found that the application of mineral fertilisers has a positive effect on the mineralisation processes of flax fabric, as does an increase in the proportion of annual crops in crop rotation. This contrasts with the decomposition of fabric observed after sowing perennial grasses. Thus, the decomposition of flax fabric over two years without the application of mineral fertilisers on perennial grass mixtures was 35%, while in grass-cereal crop rotation it was

58%, and in crop rotation containing only annual crops it was 63%. With the application of the recommended fertiliser doses ($P_{45}K_{120}$), these figures increased to 53%, 64% and 69% respectively, while the estimated yield increase under these conditions was 48%, 71% and 67%.

An important indicator for the use of drained organogenic soils is the determination of the actual mineralisation of peat, which allows assessing the efficiency of peatland exploitation

depending on the method of their use (Slyusar *et al.*, 2023). To this end, during 2021-2023, observations were made of the intensity of CO₂ release, which is a consequence of peat mineralisation under spring rapeseed crops under various conditions of organogenic soil use (Table 4).

Table 4. Mineralisation of organic matter in peat soil depending on the method of peat use

Year	Method of use	Level of fertilisation	Intensity of CO ₂ release from the soil, kg/ha per day	Intensity of CO ₂ release by the root system per day, kg/ha	Intensity of peat mineralisation during vegetation, t/ha
2021	Perennial grass crops without rotation	without fertilisers (control)	31.4	3.14	3.17
		recommended fertiliser dose based on experiments	33.0	6.29	3.33
		calculated dose for yield increase	40.9	4.71	4.13
	Spring rapeseed in grass crop rotation	without fertilisers (control)	51.9	9.43	5.24
		recommended fertiliser dose based on experiments	72.3	6.29	7.30
		calculated dose for yield increase	59.3	11.00	6.03
	Spring rapeseed in row crop rotation	without fertilisers (control)	83.3	7.86	8.41
		recommended fertiliser dose based on experiments	91.1	11.00	9.21
		calculated dose for yield increase	91.1	12.57	9.21
2022	Perennial grass crops without rotation	without fertilisers (control)	73.1	7.86	7.38
		recommended fertiliser dose based on experiments	66.8	9.43	6.75
		calculated dose for yield increase	58.9	9.43	5.95
	Spring rapeseed in grass crop rotation	without fertilisers (control)	57.4	12.57	5.79
		recommended fertiliser dose based on experiments	69.1	9.43	6.98
		calculated dose for yield increase	53.4	14.14	5.40
	Spring rapeseed in row crop rotation	without fertilisers (control)	80.1	11.00	2.88
		recommended fertiliser dose based on experiments	75.4	13.36	2.59
		calculated dose for yield increase	72.3	15.71	2.36
Average	Perennial grass crops without rotation	without fertilisers (control)	52.2	5.50	5.27
		recommended fertiliser dose based on experiments	49.9	7.86	5.04
		calculated dose for yield increase	49.9	7.07	5.04
	Spring rapeseed in grass crop rotation	without fertilisers (control)	54.7	11.00	5.49
		recommended fertiliser dose based on experiments	70.7	7.86	7.02
		calculated dose for yield increase	56.4	12.57	5.72
	Spring rapeseed in row crop rotation	without fertilisers (control)	81.7	9.43	6.05
		recommended fertiliser dose based on experiments	83.2	12.18	5.90
		calculated dose for yield increase	81.7	14.14	5.78
HiP ₀₅			4.3	0.39	1.05

Source: developed by the authors

It was found that CO₂ emissions from the soil during the exposure period on unfertilised plots under perennial grass mixtures amounted to 52.2 kg/ha per day. Under spring rapeseed in a grass-crop rotation with two annual crops, CO₂

emissions per day increased by 2.2 kg/ha, and in a row-crop rotation – by 29.5 kg/ha. The application of mineral fertilisers under rapeseed resulted in even greater CO₂ emissions from the soil. On plots with the recommended fertiliser

doses in the grass-based system, CO₂ emissions increased by 35.4%, and in the crop rotation with annual crops – by 59.4%. Thus, the data obtained confirm the importance of proper mineral nutrition management and crop selection in crop rotations to optimise microbiological processes in the soil and increase the efficiency of drained organogenic soils.

It should be noted that the mineralisation of peatlands and their increased depletion under agricultural use, especially with the introduction of crop rotations that include only annual crops, contributes to a greater accumulation of mobile nitrogen and mobile organic matter in the topsoil. Such accumulation is particularly pronounced in areas where groundwater is close to the surface (40–60 cm). Under such

conditions, especially during heavy rainfall, there is a risk of biogenic substances being washed into the groundwater. Groundwater has a hydrological connection with rivers, which causes pollution of water bodies with various biogenic elements, such as nitrates, phosphates and other soluble compounds. In view of this, studies were conducted to investigate the process of leaching soluble substances into groundwater under spring rapeseed crops under various conditions of use of drained organogenic soils. The studies showed that nitrate nitrogen and potassium compounds were leached most intensively from rapeseed crops. The phosphorus content in drained waters, on the contrary, was significantly lower, and this indicator was stable throughout the year, regardless of the season (Table 5).

Table 5. Impact of mineral fertiliser application and crop structure on the leaching of biogenic substances into groundwater, mg/l of water, average for 2021–2023

Soil use	Fertilisation	Spring				Autumn			
		NO ₃	NH ₃	P ₂ O ₅	K ₂ O	NO ₃	NH ₃	P ₂ O ₅	K ₂ O
Permanent crops of perennial grasses	without fertilisers (control)	9.2	2.4	0.3	5.6	2.1	2.1	1.5	8.2
	recommended fertiliser dose based on experiments	6.8	2.5	0.3	9.9	1.1	1.3	3.6	25.9
	calculated dose for yield increase	9.8	1.9	0.5	-	3.4	2.9	1.5	20.9
Grass-based crop rotation	without fertilisers (control)	2.8	2.5	0.1	5.7	4.7	2.5	1.1	14.2
	recommended fertiliser dose based on experiments	2.3	1.1	0.3	6.6	4.3	3.2	3.0	19.1
	calculated dose for yield increase	-	1.5	0.3	6.1	7.0	3.5	3.3	18.6
Spring rapeseed in row crop rotation	without fertilisers (control)	11.9	2.0	0.1	4.1	8.6	0.8	1.2	10.1
	recommended fertiliser dose based on experiments	12.7	2.6	0.3	5.1	11.2	1.0	3.8	15.1
	calculated dose for yield increase	12.7	1.2	0.3	6.3	12.6	0.7	2.3	25.4
Hip ₀₅		1.6	0.4	0.02	0.5	1.1	0.3	0.02	1.1

Source: developed by the authors

The results of seasonal observations showed that different elements are leached at different times of the year. Thus, the largest amount of nitrate nitrogen was leached in spring, while potassium migrated most in autumn. In crop rotation with annual crops, the concentration of nitrate nitrogen in drainage water was recorded at 11.9–12.7 mg/l in spring and 8.6–11.6 mg/l in autumn. The concentration of potassium in water in spring was 4.1–6.3 mg/l, while in autumn it was 10.1–25.4 mg/l.

Such seasonal dynamics are associated with the peculiarities of mineral fertiliser application and plant assimilation processes.

In particular, potash fertilisers are often applied in spring, which leads to a decrease in the potassium content in drainage waters in spring and due to the active consumption of this element by plants during the growing season. Nitrogen fertilisers, which are important for the growth and development of rapeseed throughout the season, are also intensively used

by plants, but part of them decomposes and accumulates in the soil during autumn and winter. With the onset of spring, when the groundwater level rises closer to the arable layer, the nitrate nitrogen accumulated during the winter is intensively washed out of the soil into drainage water.

The results obtained indicate the need for a rational approach to fertiliser application on peat soils, especially in conditions of close groundwater occurrence. To minimise the negative impact on the environment, it is necessary to optimise the application of nitrogen and potassium fertilisers, taking into account the seasonal needs of plants and the risk of leaching of

biogenic elements. This will reduce groundwater pollution and ensure stable crop yields on drained organogenic soils.

Studies have shown that the highest yield of spring rapeseed on drained organogenic soils was achieved with grass-crop rotation (5-6 fields of perennial grasses with 2-3 fields of annual crops, including rapeseed) under conditions of applying the recommended doses of mineral fertilisers or doses calculated for a yield increase of 2.1-3.8 cwt/ha (compared to the option without fertilisers). According to the average figures for 2021-2023, the yield in this crop rotation was 3.0-3.3 cwt/ha (Table 6).

Table 6. Spring rapeseed yield depending on mineral fertilisation and method of use on drained organogenic soils, t/ha

Fertilisation	Method of using organogenic soil	Year			average
		2021	2022	2023	
Without fertilisers (control)	grass-based crop rotation	1.8	3.0	1.4	2.1
	crop rotation with annual crops	2.4	2.4	1.6	2.1
Recommended fertiliser dose based on experiments	grass-based crop rotation	2.1	3.4	3.4	3.0
	crop rotation with annual crops	2.8	3.1	3.1	3.0
Calculated dose for yield increase	grass-based crop rotation	2.9	3.3	3.8	3.3
	crop rotation with annual crops	2.7	3.4	3.0	3.0
Hip ₀₅		0.31	0.29	0.31	-

Source: developed by the authors

The use of crop rotation, which includes only annual crops, also provided similar rapeseed yields, although they were on average 0.3 t/ha lower. However, this approach has negative environmental consequences: due to the more active mineralisation of organic peat mass, peatlands are being intensively depleted. This leads to accelerated decomposition of organic matter, a decrease in the organic content of the soil, and increased carbon dioxide (CO₂) emissions into the environment, which negatively affects the environment and increases the risk of soil fertility loss.

Under conditions of grass-field crop rotation with perennial grasses, which ensure reduced peat depletion, there is a more stable preservation of organic matter in the soil. Perennial grasses act as a kind of “protective barrier”, preventing the intensive decomposition of organic matter. In addition, such crop rotation contributes to improving soil structure,

preserving its water-air balance and ensuring the gradual accumulation of organic matter.

The use of mineral fertilisers in grass-based crop rotation increases the efficiency of nutrient use and allows for stable rapeseed yields, reducing the risk of peat soil depletion. This indicates the advisability of introducing crop rotations with perennial crops, which minimise degradation processes in organogenic soils, ensuring their long-term fertility. Thus, the results obtained indicate the advantages of grass-based crop rotations for growing spring rapeseed on peat soils. The use of perennial grasses in the crop rotation structure allows to preserve the organic matter of the soil, reduces the intensity of peat mineralisation, ensuring stable crop productivity and increasing the ecological stability of the agroecosystem.

The effective and environmentally friendly use of drained organogenic soils in the context of climate change is one of the key conditions for

ensuring the sustainable development of agricultural production (Jauhiainen *et al.*, 2019). Climate warming is accompanied by an increase in the rate of peat mineralisation, which poses a threat of soil degradation and water pollution. In this context, the introduction of agricultural technologies aimed at stabilising the carbon balance and limiting the loss of organic matter is particularly relevant (Truskavetskyi, & Tsapko, 2016; Klymenko *et al.*, 2022). According to the results of research by I. Slyusar (2019), one of the promising solutions is the technology of growing annual crops in the structure of grass-field crop rotation with the inclusion of 5-6 fields of perennial grasses and 2-3 annual crops. This approach allows for the comprehensive solution of several problems: increasing the biological activity of the soil, stabilising its agrochemical indicators, and reducing the intensity of peat mineralisation processes. The works of S. Kolomiyets & P. Pyyipchuk (2017), I. Slyusar (2019), Yu. Tarariko *et al.* (2025) highlight that the application of calculated doses of phosphorus and potassium fertilisers in this system is a balanced solution, which, on the one hand, meets the nutritional needs of crops and, on the other hand, prevents the leaching of biogenic substances into subsoil horizons and groundwater, as confirmed in the works of M. Heino *et al.* (2020) on obtaining high yields of agricultural crops in various cultivation systems.

As shown by the studies of V. Polyovy *et al.* (2022) and V. Tymofeyev *et al.* (2022), ecological and economic aspects are also an integral part of the proposed approach. The inclusion of both spring rapeseed and other annual crops in the structure of cultivated areas provides additional commercial production and creates financial reserves to maintain the operability of land reclamation systems. Thus, the technology combines environmental feasibility with economic efficiency, which meets the modern requirements for farming systems in the context of climate change. According to the results of studies by L. Hlisnikovskiy & E. Kunzova (2014) and G. Voropai *et al.* (2024), the proposed system allows for a 5-10% reduction in organic matter losses, as well as a reduction in energy costs per unit of production, which is a strong argument in favour of its implementation in production

practice. In addition, according to S. Balyuk & R. Truskavetskyi (2025), the development of the concept of "soil health" can only be ensured by establishing an optimal nutrient regime that contributes to increased crop yields compared to existing technologies of both domestic and foreign origin.

In general, the results of these scientific developments are important for the formation of adaptive models of sustainable agriculture on drained organogenic soils. They confirm that the integration of agroecological principles into technological solutions allows achieving a balance between soil fertility conservation, crop productivity improvement, and economic feasibility of agricultural production in the context of global climate challenges.

CONCLUSIONS

The developed technology for achieving high yields of spring rapeseed (3.4-3.8 t/ha of grain) is based on the introduction of environmentally friendly grass-cereal crop rotations, which include 5-6 fields of perennial grasses and 2-3 fields of annual crops. The use of such crop rotations in combination with the application of phosphorus and potassium fertilisers in calculated doses or doses justified by long-term agrochemical observations ensures balanced crop nutrition and contributes to the ecological stability of agroecosystems. This approach prevents excessive mineralisation of organic matter in peat and reduces the risk of leaching of biogenic elements – primarily nitrates and potassium – from the active soil layer into groundwater, which is particularly important for preserving the quality of the aquatic environment.

The developed grass-field crop rotation with the inclusion of perennial grasses in the structure of spring rapeseed crops ensures the stabilisation of microbiological processes in the soil, maintains a moderate rate of mineralisation that corresponds to the rate of nutrient consumption by crops, and prevents the imbalance of biogeochemical cycles. This contributes to maintaining the ecological sustainability of agroecosystems, prevents excessive carbon dioxide emissions into the atmosphere, and reduces the environmental impact of agricultural activities. The inclusion of perennial grasses in crop rotation has

a positive effect on the structural and agronomic properties of the soil: its structure improves, the organic matter content increases, and the water-air regime stabilises, which is especially important on drained organogenic soils. In addition, this approach reduces anthropogenic impact on ecosystems, prevents degradation processes in the soil cover, and contributes to the long-term preservation of peat soil fertility. As a result, an optimal environment for growing spring rapeseed is formed, the efficiency of agricultural production is increased, and a harmonious combination of productivity and environmental protection potential of agricultural land use is ensured.

Prospects for further research lie in an in-depth study of the mechanisms of interaction between the components of the agroecosystem under different options for grass-field crop rotations, refinement of the dynamics of the carbon balance in soils of organogenic origin, and modelling of nutrient leaching into drained waters under different climate scenarios. Particular

attention should be paid to assessing the energy and economic efficiency of agricultural technologies, as well as the impact of anthropogenic factors on the long-term fertility of drained soils in the context of climate change.

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CONFLICT OF INTEREST

None.

REFERENCES

- [1] Balyuk, S.A., & Truskavetskyi, R.S. (2025). Authentic analysis and prospective development of the concept of “soil health”. *Herald of Agrarian Science*, 103(4), 56-64. [doi: 10.31073/agrovisnyk202504-06](https://doi.org/10.31073/agrovisnyk202504-06).
- [2] DSTU 4114-2002. (2003). *Soils. Determination of mobile phosphorus and potassium compounds by the modified Machygin method*. Retrieved from https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=58928.
- [3] DSTU 4725-2007. (2008). *Soil quality. Determination of the activity of potassium, ammonium, nitrate and chlorine ions by potentiometric method*. Retrieved from https://online.budstandart.com/ua/catalog/doc-page?id_doc=72424.
- [4] DSTU ISO/TS 14256-1:2005. (2006). *Soil quality. Determination of nitrate, nitrite and ammonium in field moisture soils by extraction with potassium chloride solution. Part 1. Manual method (ISO/TS 14256-1:2003, IDT)*. Retrieved from https://online.budstandart.com/ua/catalog/doc-page?id_doc=53548.
- [5] Heino, M., Guillaume, J.H.A., Müller, C., Iizumi, T., & Kummu, M. (2020). A multi-model analysis of teleconnected crop yield variability in a range of cropping systems. *Earth System Dynamics*, 11(1), 113-128. [doi: 10.5194/esd-11-113-2020](https://doi.org/10.5194/esd-11-113-2020).
- [6] Hlisnikovsky, L., & Kunzova, E. (2014). [Effect of mineral and organic fertilizers on yield and technological parameters of winter wheat \(*Triticum aestivum* L.\) on illimerized luvisol](https://doi.org/10.15663/2014-17-18-24). *Polish Journal of Agronomy*, 17, 18-24.
- [7] Jajor, E., & Mrówczyński, M. (Eds.). (2016). [Methodology of integrated protection and production of winter and spring rapeseed for advisors](https://doi.org/10.2478/9788376170000). Poznan: Institute of Plant Protection – National Research Institute.
- [8] Jauhainen, J., et al. (2019). Reviews and syntheses: Greenhouse gas exchange data from drained organic forest soils – a review of current approaches and recommendations for future research. *Biogeosciences*, 16(23), 4687-4703. [doi: 10.5194/bg-16-4687-2019](https://doi.org/10.5194/bg-16-4687-2019).

- [9] Klymenko, M.O., Dolzhenchuk, V.I., Varzhel, O.V., Klymenko, V.O., & Tsinivsky, I.O. (2022). [Dynamics of humus balance in arable lands of Rivne region](#). In E. Pluzhnik et al. (Eds.), *The latest problems of modern science and practice* (pp. 22-25). Boston: International Science Group.
- [10] Kolesnikov, O.V. (2019). [Fundamentals of scientific research](#). Kyiv: Centre for Educational Literature.
- [11] Kolomiyets, S.S., & Pyyipchuk, I.M. (2017). [Ecologically balanced use of drained peat lands in the field of land reclamation](#). *Land Reclamation and Water Management*, 105(1), 67-70.
- [12] Malinovska, I.M., & Tkachenko, M.A. (2023). [Microbiological processes in gray forest soil. Monograph](#). Kyiv: Agrarian Science.
- [13] Markova, N., Smirnova, I., Zadorozhnii, Yu., & Horbunov, M. (2025). Irrigation systems as a factor in increasing productivity in agricultural regions of Ukraine. *Scientific Horizons*, 28(4), 107-119. [doi: 10.48077/scihor4.2025.107](#).
- [14] Parkhomets, M., Uniat, L., Chornyi, R., Chorna, N., & Hradovyi, V. (2023). Efficiency of production and processing of rapeseed for biodiesel in Ukraine. *Agricultural and Resource Economics: International Scientific E-Journal*, 9(2), 245-275. [doi: 10.51599/are.2023.09.02.11](#).
- [15] Polyovy, V.M., Yashchenko, L.A., Rovna, G.F., & Kolesnyk, T.M. (2022). Ecological and economic aspects of growing agricultural crops on sod-podzolic soil of Western Polissya of Ukraine. *Agroecological Journal*, 1, 91-98. [doi: 10.33730/2077-4893.1.2022.257127](#).
- [16] Ryzhuk, S.M., Savchuk, O.I., Melnychuk, A.O., & Priymachuk, T.Yu. (2022). The effectiveness of short-rotation crop rotations with economically attractive crops on drained sod-podzolic soils. *Bulletin of Agricultural Science*, 100(2), 11-18. [doi: 10.31073/agrovisnyk202202-02](#).
- [17] Slyusar, I.T. (2019). Methodological features of calculating fertilizer doses in crop rotation on drained organic soils. *Bulletin of Agricultural Science*, 9, 72-79. [doi: 10.31073/agrovisnyk201909-11](#).
- [18] Slyusar, I.T., Serbeniuk, V.O., & Serbeniuk, G.A. (2023). Ecological aspects of mineral fertilization of perennial grass mixtures on drained organic soils. *Agroecological Journal*, 2, 100-108. [doi: 10.33730/2077-4893.2.2023.283702](#).
- [19] Tarariko, Yu.O., Pysarenko, P.V., Sajdak, R.V., Knysh, V.V., & Vdovichenko, O.P. (2025). Balance studies in crop rotations with forest-steppe crops on drained lands of Western Polissya under variable hydrothermal conditions. In *Water for the future: Management, conservation, innovations. Collection of abstracts* (pp. 54-57). Kyiv: Institute of Water Problems and Melioration. [doi: 10.31073/mivg2025](#).
- [20] Truskavetskyi, R.S., & Tsapko, Y.L. (2016). [Fundamentals of soil fertility management](#). Kharkiv: FOP "Brovin O.V".
- [21] Tymofeyev, V.E., Klok, S.V., Kornus, A.O., Kornus, O.G., & Danilchenko, O.S. (2022). [Ukrainian Polissya: Problems and trends of modern development](#). In M.O. Baranovskyi, V.V. Ostapchuk, O.O. Afonina, Y.M. Filonenko, T.M. Shovkun, O.V. Baranovska, I.M. Filonenko, I.V. Myron & O.A. Bezdukhov, *Ukrainian Polissya as an indicator of modern climate change* (pp. 102-105). Nizhyn: Mykola Gogol Nizhyn State University.
- [22] Voropai, G.V., Kotykovych, I.V., Kuzmich, L.V., Moleshcha, N.B., Kharlamov, O.I., & Styozhka, D.O. (2024). [Information materials for assessing the influence of climatic factors on the formation of the soil water regime on drained lands](#). *Land Reclamation and Water Management*, 1(119), 24-39.
- [23] Yevtushenko, M.Yu., & Khyzhnyak, M.I. (2019). [Methodology and organization of scientific research](#). Kyiv: Centre for Educational Literature.

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Агробіологічні й природоохоронні заходи підвищення врожайності ріпаку ярого на дренажних органогенних ґрунтах за умов кліматичних змін

Анотація. У статті досліджено агробіологічні та природоохоронні методи підвищення врожайності ріпаку ярого на дренажних органогенних ґрунтах в умовах кліматичних змін, що враховують особливості характеристики цих ґрунтів та методологічні підходи визначення доз мінеральних добрив в умовах польового стаціонарного дослідження на дренажних органогенних ґрунтах заплави р. Супій. Мета досліджень полягала у визначенні ефективності методології розрахунків найдоцільніших доз добрив та особливості формування оптимального режиму під посіви ріпаку ярого на дренажних органогенних ґрунтах через визначення обґрунтованих норм внесення мінеральних добрив залежно від методик, що враховують специфіку цих ґрунтів. В дослідженні використано такі методи, як польовий з комплексом біометричних, агрохімічних і лабораторних досліджень та математично-статистичний. Дослідження фокусувались на розробці оптимальних систем мінерального удобрення та ефективних методів використання торфовищ, враховуючи екологічні аспекти. Було встановлено, що внесення мінеральних добрив призводить до посилення мінералізаційних процесів, які зростають зі збільшенням доз добрив, а це зумовлює накопичення поживних речовин, що впливають на урожайності вирощуваних культур та міграцію їх у дренажні води. Використовуючи польові, лабораторні та статистичні методи, автори визначили, що найбільша мінералізація торфу та виділення CO₂ відбувається в сівозміні з однорічними культурами, тоді як багаторічні трави знижують

спрацювання торфу. Також встановлено, що найвища врожайність ріпаку досягається у травопільній сівозміні з внесенням мінеральних добрив (3,0-3,3 т/га), що забезпечує зменшення енерговитрат і підвищення економічної ефективності. Дослідження виявили значне вимивання нітратного азоту і калію в дренажній воді, особливо навесні та восени, що сприяє забрудненню водних ресурсів. Запропоновані методи також підвищили стабільність агроєкосистеми, мінімізуючи деградаційні процеси в органічних ґрунтах та знижуючи екологічне навантаження на навколишнє середовище. Отримані результати мають практичну цінність у вдосконаленні органічних систем удобрення бінарних посівів культур та забезпечення стійкості агроєкосистем і можуть бути використані виробниками сільськогосподарської продукції різних форм власності

Ключові слова: торфові ґрунти; розклад льняної тканини; органічна речовина; удобрення; обробіток ґрунту; продуктивність; біогенні речовини