UDC 631.582.5:631.8:633.11
DOI https://doi.org/10.32782/2226-0099.2023.132.14

YIELD AND PRODUCTIVITY OF WINTER WHEAT DEPEND ON THE FERTILIZER SYSTEM AND BIOPREPARATION

Mashchenko Yu.V. *– Ph.D.,*
Head of the Scientific and Technological Department for Soil Fertility Conservation,
Institute of Agriculture of the Steppe, National Academy of Agrarian Sciences
Sokolovska I.M. *– Ph.D.,*
Associate Professor at the Department of Crop Farming and Agroengineering,
Kherson State Agrarian Economic University

Increasing grain yield of winter wheat, reducing resource and chemical inputs, and soil load are a priority direction for the development of agriculture. An important technological link in the cultivation of winter wheat is the fertilization system, which depends on the specific soil and climatic conditions of the region, crop rotation, and variety characteristics. Therefore, studying and developing biotechnological methods of crop cultivation, taking into account the requirements of modern high-yielding varieties and the variability of weather conditions, is a relevant research direction.

Field research was conducted from 2019 to 2023 at the Laboratory of Agriculture of the Institute of Agriculture of the Steppe. Winter wheat variety Oranta Odeska was grown in a short-rotation grain-fallow crop rotation.

According to the results of our research, the highest yield level without fertilizers was observed in 2022, reaching 7.88 t/ha. The highest yields with mineral and organic-mineral fertilizer systems were recorded in 2023, at 8.94 t/ha and 9.09 t/ha respectively. The maximum yield of 9.61 t/ha was achieved in 2023 using the organic-mineral fertilizer system combined with the use of a biopreparation. The use of the microbial biopreparation Mycofriend resulted in significant yield increases compared to no fertilizer application (0.48 t/ha or 8.4 %), the organic-mineral fertilizer system (0.37 t/ha or 5.5 %), and the mineral fertilizer system (0.34 t/ha or 5.2 %).

The highest productivity was observed in plants grown with the organic-mineral fertilizer system combined with the use of the biopreparation Mycofriend: 7.96 t/ha of grain units, 10.21 t/ha of feed units, and 0.87 t/ha of digestible protein. The highest biopreparation effect was observed without fertilizer application, with yield increases of 0.52 t/ha (8.4 %) for grain units, 0.67 t/ha (8.4 %) for feed units, and 0.06 t/ha (9.3 %) for digestible protein. The highest nutrient content was obtained in 2022 and 2023 using the organic-mineral fertilizer system combined with the biopreparation: 10.39 t/ha and 10.57 t/ha of grain units, 13.32 t/ha and 13.55 t/ha of feed units, and 1.13 t/ha and 1.15 t/ha of digestible protein, respectively.

Key words: *fertilization systems, biopreparation, yield, productivity, winter wheat.*

Мащенко Ю.В., Соколовська І.М. Урожайність та продуктивність пшениці озимої залежно від систем удобрення і біопрепарату

Підвищення врожайності зерна пшениці озимої, зменшення витрат ресурсів і хімічних речовин, навантаження на ґрунт – є пріоритетним напрямком розвитку сільського господарства. Важливою технологічною ланкою при вирощуванні пшениці озимої є система удобрення, специфіки ґрунтово-кліматичних умов зони, попередників та сортових особливостей пшениці озимої. Таким чином, вивчення та розробка біотехнологічних прийомів вирощування культури, враховуючи вимоги сучасних, високоврожайних сортів та кліматичні умови, які постійно змінюються, є актуальним напрямком досліджень.

Польові дослідження проводилися протягом 2019–2023 рр. в лабораторії землеробства Інституту сільського господарства Степу НААН. Пшеницю озиму сорту Оранта одеська вирощували у короткоротаційній зернопаропросапній сівозміні.

За результатами наших досліджень було встановлено, що найбільший рівень врожайності на фоні без добрив формували рослини пшениці озимої сорту Оранта одеська в умовах 2022 року, який становив 7,88 т/га. На фонах мінеральної та органо-мінеральної систем удобрення найбільша урожайність була у 2023 році і становила 8,94 т/га та 9,09 т/га відповідно. Максимальний рівень врожайності – 9,61 т/га був також 2023 року за умов

вирощування пшениці озимої при поєднанні органо-мінеральної системи удобрення з використанням біопрепарату. Використання мікробного біопрепарату Мікофренд сприяло отриманню достовірних прибавок за врожайністю на фоні без внесення добрив 0,48 т/га (8,4 %), за органо-мінеральної системи удобрення 0,37 т/га (5,5 %) та за мінеральної системи удобрення 0,34 т/га (5,2 %).

Найвищій рівень продуктивності формували рослини пшениці озимої за органо-мінеральної системи удобрення з використанням біопрепарату Мікофренд: 7,96 т/га зернових одиниць, 10,21 т/га кормових одиниць, 0,87 т/га перетравного протеїну. Найвища дія біопрепарату була на фоні без внесення добрив, при цьому прибавки за зерновими одиницями становили 0,52 т/га (8,4 %), за кормовими одиницями – 0,67 т/га (8,4 %) та перетравним протеїном – 0,06 т/га (9,3 %). Найбільший збір поживних речовин отримано в умовах 2022 р. та 2023 р. за органо-мінеральної системи удобрення з використання біопрепарату: 10,39 т/га та 10,57 т/га зернових одиниць, 13,32 т/га та 13,55 т/га кормових одиниць та 1,13 т/га та 1,15 т/га перетравного протеїну відповідно.

Ключові слова: *системи удобрення, біопрепарати, урожайність, продуктивність, пшениця озима.*

Problem statement. Winter wheat is the main agricultural crop in many countries around the world and the main food crop in the Steppe Zone of Ukraine. Increasing production and improving the quality of winter wheat grain remains an important task for scientists and farmers. Scientifically justified fertilizer systems, intensive technologies for growing grain crops using bioresources are the main tools in solving the set tasks [1; 2].

The fertilizer system is considered an important technological link in the cultivation of winter wheat, which should be based on knowledge of the main stages of plant development, their nutrient requirements, as well as the specific soil and climatic conditions of the zone, predecessors, and varietal characteristics of winter wheat [3–5].

The issue of intensifying grain production is inseparable from the production and use of new biogenic effective preparations that positively affect the growth and development of cultivated plants [6].

Thus, studying and developing biotechnological methods of cultivating crops, taking into account the requirements of modern high-yielding varieties and constantly changing climatic conditions, is a relevant research direction. Increasing the yield of winter wheat grain while reducing resource costs and chemical substances load on the soil is a priority direction for the development of agriculture, success in which can be achieved through the ecologization of crop farming [7; 8].

Analysis of recent research and publications. Correction of the component composition and quantity of mineral fertilizers, taking into account all necessary nutrients for the formation of healthy and high-yielding plants, in combination with biologically active substances, can significantly reduce production costs and increase the efficiency of winter wheat grain cultivation [9].

Recently, due to insufficient use of organic fertilizers, the role of mineral fertilizers has significantly increased. In order to obtain stable yields of winter wheat with high grain productivity, it is necessary to create optimal conditions for plant nutrition, primarily with macroelements. One of the important conditions for effective fertilizer use is determining the plant's nutrient requirements for the desired yield level, taking into account the content of mobile NPK compounds in the soil [10].

Increasing the grain yield of winter wheat is directly related to various elements of crop structure, for example, the amount of productive straw per unit area. Previous researchers have found that the productivity and grain yield of wheat depend on 50 % on productive straw, 25 % on the number of grains per spike, and 25 % on the weight of 1000 grains. These indicators are also influenced by the nutrient content of crop

residues from previous crops, but to a greater extent, by weather conditions in the year of sowing [11–14].

Due to active climate change and global warming, moisture has become the main key factor affecting the yield of agricultural crops. In the conditions of the Northern Steppe of Ukraine, it is especially important to accumulate and preserve moisture in the soil in order to provide plants with maximum moisture, which has the greatest impact on the yield level of agricultural crops, including winter cereals. In addition, soil moisture not only determines the level of plant vitality but also determines the activity of microorganisms that ensure the intensity of many physicochemical processes in plants.

Recently, there has been an increasing interest among domestic farmers in biological preparations [15]. Biopreparations stimulate the growth and development of agricultural crops, increase resistance to stress and diseases, and balance nutrition. This effect is achieved through the action of live bacteria that convert insoluble compounds in the soil into available forms. Active microorganisms provide additional nitrogen nutrition and protect plants from bacterial and fungal diseases [16].

Biopreparations allow fully realizing the potential of varieties when the cultivation technology does not correspond to their genetic capabilities to ensure an adequate level of reliability and protection of the genotype from the adverse effects of biotic and abiotic factors of the external environment [17].

The complex use of traditional methods of winter wheat cultivation with new innovative elements of biologization makes it possible to significantly increase plant productivity and the quality of the cultivated products in different soil-climatic zones [18–20].

Task of research. Justify the yield level and productivity of winter wheat depending on the fertilization system and biopreparation for its cultivation in a short crop rotation.

Materials and methods of research. Field research was conducted from 2019 to 2023 in the agriculture laboratory of Institute of Agriculture of the Steppe, National Academy of Agrarian Sciences. Research methods included field and laboratory-field experiments. The object of the research was the fertilization systems and biopreparation.

Winter wheat variety Oranta Odeska was grown in a short crop rotation, which included the following crop rotation: 1) Fallow and occupied fallow; 2) Winter wheat; 3) Soybean; 4) Corn for grain; 5) Sunflower. Peas were sown in the occupied fallow, and mineral fertilizers were applied at a rate of $N_{30}P_{30}K_{30}$.

The cultivation technology of winter wheat in crop rotations is generally accepted for the zone, except for the techniques that are being studied.

Winter wheat was sown at optimal sowing dates with a seeding rate of 4.5 million seeds/ha, using three fertilization systems: 1. Without fertilizers; 2. Mineral fertilization system ($N_{90}P_{60}K_{60}$); 3. Organic-mineral ($N_{30}P_{30}K_{30}$ – at sowing, $N_{30}P_{30}K_{30}$ – under the cover crop, and N_{30} – in early spring fertilization) using by-products of the cover crop as organic matter. The variants with fertilization systems were divided into variants without seed inoculation with a biopreparation for winter wheat and with the use of the biologically active preparation Mycofriend (1.0 L/ton). Mycofriend is a mycorrhizal biopreparation, the main biological action of which is plant nutrition and protection against diseases.

The general cultivation technology was as follows: primary soil tillage began with two-time plowing. The first plowing was done to a depth of 6–8 cm, and the second plowing was done to a depth of 8–10 cm 2–3 weeks after the first plowing (when weeds appeared).

In the fall, deep plowing was carried out to a depth of 23–25 cm. Pre-sowing soil preparation consisted of cultivation to a depth of 5–8 cm. If necessary, chemical protection against weeds was applied as insurance herbicides.

Care for the crops consisted of post-sowing harrowing. Control of pests and diseases was carried out according to existing recommendations in the zone. The establishment and conduct of experiments were carried out according to the methodology of field research.

The weather conditions during the cultivation of winter wheat from 2019 to 2021 were not favorable enough to achieve high productivity indicators for the studied crop. The weather conditions during the research period from 2022 to 2023 were favorable enough to achieve high yields and productivity of winter wheat.

The results of the research conducted in 2019 showed that the yield of winter wheat depended on the fertilization systems and their interaction with the biopreparation. The yield level was significantly higher in the mineral and organic-mineral fertilization systems compared to the variant without fertilizers, with an increase of 0.41 t/ha and 0.64 t/ha, respectively (Table 1). When the organic-mineral fertilization system was combined with seed inoculation using the biopreparation, a significant yield increase of 0.29 t/ha was observed compared to the control without fertilizers. The biopreparation resulted in a significant yield increase of 0.37 t/ha in the variant without fertilizers.

Table 1

Yield of winter wheat variety Oranta Odeska depending on the fertilization system and biopreparation (2019–2023)

Fertilization system (factor A)	Biopreparation (factor B)	Years					Average for the years	Difference			
		2019	2020	2021	2022	2023		for factor A		for factor B	
								t/ha	%	t/ha	%
Without fertilizers	Without biopreparation	4,59	5,12	3,78	7,88	7,04	5,68	–	–	–	–
	Mycofriend	4,96	5,94	4,40	8,26	7,24	6,16	–	–	0,48	8,4
Mineral	Without biopreparation	5,00	6,07	4,59	8,18	8,94	6,56	0,87	15,4	–	–
	Mycofriend	5,16	6,44	4,84	8,65	9,40	6,90	0,74	12,0	0,34	5,2
Organic-mineral	Without biopreparation	5,22	6,22	4,87	8,92	9,09	6,86	1,18	20,8	–	–
	Mycofriend	5,25	6,53	5,35	9,45	9,61	7,24	1,08	17,5	0,37	5,5
LSD_{05}	Factor A	0,33	0,28	0,32	0,09	0,21	0,36	–	–	–	–
	factor B	0,27	0,23	0,26	0,08	0,17	0,29	–	–	–	–
	Interaction of factors AB	0,47	0,40	0,46	0,13	0,29	0,50	–	–	–	–

In 2020, the yield of winter wheat ranged from 5.12 t/ha in the control variant without fertilizers to 6.53 t/ha in the variant with the organic-mineral fertilization system using Mycofriend. Significant yield increases were observed when using the biopreparation, ranging from 0.31–0.38 t/ha in the mineral and organic-mineral fertilization systems to 0.83 t/ha in the variant without fertilizers. The use of both mineral and organic-mineral fertilization systems, either alone or in combination with seed inoculation, resulted in significant yield increases ranging from 0.50 t/ha in the mineral fertilization system with the biopreparation to 1.10 t/ha in the organic-mineral fertilization system.

Analyzing yield data y years of research, it was determined that the lowest winter wheat yield was obtained in 2021. However, the yield increases from the use of fertilization systems and their combination with a biopreparation were significant this year, ranging from 0.45 t/ha for a mineral fertilization system with a biopreparation to 1.10 t/ha for an organo-mineral fertilization system. The separate effect of the microbial preparation was noted in the organo-mineral fertilization system and without fertilizers, with yield increases of 0.48 t/ha and 0.62 t/ha respectively.

Favorable weather conditions in 2022 allowed for a winter wheat yield ranging from 7.88 t/ha without fertilizers to 9.45 t/ha for an organo-mineral fertilization system with the use of a bioinoculant. The yield increases from the investigated factors were significant, ranging from 0.30 t/ha for a mineral fertilization system to 1.19 t/ha for the use of an organo-mineral fertilization system and microbial preparation. The yield increases from the application of the biopreparation were determined as follows: without fertilizers – 0.38 t/ha, mineral fertilization system – 0.47 t/ha, organo-mineral fertilization system – 0.53 t/ha. A similar dependence on the use of a microbiologically active preparation was observed in the conditions of 2023, with yield increases of 0.20 t/ha without fertilizers, 0.45 t/ha for a mineral fertilization system, and 0.52 t/ha for an organo-mineral fertilization system.

Comparing winter wheat yield indicators, it can be stated that the most favorable conditions in five years of research were observed in 2022 when all fertilization systems contributed to high yields.

In the conditions of 2023, Oranta Odeska winter wheat plants had the opportunity to reach their highest yield potential with an organo-mineral fertilization system using the biologically active preparation Mycofriend, reaching 9.61 t/ha. This was facilitated by the application of fertilizers, while the yield without fertilizers was 0.84 t/ha lower compared to the indicators of 2022. Therefore, the conditions of 2022 were more favorable for the investigated variants and to some extent neutralized the investigated factors. It was established that in the conditions of 2023, the use of a mineral and organo-mineral fertilization system, along with their combination with a microbial preparation, contributed to significantly higher yields compared to variants without fertilizers and without a biopreparation. The yield increases ranged from 1.90 t/ha for a mineral fertilization system to 2.38 t/ha for an organo-mineral fertilization system with the use of an inoculant.

Taking into account that the winter wheat yield, under the influence of unfavorable weather conditions from 2019 to 2021, ranged from 3.78 to 6.53 t/ha, the average yield over the years of research ranged from 5.68 t/ha without fertilizers to 7.24 t/ha for an organo-mineral fertilization system with a microbial preparation. Significant yield increases were determined for mineral (0.87 t/ha or 15.4 %) and organo-mineral fertilization systems (1.18 t/ha or 20.8 %), as well as their combination with a biopreparation – 0.74 t/ha and 1.08 t/ha respectively.

It was established that the average yield increase indicators for winter wheat from 2019 to 2023 were significant and amounted to 0.34 t/ha for a mineral fertilization system, 0.37 t/ha for an organo-mineral fertilization system, and 0.48 t/ha without the application of fertilizers.

Therefore, the highest level of productivity was formed by winter wheat plants of the Oranta Odeska variety in 2022 in the variant without fertilizers, which amounted to 7.88 t/ha. In 2023, the highest yield was obtained in the mineral fertilization system – 8.94 t/ha, and in the organic-mineral fertilization system – 9.09 t/ha. The highest yield of winter wheat was formed in 2023 in the organic-mineral fertilization system with the use of the biopreparation, reaching 9.61 t/ha. It was found that on average over the

five years of research, the use of the mineral fertilization system and its combination with the biopreparation contributed to significant yield increases, amounting to 0.87 t/ha and 0.74 t/ha, respectively. The use of mineral fertilizers with a cover crop and its combination with seed inoculation before sowing also resulted in significant yield increases, amounting to 1.18 t/ha and 1.08 t/ha, respectively. The use of the microbial preparation led to significant yield increases, which amounted to 0.48 t/ha (8.4 %) in the variant without fertilizer application, 0.37 t/ha (5.5 %) in the organic-mineral fertilization system, and 0.34 t/ha (5.2 %) in the mineral fertilization system.

Over the years of conducting research on winter wheat cultivation in the conditions of the northern steppe of Ukraine, we determined the indicators of yield productivity elements depending on fertilization systems and seed treatment with a biopreparation. The analysis of the obtained data showed that the increase in grain units yield per unit area occurred both due to the fertilization system and the biopreparation. However, it should be noted that a more significant increase in this indicator was observed in the mineral and organo-mineral fertilization systems. For example, the application of only $N_{90}P_{60}K_{60}$ per hectare allowed for an additional 0.96 tons of grain yield (15.4 %) and with the use of by-products of the previous crop – 1.30 t/ha (20.8 %), which resulted in a winter wheat productivity of 7.21 t/ha and 7.55 t/ha, respectively (Table 2).

Table 2

Winter wheat productivity of the Oranta Odeska variety depending on the fertilization system and biopreparation (2019–2023)

Fertilization system (factor A)	Biopreparation (factor B)	Average for 2019–2023	Difference			
			for f actor A		for factor B	
			t/ha	%	t/ha	%
Grain units yield						
Without fertilizers	Without biopreparation	6,25	–	–	–	–
	Mycofriend	6,77	–	–	0,52	8,4
Mineral	Without biopreparation	7,21	0,96	15,4	–	–
	Mycofriend	7,59	0,81	12,0	0,37	5,2
Organic-mineral	Without biopreparation	7,55	1,30	20,8	–	–
	Mycofriend	7,96	1,19	17,5	0,41	5,5
Feed units yield						
Without fertilizers	Without biopreparation	8,01	–	–	–	–
	Mycofriend	8,68	–	–	0,67	8,4
Mineral	Without biopreparation	9,24	1,23	15,4	–	–
	Mycofriend	9,73	1,04	12,0	0,48	5,2
Organic-mineral	Without biopreparation	9,68	1,67	20,8	–	–
	Mycofriend	10,21	1,52	17,5	0,53	5,5
Protein units yield						
Without fertilizers	Without biopreparation	0,68	–	–	–	–
	Mycofriend	0,74	–	–	0,06	9,3
Mineral	Without biopreparation	0,79	0,11	16,4	–	–
	Mycofriend	0,83	0,09	12,0	0,04	5,2
Organic-mineral	Without biopreparation	0,82	0,15	21,8	–	–
	Mycofriend	0,87	0,13	17,5	0,04	5,5

Seed inoculation with the biopreparation significantly influenced the productivity of winter wheat in the mentioned fertilization systems. Despite the highest grain units yield with the use of Mycofriend in the organo-mineral fertilization system – 7.96 t/ha, the most effective action of the preparation was observed without the application of fertilizers – +0.52 t/ha (8.4 %). The use of the biopreparation in the mineral fertilization system was least effective – +0.37 t/ha (5.2 %).

It should be noted that in our experiments, similar trends were observed in the formation of other indicators of winter wheat productivity. Thus, the feed units yield in the mineral and organo-mineral fertilization systems was higher than in the variant without fertilizers – 9.24 t/ha and 9.68 t/ha, with an increase of 1.23 t/ha (15.4 %) and 1.67 t/ha (20.8 %), respectively. The interaction of the organo-mineral fertilization system with the biopreparation resulted in the highest feed units yield – 10.21 t/ha, but in terms of intensity, the combined effect of these factors was inferior to the variant without the use of the inoculant in the organo-mineral fertilization system – +1.52 t/ha (17.5 %). The biopreparation had the most effective action in the natural nutrition system, providing an additional 0.67 tons of feed units per hectare or 8.4 %.

The increase in digestible protein yield depended on the application of mineral and organic substances under winter wheat cultivation. The largest increase in additional production was obtained with the organo-mineral fertilization system – +0.15 t/ha (21.8 %), and seed treatment with Mycofriend in this fertilization system resulted in the highest digestible protein yield – 0.87 t/ha. It should be noted that the intensity of Mycofriend's action decreased equally in the mineral and organo-mineral fertilization systems – +0.04 t/ha compared to the control – +0.06 t/ha.

The indicators of winter wheat productivity of the Oranta Odeska variety varied significantly over the years of research, confirming the influence of weather and climatic conditions on the biological potential of the crop. The highest grain units yield, feed unit yield, and digestible protein yield were obtained in 2022 and 2023.

The conditions in 2022 were the most favorable for the formation of crop productivity for the cultivation of winter wheat without the application of fertilizers: we got 8.67 t/ha of grain units yield, 11.12 t/ha of feed units yield, and 0.94 t/ha of digestible protein. Seed treatment with the biopreparation increased these indicators in these conditions to 9.09 t/ha, 11.65 t/ha, and 0.99 t/ha, respectively (Figure 1, 2, 3).

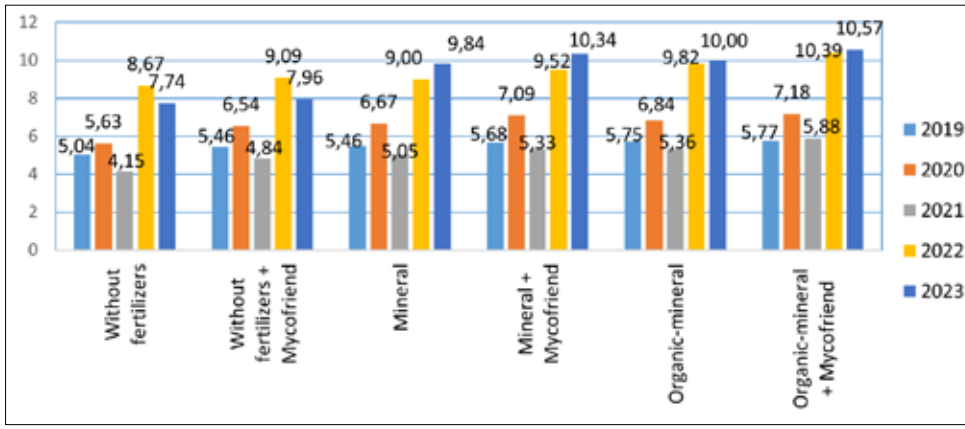

Fig. 1. Yield of grain units from the harvest of winter wheat variety Oranta Odeska depending on the fertilization system and biopreparation (2019–2023)

However, the highest nutrient yield from the produced crop was obtained in 2023 with the use of mineral and organo-mineral fertilization systems. Seed treatment with the biopreparation provided the highest productivity indicators for the Oranta Odeska variety in this year: 10.57 t/ha of grain units yield, 13.55 t/ha of feed units yield, and 1.15 t/ha of protein units.

Over the years of research, the yield of grain units per unit area of winter wheat variety Oranta Odessa varied between 4.15 and 10.57 t/ha. Despite the lowest grain units obtained in 2021 (4.15–5.88 t/ha), the variation of this indicator was within 1.73 t/ha (1.55 t/ha in 2020, 1.72 t/ha in 2022).

It should be noted that the formation of winter wheat productivity in 2019 was characterized by unfavorable weather conditions for achieving high performance indicators of the studied crop. However, the fertilization systems and biopreparations had the least impact on yield grain units in this year, within the range of 0.73 t/ha (Figure 2).

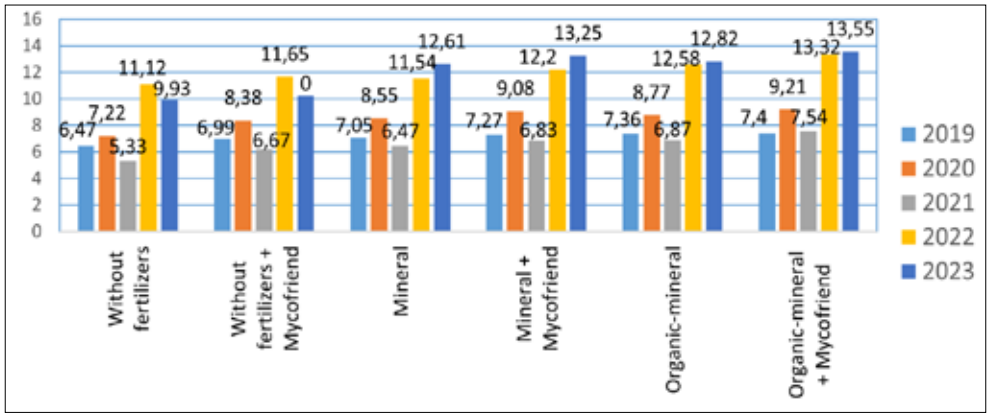

Fig. 2. Yield of feed units from the harvest of winter wheat variety Oranta Odeska depending on the fertilization system and biopreparation (2019–2023)

In the conditions of the northern Steppe of Ukraine, the indicators of winter wheat yieldfeed units ranged from 5.33 t/ha to 13.55 t/ha. The highest collection of feed units was in 2023 with the use of a biopreparation under a mineral and organo-mineral fertilization system – 13.25 t/ha and 13.55 t/ha respectively (Figure 2). Moreover, the variation of this indicator in such conditions was also the highest – 3.62 t/ha. Attention should be paid to the indicators of feed unit yield in 2019 – they ranged from 6.47 to 7.40 t/ha, with a difference depending on the fertilization system and the use of biopreparation within the range of 0.93 t/ha. Thus, the influence of the factors we studied in this year was the smallest over the years of research.

Over the course of five years of research, we observed a similar trend in terms of accumulating protein units in the grain of Oranta Odeska. The highest indicator was recorded in 2023 with the use of a mineral and organo-mineral fertilization system with seed treatment with a biopreparation – 1.13 t/ha and 1.15 t/ha respectively, and the difference between them was not significant. The lowest output of protein units was in 2021 – 0.45–0.64 t/ha. In the conditions of 2019, the difference in protein collection from grain, which was formed under different fertilization systems and with the use of the biopreparation Mycofriend, was not significant, and the fluctuation of the indicator was within 0.08 t/ha (Figure 3).

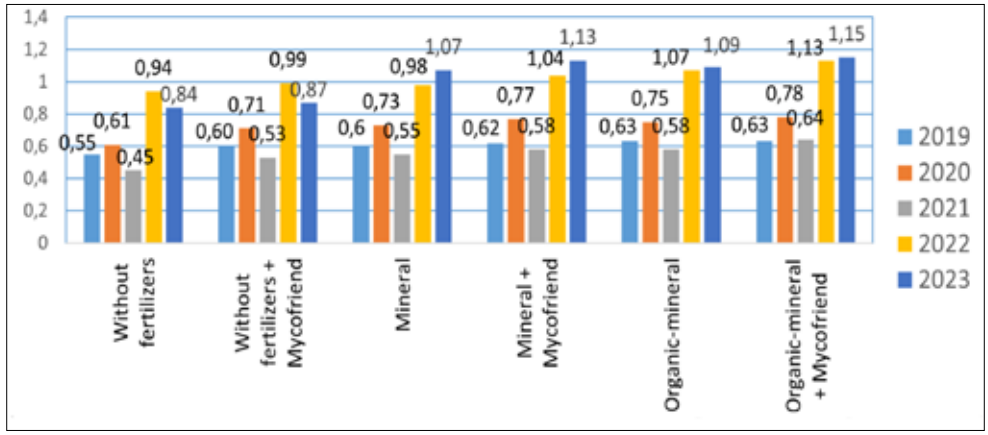

Fig. 3. Yield of protein units from the harvest of winter wheat variety Oranta Odeska depending on the fertilization system and biopreparation (2019–2023)

Despite the fact that the lowest protein output was in 2021 (0.45 t/ha), the application of fertilizers and seed treatment with a biopreparation increased the indicators to 0.64 t/ha under the organo-mineral fertilization system.

Thus, the highest level of productivity was achieved by plants of winter wheat variety Oranta Odeska under the organo-mineral fertilization system with the use of the biopreparation Mycofriend: 7.96 t/ha of grain units, 10.21 t/ha of feed units, 0.87 t/ha of protein units. However, the most intensive accumulation of nutrients occurred without seed treatment with the biopreparation: an additional were obtained 1.30 t/ha (20.8 %) of grain units, 1.67 t/ha (20.8 %) of feed units, 0.15 t/ha (21.8 %) of protein units. The effectiveness of the Mycofriend preparation was highest without the application of fertilizers: +0.52 t/ha (8.4 %) of grain units, +0.67 t/ha (8.4 %) of feed units, +0.06 t/ha (9.3 %) of protein units. The influence of the biopreparation on the productivity of the Oranta Odeska variety was minimal under the mineral fertilization system.

The highest collection of nutrients was obtained in favorable weather conditions during the years of research – 2022 and 2023. The highest level of productivity in these years was achieved under the organo-mineral fertilization system with the use of the biopreparation: 10.39 t/ha and 10.57 t/ha of grain units, 13.32 t/ha and 13.55 t/ha of feed units, and 1.13 t/ha and 1.15 t/ha of protein units. Fertilization systems and biologization had the most intensive impact on productivity indicators in more favorable weather conditions. Critically insufficient moisture and high temperatures neutralized the effect of nutrients and microorganisms, and the output of nutrient units was the lowest in 2021 and 2019 – 4.15–5.88 t/ha and 5.04–5.77 t/ha of grain units, 5.33–7.54 t/ha and 6.47–7.40 t/ha of feed units, 0.45–0.64 t/ha and 0.55–0.63 t/ha of protein units, respectively.

Conclusions:

1. The highest level of productivity was achieved by plants of winter wheat variety Oranta Odessa without the application of fertilizers in 2022, which amounted to 7.88 t/ha. On the backgrounds of mineral and organo-mineral fertilization systems, the highest yield was in 2023, reaching 8.94 t/ha and 9.09 t/ha, respectively. The maximum level of productivity – 9.61 t/ha was also in 2023 under the conditions of growing winter wheat with the combination of organo-mineral fertilization system and the use of a biopreparation.

2. The use of the microbial biopreparation Mycofriend contributed to significant increases in productivity without the application of fertilizers: 0.48 t/ha (8.4 %), under the organo-mineral fertilization system: 0.37 t/ha (5.5 %), and under the mineral fertilization system: 0.34 t/ha (5.2 %).

3. The highest level of productivity was achieved by plants of winter wheat under the organo-mineral fertilization system with the use of the biopreparation Mycofriend: 7.96 t/ha of grain units, 10.21 t/ha of feed units, 0.87 t/ha of protein units.

4. The most significant effect of the biopreparation was observed without the application of fertilizers, with additional gains of 0.52 t/ha (8.4 %) of grain units, 0.67 t/ha (8.4 %) of feed units, and 0.06 t/ha (9.3 %) of protein units.

5. The highest collection of nutrients was obtained in favorable weather conditions during the years 2022 and 2023 under the organo-mineral fertilization system with the use of the biopreparation: 10.39 t/ha and 10.57 t/ha of grain units, 13.32 t/ha and 13.55 t/ha of feed units, and 1.13 t/ha and 1.15 t/ha of protein units, respectively.

REFERENCES:

1. Korkhova M., Smirnova I., Panfilova A., Bilichenko O. Productivity of winter wheat depending on varietal characteristics and pre-sowing treatment of seeds with biological products. *Scientific Horizons.* 2023. № 26 (5). P. 65–75. DOI: 10.48077/scihor5.2023.65.

2. Gamayunova, V., Kovalenko O., Smirnova I., Korkhova M. The Formation of the Productivity of Winter Wheat Depends on the Predecessor, Doses of Mineral Fertilizers and Bio Preparations. *Scientific Horizons*. 2022. Vol. 25. № 6. DOI: 10.48077/scihor.25(6).2022.65–74.

3. Хорішко С. А., Козелецький О.М. Системи удобрення та їх вплив на продуктивність культури. *Агроном.* 2016. URL: https://www.agronom.com.ua/udobrennya-pshenytsi-porivnyannya-riznyh-dobryv-ta-terminiv-yih-zastosuvannya/

4. Мащенко Ю. В., Кулик Г. А., Трикіна Н. М., Малаховська В. О. Урожайність пшениці озимої у сівозмінах степу залежно від систем удобрення та біопрепарату. *Аграрні інновації.* 2023. № 18. P. 77–83. DOI: 10.32848/agrar.innov.2023.18.11

5. Orlovsky M., Tymoshchuk T., Konopchuk O., Voitsehivsky V., Didur I. The effect of growth technology features on the productivity of winter wheat in the context of ukrainian western polissia. *Scientific horizons*. 2019, № 11 (84). P. 77–85. DOI: 10.33249/2663-2144-2019-84-11-77-85.

6. Вожегова Р. А., Кривенко А. І., Вплив біопрепаратів на продуктивність пшениці озимої та економічно-енергетичну ефективність технології її вирощування в умовах півдня України. *Вісник аграрної науки Причорномор'я*. 2019. Вип. 1. DOI: 10.31521/2313-092X/2019-1 (101)

7. Madushanki R., Halgamuge A. A., Surangi Wirasagoda M. N., Syed W. A. H. Adoption of the internet of things (iot) in agriculture and smart farming towards urban greening: A review. *International Journal of Advanced Computer Science and Applications*. 2019. № 10 (4). P. 11–28.

8. Soto-Gómez D., Pérez-Rodríguez P. Sustainable agriculture through perennial grains: Wheat, rice, maize, and other species. A review. *Agriculture, Ecosystems & Environment*. 2022. № 325. P. 10747. DOI: 10.1016/j.agee.2021.107747

9. Lukashchuk L., Kurach O., Snizhok O., Huk L., Kucherova A. Influence of fertilization and care systems on productivity and quality of winter wheat grain. *Bulletin of Agricultural Science*. 2020. Vol. 98. № 10. DOI: 10.31073/agrovisnyk202010–02

10. Yan F., Zhang F., Fan X., Fan J., Wang Y., Zou H., Wang H., Li G. Determining irrigation amount and fertilisation rate to simultaneously optimize grain yield, grain nitrogen accumulation and economic benefit of drip-fertigated spring maize in northwest China. *Agricultural Water Management*. 2021. № 243. Article number 106440. DOI: 10.1016/j.agwat.2020.106440

11. Olkhovskyi G., Bobro M., Chechui O. The detailed method for determining the structure of winter wheat crops. *Herald of Agrarian Science*. 2019. № 97 (12). P. 22–29. DOI: 10.31073/agrovisnyk201912–03

12. Korkhova M., Mykolaichuk V. Influence of weather conditions on the duration of interphysical periods and yield of durum winter wheat. *Scientific Horizons*. 2022. № 25 (2). P. 36–46. DOI: 10.48077/scihor

13. Panfilova A., Korkhova M., Gamayunova V., Drobitko A., Nikonchuk N., Markova N. Formation of photosynthetic and grain yield of soft winter wheat (*Triticum aestivum L.*) depending on varietal characteristics and optimisation of nutrition. *Research Journal of Pharmaceutical, Biological and Chemical Sciences.* 2019. № 10 (2). P. 78–85.

14. Andriichenko L. V., Kachanova T. V. Formation of winter wheat grain yield in the Steppe zone of Ukraine depending on the variety, fertiliser and precursor. *Taurian Scientific Bulletin*. 2018. № 100 (1). P. 3–8.

15. Kulkarni S., Goswami A. Effect of excess fertilisers and nutrients: A review on impact on plants and human population. *In Proceedings of international conference on sustainable computing in science, technology and management* (SUSCOM). 2019. P. 2094–2099. Jaipur: Amity University Rajasthan.

16. Krutyakova, V. Biological method as the basis of sustainable development of domestic agriculture. *Herald of Agrarian Science*. 2020. № 9 (810). P. 5–14. DOI: 10.31073/agrovisnyk202009–01

17. Smetanko, A. V., Burykina, S. I., Krivenko, A. I. The influence of the elements of the biologization of the cultivation of winter wheat on various backgrounds of mineral nutrition in the conditions of the Southern Steppe of Ukraine. *Bulletin of Agrarian Science*. 2018. № 8. P. 33–37. URL: http://nbuv.gov.ua/UJRN/vaan_2018_8_7

18. Voloschuk I., Voloschuk O., Stasiv V., Hlyva L. Baistruk-Hlodan Regulation of winter wheat productivity. *Ukrainian Journal of Ecology.* 2021. № 11 (9). P. 127–130. DOI: 10.15421/2021_306

19. Voloshchuk, I. S. Elements of production technology of high-quality winter wheat seeds in the Western Forest-Steppe of Ukraine. Lviv : Spolom, 2017.

20. Voloshchuk, I. S. The effect of presowing seed treatment with microbial preparations on winter hardiness of winter wheat plants. *Foothill and Mountain Agriculture and Stockbreeding*. 2011. № 53. P. 11–17.