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BIOTECHNOLOGICAL DIRECTION OF WINTER WHEAT CULTIVATION DEPENDING ON THE CROP ROTATION FACTOR IN THE CONDITIONS OF THE STEPPE OF UKRAINE

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Problem statement. Among the most important grain crops, winter wheat ranks first in Ukraine in terms of sown areas and is the main food crop. This indicates the great economic importance of winter wheat, its necessity in satisfying people with high-quality food products, therefore the demand for the products of this crop is constantly increasing.

However, modern conditions of agricultural sector development require not only increasing the production volumes of quality agricultural products, but also simultaneously reducing economic and energy costs for cultivation. These issues become especially relevant due to global climate changes, scientifically justified approaches to the structure of sown areas and fertilization systems, and the biologicalization of agriculture.

Therefore, further growth in winter wheat production, increasing its productivity and improving grain quality require constant improvement and optimization of cultivation technology based on the latest scientific developments.

Analysis of recent research and publications. The conditions of the agricultural market force producers of agricultural products of various ownership forms to increase sown areas under economically attractive crops such as sunflower, corn for grain, soybeans, which has led not only to a reduction in the crop rotation period, but also to a disruption of crop rotation structure, saturating them with specific crops [1, 9].

Significant role in optimizing agricultural production, especially in the Steppe zone of Ukraine, belongs to the implementation of short rotation crop rotations with different saturation of legumes and fertilizer systems with elements of biologicalization [10]. Therefore, for small farms, there is a need to introduce specialized short rotation crop rotations. The construction of such crop rotations should be carried out based on scientifically justified principles, the main of which is the placement and rotation of crops according to the laws of crop rotation [2, 5, 6, 8, 14, 17, 18, 19, 20].

The introduction of legume crops in short rotation crop rotations ensures increased yields and improved quality of agricultural crops, special attention should be paid to increasing the productivity of the crop rotation as a whole. At the same time, legume crops improve biological processes in the soil due to favorable symbiosis with the soil environment, which increases enzymatic activity and the ability of subsequent crops in the crop rotation to use low-soluble nutrients such as phosphorus and potassium. Accumulated calcium in the roots of legume crops and released after their decay improves soil structure.

In the scientific literature, you can find a lot of information about the features of short rotation crop rotations, this is due to the relevance of such crop rotations under conditions of decreasing arable land area and a list of crops grown on farms [7, 17].

Crop rotation plays a significant role in providing soil moisture, available forms of nutrients, affects soil temperature, microbial activity, soil structure, etc. It has been proven that the crop rotation factor significantly influences the yield and productivity of winter wheat, but the impact of crop rotation structure, especially its saturation with crops such as soybeans, has not been sufficiently studied for the conditions of the Steppe zone of Ukraine [3, 12, 13, 15, 16].

Rational application of fertilizers and the use of biopreparations are also important elements in optimizing winter wheat cultivation [11]. The use of treatment of winter wheat crops with bio-preparations ensures an increase in grain yield from 2.89 to 4.99 t/ha against the background of basic fertilizer application [4].

Thus, studying the impact of short rotation crop rotations with different saturation of soybeans and elements of biologicalization on winter wheat cultivation to increase winter wheat productivity is a relevant issue today.

Objective. To establish the relationship between the yield level and economic efficiency of winter wheat cultivation in short rotation crop rotations using a biopreparation in the conditions of the Northern Steppe region of the Ukraine.

Materials and methods of research. Field research was conducted during 2021-2023 at the Institute of Agriculture of the Steppe NAAS laboratory according to the scheme below. The experiment was set up using a randomized block design, with each crop rotation being a separate block. The stationary experiment was established in 2005 on plots after spring barley, which were leveled in terms of natural fertility and relief. The degree of soil contamination at the agriculture institute's laboratory station where field research was conducted is high, corresponding to the conditions of the northern part of the Steppe region of Ukraine.

Winter wheat variety Oranta Odeska was sown in the second decade of September at a seeding rate of 4.5 million seeds per hectare. The winter wheat seeds were treated with the bio-preparation Mycofriend (1.0 L/ton) – factor A. Winter wheat was grown in three short rotation crop rotations – factor B.

The grain-fallow-row crop rotation with soybean saturation up to 20 % included the following crop rotation: 1. Fallow; 2. Winter wheat; 3. Soybean; 4. Corn for grain; 5. Sunflower.

The grain-row crop rotation with soybean saturation up to 40% consisted of the following crops: 1. Soybean; 2. Winter wheat; 3. Soybean; 4. Corn for grain; 5. Buckwheat.

The grain-row crop rotation with soybean saturation up to 60% consisted of the following crops: 1. Soybean; 2. Winter wheat; 3. Soybean; 4. Corn for grain; 5. Soybean.

Winter wheat crops were fertilized with nitrogen fertilizers (ammonium nitrate) at a rate of 30 kg/ha of active substance in the spring. In April, the winter wheat crops were treated with the retardant Gulliver (1.4 L/ha), micronutrients Green-Active (0.2 L/ha), and Avangard RK (0.9 L/ha) with the addition of magnesium sulfate (2.5 kg/ha physical weight). In the first decade of May, the winter wheat crops were treated with the herbicide Grenader (0.25 kg/ha) with the addition of PAR Tandem (0.2 L/ha), micronutrients Green-Active (0.2 L/ha), and mineral fertilizers urea (5 kg/ha physical weight) and magnesium sulfate (2.5 kg/ha physical weight).

Weather conditions during the years of the study were favorable for obtaining high yields of winter wheat, except for the sowing period in 2021. The sowing period was characterized by rainy weather, which prevented timely sowing due to high soil moisture, while in 2022-2023, on the contrary, dry weather with a lack of moisture in the sowing layer of the soil during sowing led to a prolonged period from sowing to emergence.

Research results. The results of the three-year study showed that treating winter wheat seeds with a biologically active preparation when grown in crop rotations with different soybean saturation contributed to an increase in crop yield. The yield indicators presented in Table 1 demonstrate that as the concentration of soybeans in the crop rotation decreased, the yield of winter wheat grain increased. In the soybean crop rotation, where this crop occupied three fields, the average yield of wheat was 5.58 t/ha, while reducing the number of fields to two resulted in a yield of 5.98 t/ha.

The most significant effect of the biopreparation was observed in grain-row crop rotations with soybean saturation at 60 % and 40 %. Due to the action of the biopreparation factor, the highest increase in winter wheat grain yield was obtained in the crop rotation with the highest concentration of soybeans, +0.67 t/ha or 13.6 % (LSD05 = 0.45 t/ha). In the crop rotation with 40 % soybean saturation, a significant increase in winter wheat grain yield was also observed, +0.48 t/ha or 8.7 %, but the effectiveness of the biological component of the inoculant decreased.

Replacing two soybean fields with other crops in the crop rotation, although resulting in the highest winter wheat yield in our study, 6.63 t/ha, did not show a significant effect of the biopreparation in the crop rotation with 20 % soybean saturation. The difference between the grain-fallow-row crop rotation where the biopreparation was not used was only 0.40 t/ha or 6.4 %.

Our research confirms a more significant impact of the crop rotation factor on winter wheat yield. Despite higher crop yield values being recorded in variants where treated seeds were grown, the saturation factor of the crop rotation with soybeans had a more effective influence on increasing yield. For instance, replacing one soybean field in the crop rotation with another crop and reducing its concentration to 40 % resulted in a yield increase of 0.58 t/ha or 11.9 % (LSD05 = 0.55 t/ha).

However, it is important to note that using the biopreparation in the crop rotation with 60 % soybean saturation had a greater effect than changing the structure of the crop rotation, with a yield increase of 0.67 t/ha or 13.6 %. Moreover,

Table 1

Winter wheat yield depending on the biopreparation in different crop rotations

Biopreparation (factor A)	**Crop rotation (factor B)**	**Average for 2021-2023**	**Difference**			
			factor A		**factor B**	
			t/ha	**%**	**t/ha**	**%**
Without biopreparation	Grain-row (60 % of soybeans)	4.92	–	–	–	–
	Grain-row (40 % of soybeans)	5.50	–	–	0,58	11,9
	Grain-fallow-row (20 % of soybeans)	6.23	–	–	1.32	26.8
Seed treatment with biopreparation	Grain-row (60 % of soybeans)	5.58	0.67	13.6	–	–
	Grain-row (40 % of soybeans)	5.98	0.48	8.7	0.40	7.1
	Grain-fallow-row (20 % of soybeans)	6.63	0.40	6.4	1.05	18.8
LSD05, t/ha	Factor A	0.45	–			
	Factor B	0.55	–			
	Factors A	0.78	–			

no significant difference was established between such agronomic practices as selecting crop rotations and applying biopreparations: yields of 5.50 t/ha and 5.58 t/ha respectively showed the smallest significant interaction difference between the two factors of 0.78 t/ha.

Seed inoculation with the biopreparation somewhat mitigates the effect of the crop rotation factor. In the grain-row crop rotation, where soybean fields occupied 40 % of the area, the yield increase was within a significant difference compared to the crop rotation where soybeans occupied 60 %, at 0.40 t/ha or 7.1 % (LSD05 = 0.55 t/ha). The effectiveness of the factor was almost half as much compared to the variant without using the biopreparation, where the increase was 11.9 %.

The most significant impact of the crop rotation factor was observed in the grain-fallow-row crop rotation with 20 % soybean saturation. Introducing a fallow field and reducing the concentration of leguminous crops in the crop rotation provided the highest increase in winter wheat grain yield in our experiments, at 1.32 t/ha or 26.8 %, which is the highest indicator in our study.

According to the economic efficiency of winter wheat cultivation, it was found that the lowest production costs (15540 UAH/ha) were in the grain-row crop rotation with soybean saturation up to 60 % without using the biopreparation. However, this led to the lowest value of the produced output (28413 UAH/ha), net profit (12873 UAH/ha), and profitability (82.8 %) (Table 2).

The highest economic indicators were under the conditions of winter wheat cultivation in the grain-fallow-row crop rotation with soybean saturation up to 20 % using the biopreparation. Under these conditions, there were the highest production costs (16436 UAH/ha), the highest value of the produced output (38288 UAH/ha), the highest net profit (21852 UAH/ha), and profitability (132.9 %).

The determination of additional net income allowed us to identify the specific effect of the factors under study. According to Table 3, the use of the biopreparation contributed to an additional income of 3466.0 UAH/ha in winter wheat cultivation in the grain-row crop rotation with soybean saturation up to 60 %, 2520.0 UAH/ha in the grain-row crop rotation with soybean saturation up to 40 %, and

Table 2

Economic efficiency of winter wheat cultivation depending on the biopreparation in different crop rotations

Crop rotation	Production costs, UAH/ha	Gross output value, UAH/ha	Notional profit, UAH/ha	Profitability, %
Without biopreparation				
Grain-row (60 % of soybeans)	15540	28413	12873	82.8
Grain-row (40 % of soybeans)	15844	31763	15919	100.5
Grain-fallow-row (20 % of soybeans)	16227	35978	19751	121.7
Seed treatment with biopreparation				
Grain-row (60 % of soybeans)	15886	32225	16339	102.8
Grain-row (40 % of soybeans)	16096	34535	18439	114.6
Grain-fallow-row (20 % of soybeans)	16436	38288	21852	132.9

Table 3

Additional notional profit due to the use of the biopreparation in different crop rotations

Biopreparation (factor A)	Crop rotation (factor B)	Notional profit, UAH/ha	Difference			
			factor A		factor B	
			UAH/ha	%	UAH/ha	%
Without biopreparation	Grain-row (60 % of soybeans)	12873.0	–	–	–	–
	Grain-row (40 % of soybeans)	15919.0	–	–	3046.0	23.7
	Grain-fallow-row (20 % of soybeans)	19751.0	–	–	6878.0	53.4
Seed treatment with biopreparation	Grain-row (60% of soybeans)	16339.0	3466.0	26.9	–	–
	Grain-row (40 % of soybeans)	18439.0	2520.0	15.8	2100.0	12.9
	Grain-fallow-row (20 % of soybeans)	21852.0	2101.0	10.6	5513.0	33.7

the least – 2101.0 UAH/ha in the grain-fallow-row crop rotation with soybean saturation up to 20 %. This suggests that deviating from the traditional crop rotation requires the mandatory use of the biopreparation.

The highest increases by the crop rotation factor were observed without using the biopreparation. Comparing the grain-row crop rotation with soybean saturation up to 60 % to the grain-row crop rotation with soybean saturation up to 40 %, the additional net income was 3046.0 UAH/ha or 23.7 %, and compared to the grain-fallow-row crop rotation – 6878.0 UAH/ha or 53.4 %.

Discussion. Thus, our research has demonstrated the significant impact of the biopreparation and soybean saturation in short crop rotations on the yield and economic efficiency of winter wheat cultivation in the conditions of the Northern Steppe of Ukraine.

Seed inoculation with the Mycofriend preparation contributed to higher winter wheat yield indicators in crop rotations with different soybean saturations: 60 % – 5.58 t/ha, 40 % – 5.98 t/ha, 20 % – 6.63 t/ha, but a significant yield increase due to the action of the biopreparation was obtained in crop rotations with soybean concentrations of 60 % and 40% (+0.67 t/ha or 13.6 % and 0.48 t/ha or 8.7 %, respectively). In the crop rotation with 20 % soybean saturation, the impact of the preparation was not significant, +0.40 t/ha at LSD05 = 0.45 t/ha.

The crop rotation factor had a more significant impact on winter wheat yield in the conditions of the Northern Steppe of Ukraine. The highest increases were observed in the variant without seed treatment with the biopreparation, in the grain-fallow-row crop rotation with 20% soybean saturation, where these indicators were the highest, +1.32 t/ha or 26.8 %.

The application of biotechnological methods in winter wheat cultivation somewhat mitigated the effect of the crop rotation factor, with a significant yield increase only in the crop rotation with 20 % soybean saturation, +1.05 t/ha or 18.8 %.

The highest economic efficiency was observed in the grain-fallow-row crop rotation with soybean saturation up to 20 % using the biologically active preparation, where under these conditions, the gross production value was 38288 UAH/ha, net income was 21852 UAH/ha, with a profitability of 132.9 %.

The crop rotation factor had a greater impact on obtaining additional net income. The maximum increase was observed without using the biopreparation in the grain-fallow-row crop rotation with soybean saturation up to 20 %, which amounted to 6878 UAH/ha.

The biopreparation factor provided an increase from 2101 UAH/ha in the grain-fallow-row crop rotation with 20 % soybean saturation to 3466 UAH/ha in the grain-row crop rotation with 60 % soybean saturation.

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Mashchenko Yu.V., Sokolovska I.M., Kulyk G.A. Biotechnological direction of winter wheat cultivation depending on the crop rotation factor in the conditions of the Steppe of Ukraine

Modern conditions of agricultural sector development require constant increase in the production volumes of high-quality agricultural products. These issues are becoming particularly relevant due to global climate changes, scientifically justified approaches to crop structure and fertilization systems, and the biologization of agriculture. Therefore, further growth in winter wheat production, increasing its productivity and improving grain quality require continuous improvement and optimization of cultivation technology based on the latest scientific developments.

The aim of our research was to establish the correlation between yield levels and economic efficiency of winter wheat cultivation in short crop rotations using a biopreparation in the conditions of the Northern Steppe region of the country.

Field research was conducted during 2021-2023 at the Institute of Agriculture of the Steppe NAAS. Winter wheat variety Oranta Odeska was grown in three short rotation crop rotations with soybean saturation levels of 20 %, 40 %, and 60 %. The winter wheat seeds were treated with the biopreparation Mycofriend.

Seed treatment with the Mycofriend preparation contributed to higher winter wheat yield indicators in crop rotations with different soybean saturations: 60 % – 5.58 t/ha, 40 % – 5.98 t/ha, 20 % – 6.63 t/ha. However, a significant yield increase due to the action of the biopreparation was obtained in crop rotations with soybean concentrations of 60 % and 40 %. The crop rotation factor had a more significant impact on winter wheat yield in the conditions of the Northern Steppe of Ukraine.

The highest economic efficiency was observed in the grain-fallow-row crop rotation with soybean saturation up to 20 % using the biologically active preparation, where under these conditions, the profitability was 132.9 %.

The crop rotation factor had a greater impact on obtaining additional net income, with the maximum increase observed without using the biopreparation in the grain-fallow-row crop rotation with 20 % soybean saturation.

Overall, our research highlights the importance of crop rotation, soybean saturation levels, and biopreparation in enhancing winter wheat yield and economic efficiency in the Northern Steppe region of Ukraine.

Key words: crop rotation, soybean saturation in crop rotation, biopreparation, yield and economic efficiency of winter wheat cultivation.

Мащенко Ю.В., Соколовська І.М., Кулик Г.А. Біотехнологічний напрямок вирощування пшениці озимої залежно від сівозмінного фактору в умовах Степу України

Сучасні умови розвитку аграрного сектору вимагають постійне збільшення обсягів виробництва якісної сільськогосподарської продукції. Особливої актуальності ці питання набувають через глобальні зміни клімату, науково-обґрунтовані підходів до структури посівних площ та систем удобрення, біологізацію землеробства. Тому подальше зростання виробництва пшениці озимої, підвищення її продуктивності та покращення якості зерна потребують постійного вдосконалення та оптимізації технології вирощування на основі новітніх наукових розробок.

Метою наших досліджень було встановити залежність рівня врожайності та економічної ефективності вирощування пшениці озимої в сівозмінах короткої ротації з використанням біопрепарату в умовах Північного Степу країни.

Польові дослідження проводили протягом 2021-2023 рр. в лабораторії землеробства Інституту сільського господарства Степу НААН. Пшеницю озиму сорту Оранта одеська вирощували в трьох короткоротаційних сівозмінах з насиченням соєю 20%, 40 % та 60 %. Насіння пшениці озимої обробляли біопрепаратом Мікофренд.

Обробка насіння препаратом Микофренд сприяла отриманню вищих показників врожайності пшениці озимої по сівозмінах з різним насиченням сої: 60 % – 5,58 т/га, 40 % – 5,98 т/га, 20 % – 6,63 т/га, але достовірну прибавку врожаю за рахунок дії біопрепарату було отримано в сівозмінах, концентрація посівів сої в яких складала 60 % та 40 %. Більш ефективно на урожайність пшениці озимої в умовах Північного Степу України впливав сівозмінний фактор.

Найвища економічна ефективність вирощування пшениці озимої була у зерно-паро-просапній сівозміні з насиченням соєю до 20 % з використанням біологічно активного препарату за рентабельності 132,9 %. Більший вплив на отримання додаткового умовно-чистого прибутку мав фактор сівозміни. Максимальна прибавка, 6878 грн/га, була у зерно-паро-просапній сівозміні з насиченням соєю до 20 %. Фактор біопрепарат забезпечував прибавку від 2101 грн/га у зерно-паро-просапній сівозміні з насиченням соєю на 20 % до 3466 грн/га у зерно-просапній сівозміні з насиченням соєю на 60 %.

Ключові слова: сівозміна, насичення сівозміни соєю, біопрепарат, урожайність та економічна ефективність вирощування пшениці озимої.