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Biotechnological methods of growing sunflower in different fertilizer systems

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Abstract: The presented results of the study on the effect of biopreparations and different fertilizer systems on the formation of sunflower yield and productivity, determination of economic efficiency of sunflower cultivation under sharp fluctuations in climatic conditions through the use of biotechnology elements and fertilization. Growing sunflower without seed treatment with biopreparations under mineral fertilizer system provided an average yield of 2.93 t/ha, with an additional 0.31 t/ha of sunflower seeds. The organo-mineral fertilizer system resulted in the highest increase in additional production – 0.50 t/ha, and the increase in sunflower yield through fertilization system was the most significant, with a minimum important difference (MID_{05}) of 0.11 t/ha. Seed treatment with biopreparation contributed to an increase in sunflower yield in all fertilizer systems: without fertilizer application, only due to the action of biopreparation, the yield increased to 2.82 t/ha; application of mineral fertilizer ensured a harvest of 3.09 t/ha of sunflower seeds; the organo-mineral fertilizer system had the highest yield indicator – 3.23 t/ha. The highest output of dry matter from the production was obtained through seed treatment with biopreparation and the use of organo-mineral fertilizer system, which provided a yield per hectare of: grain units – 6.47 t, fodder units – 3.56 t, digestible protein – 1.23 t. However, the most significant increase in sunflower productivity was observed in the organo-mineral fertilizer system without seed treatment with biopreparation. The highest indicators of economic efficiency of sunflower cultivation were observed under the conditions of seed treatment with biopreparation without fertilizer application, which amounted to 18,322 UAH/ha – net profit at a profitability of 91.5 %.

Keywords: biopreparations; productivity; fertilizer systems; sunflower; yield

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1 Introduction

Sunflower is one of the most important and economically attractive crops in Ukrainian agriculture. Favorable pricing policies in domestic and international markets encourage farmers to increase the cultivation area of this crop annually. However, adverse weather conditions in recent years and unstable global fertilizer prices force farmers to constantly economize, which negatively affects yield stability. An important task for farmers is to optimize plant nutrition in order to achieve higher yields and preserve soil fertility (Haruna and Nkongolo 2019; Pinkovskyi and Mashchenko 2019; Yeremenko et al. 2017).

In modern agricultural production conditions with intensive cultivation technologies of late spring crops, fertilizers are one of the most expensive elements of agronomy. Sunflower forms highly energetic biomass, which requires a large amount of mineral nutrients. The level of nutrient consumption depends on various factors, such as timing and methods of fertilizer application, moisture availability, weather conditions, as well as genetic characteristics of the variety or hybrid. Soil is the only medium through which plant development and physiological processes can be influenced. The addition of additional nutrients – mineral or organic fertilizers, biological residues of previous crops, etc., determines the level of sunflower yield and productivity (Ashisa Sial et al. 2022; Gamayunova et al. 2019; Khodaeı-Joghan et al. 2018; Tsimbal et al. 2020).

In recent years, there has been an increasing demand among farmers for biopreparations with different mechanisms of action. Special attention has been paid to mycorrhizal biopreparations, one of which is Mycofriend. These preparations stimulate the development of beneficial soil microorganisms, contribute to the preservation and enhancement of soil fertility, activate its action against pathogens, and increase the productivity of agricultural crops, including sunflower (Mashchenko et al. 2009; Tkalich and Nitsenko 2013; Tsyhanskyi 2020; Yeremenko 2017).

2 Elements of scientific novelty

For the conditions of the Northern Steppe of Ukraine, elements of biotechnology for the cultivation of modern sunflower hybrids using the biopreparation Mycofriend and mineral and organo-mineral fertilizer systems have been developed for the first time.

3 Statement of the problem

Given the relevance of the topic, the aim of our research was to determine the level of sunflower yield and productivity indicators that were formed under different fertilizer systems recommended for the Steppe zone of Ukraine and under the influence of the biopreparation Mycofriend; to establish the economic efficiency of sunflower

cultivation under conditions of sharp fluctuations in climatic conditions through the use of the studied technological elements.

4 Methods and research materials

Laboratory, field, empirical – measurements, comparisons, observations; statistical, mathematical, graphical; economic.

Field research was conducted from 2018 to 2022 at the Institute of Agriculture of the Steppe NAAS. The climatic conditions of the research location are typical for the Northern Steppe of Ukraine with a moderate continental climate. Dry winds are observed in the summer period, while thaws with a temperature increase to +10 … +13 °C occur in winter. Frosts are often observed in April and May. Eastern winds prevail in the spring. The average annual precipitation is 499 mm. In the summer months, precipitation is mostly heavy showers. The average monthly air temperature in June-July is +18.6 … +20.0 °C, with a maximum of +37 … +39 °C. The lowest average daily relative humidity is observed in July–August.

In the experiments, the sunflower hybrid LG5478 was grown (Table 1).

The biotechnology element used in sunflower cultivation was the bio-preparation for plant nutrition and protection called Mycofriend (Table 2).

Yield and productivity of the sunflower hybrid were studied using three fertilization systems (Table 3).

Table 1: Characteristics of the studied hybrid.

Hybrid	Characteristic
LG5478	The patent applicant and owner of the variety is Limagrain Europe (France). The hybrid is used for oil production. It was included in the State Register of Plant Varieties Suitable for Distribution in Ukraine in 2018. Recommended zone forest-steppe, steppe. Maturity group – medium-early. Yield potential 2.6 t/ha. Plant height 165 cm. Oil content – 50.5 %. Head diameter 17 cm. 1000-grain weight 65 g.

[a]Statistical data and Microsoft Office Excel package were used https://minagro.gov.ua/file-storage/reyestr-sortiv-roslin.

Table 2: Characteristics of the biotechnology element.

Hybrid	Characteristic
Mycofriend	Manufacturer of the preparation Private enterprise «BTU-Center» (Ladizhin, Vinnytsia region, Ukraine), LLC «Trade House «BTU-Center» (Kyiv, Ukraine). Registration date 03.03.2017. Registration certificate, series, number A06047. Active substances: Glomus VS 1224, Trichoderma Harsianum, *Bacillus subtilis*, *Bacillus megaterium*, Bacillus mucilaginosus B-4901, *Enterobacter nimipressuralis* 32-3 bacteria strain, *Pseudomonas fluorescens*, Streptomyces spp. Main advantages of the preparation: increases the absorption area of the root system for nutrients and moisture; ensures moisture retention in the root zone of the plant; protects plants from root rot pathogens and seed mold; increases the yield of agricultural crops

[a]Statistical data were used https://agrarii-razom.com.ua/preparations/mikofrend-mycofriend-mikofrend-r.

Table 3: Characteristics of the fertilization systems.

Fertilization system	Characteristic
No fertilizers	Sunflower cultivation without the application of mineral fertilizers and removal of predecessor by-products (corn for grain)
Mineral	Recommended norms of mineral fertilizers $N_{40}P_{40}K_{40}$ for sunflower in the Steppe zone in the form of complex mineral fertilizer Superagro ($N_{10}P_{40}K_{40}$) for plowing, Ammonium nitrate (N_{30}) before sowing, with removal of predecessor by-products (corn for grain)
Organomineral	Recommended norms of mineral fertilizers $N_{40}P_{40}K_{40}$ for sunflower in the Steppe zone in the form of complex mineral fertilizer Superagro ($N_{10}P_{40}K_{40}$) for plowing, Ammonium nitrate (N_{30}) before sowing. Organic matter remaining after harvesting the predecessor (corn for grain) was crushed and incorporated into the soil.

[a]KIAPV UAAN. Edited by V.V Savranchuk, I.M. Semenyak, M.I. Mostipan, L.P. Pikash, S.M. Slobodyan. Scientifically justified system of conducting agricultural production in the Kirovograd region. Lira LTD. Kirovograd. 2005. 266 p. (ukr.).

5 The results of the study

The main factor limiting the productivity of sunflower in the natural-climatic conditions of the Northern Steppe of Ukraine is insufficient atmospheric precipitation, especially during the period of basket formation and flowering. Low relative humidity and high temperature during flowering negatively affect the pollination process of sunflower flowers. This leads to a decrease in yield, which also varies significantly from year to year. Additional crop production in such conditions is possible through the application of mineral fertilizers, organic substances, or seed treatment with biopreparations.

The results of the study showed that on average for 2018–2022, seed treatment with the biopreparation contributed to an increase in sunflower yield under all fertilizer systems (Table 4). For example, in the variant without fertilizer application, only the action of the biopreparation increased yield to 2.82 t/ha, mineral fertilizer application (Table 3) provided a harvest of 3.09 t/ha of sunflower seeds, and under the organo-mineral fertilizer system (Table 3), the yield indicator was the highest – 3.23 t/ha.

Taking into account the smallest significant difference for factor A (MID_{05} = 0.09 t/ha), the yield increase due to the action of the biopreparation was significant – 0.02–0.21 t/ha. Moreover, it should be noted that the largest amount of additional production – 0.21 t/ha – was obtained in the variant without fertilizer application.

The analysis of the results of five–year research indicates that growing sunflower without seed treatment with biopreparations also allowed for higher crop yields. Under the mineral fertilizer system, the average yield was 2.93 t/ha, with an additional 0.31 t/ha of sunflower seeds obtained. The organic matter remaining after

Table 4: Sunflower yield depending on the biopreparation under different fertilizer systems, t/ha, 2018–2022.

The biopreparation, factor A	Fertilization system, factor B	Average for 2018–2022	Average		Difference			
			Factor A	Factor B	Due to the biopreparation		Due to the fertilization system	
					t/ha	%	t/ha	%
Without seed treatment with biopreparation	No fertilizers	2.61	2.89	2.72	–	–	–	–
	Mineral	2.93		3.01	–	–	0.31	12.0
	Organomineral	3.12		3.17	–	–	0.50	19.1
Seed treatment with biopreparation	No fertilizers	2.82	3.05	–	0.21	8.0	–	–
	Mineral	3.09			0.17	5.7	0.27	9.5
	Organomineral	3.23			0.12	3.8	0.41	14.5
MID_{05}			Factor A			0.09		
			Factor B			0.11		
			The interaction of factors AB			0.16		

[a]Author's calculations.

the harvest of the predecessor, in combination with mineral fertilizers under the organomineral fertilizer system, provided the highest increase in additional production in our experiments – 0.50 t/ha. Based on the results of the variance analysis of the obtained data, we found that the increase in sunflower yield due to the fertilizer system was the most significant, with a MID_{05} of 0.11 t/ha.

It should be noted that the effectiveness of the biopreparation decreased under high nutrient backgrounds. However, due to the interaction of two factors – seed treatment and fertilizer system – the highest yield of sunflower seeds was obtained at 3.23 t/ha.

The application of fertilizers to field crops increases the availability of nutrients in the soil for plants. The additional amount of nutrients positively affected physiological processes in the plant, ensuring normal growth and development, crop formation, and seed quality.

A comprehensive economic evaluation of sunflower cultivation under different fertilizer systems and the use of biopreparations is possible by comparing not only its yield but also the output of products per unit of land area.

The productivity of sunflower seeds grown under conditions of insufficient moisture in the Northern Steppe of Ukraine during 2018–2022 was relatively high and provided a harvest of 5.23–6.47 t/ha of grain units, 2.88–3.56 t/ha of feed units, and 0.99–1.23 t/ha of digestible protein (Figure 1).

It was found that the highest yield of grain units per unit of land area, 6.47 t/ha, was obtained when sunflower seeds treated with biopreparation were grown under the organomineral fertilizer system (Figure 1a). Without seed treatment, this indicator was slightly higher, just exceeding the smallest significant difference at 6.23 t/ha with a MID_{05} of 0.23 t/ha. The most significant increase in grain unit yield per unit of land area was observed under the organomineral fertilizer system without seed treatment with a difference of 1.00 t/ha (MID_{05} 0.18). However, it should be noted that the increase in grain unit yield due to the action of the biopreparation was within the significant difference range (MID_{05} 0.23 t/ha), and the smallest increase of 0.13 t/ha was observed under the organomineral fertilizer system.

A similar trend was observed in the formation of other productivity indicators (Figure 1b). Specifically, a significantly higher output of feed units per unit of land area (+0.55 t/ha with a MID_{05} of 0.12 t/ha) was obtained under the organomineral fertilizer system without seed treatment, resulting in a yield of 3.43 t/ha. The highest amount of feed units was formed in sunflower crops influenced by both factors studied, reaching 3.56 t/ha. It was found that as the nutrient background increased, the effect of the biopreparation on the formation of feed units decreased and remained within the significant difference range (MID_{05} 0.04 t/ha).

The protein content in sunflower seeds depends on various factors, including weather conditions, soil quality, and especially the complex of agrotechnological

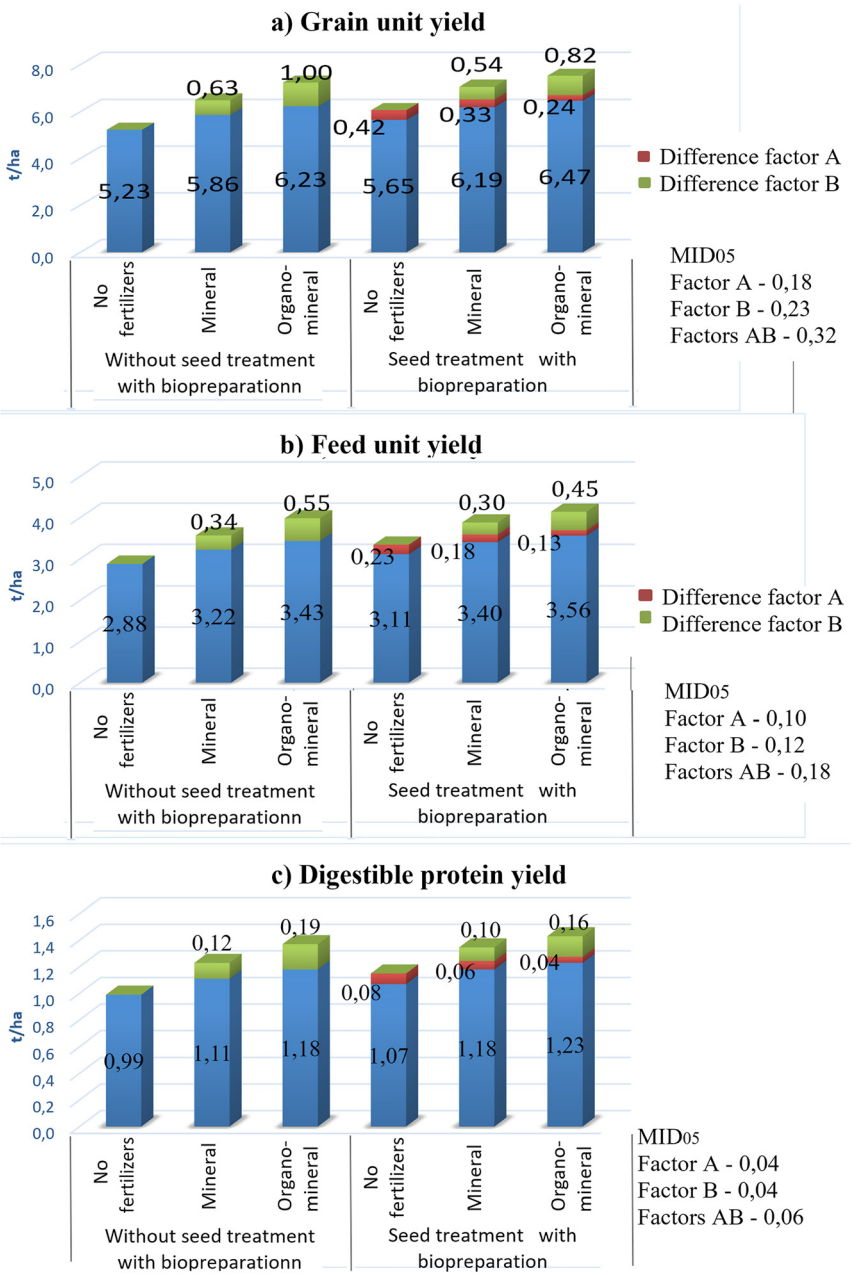

Figure 1: Sunflower productivity depending on seed treatment with biopreparation and different fertilizer systems, 2018–2022. *Author's calculations.

measures used in cultivation. To some extent, this indicator is determined by genotype. In our experiments, the protein content varied within the range of 0.99–1.23 tons per hectare (Figure 1c). The highest amount of digestible protein was obtained in the variant where sunflower seeds treated with biopreparation were grown under the organomineral fertilizer system at 1.23 t/ha. A significant increase in protein content in seeds occurred under the fertilizer system (+0.12 t/ha, +0.19 t/ha with a MID_{05} of 0.04 t/ha).

Thus, according to the results of our research, the highest dry matter output from the crop was obtained when sunflower seeds were treated with biopreparation and grown under the organo–mineral fertilizer system. The most significant increase in crop productivity was due to the fertilizer system. The effect of the biopreparation on this indicator decreased under high nutrient backgrounds.

Based on the research results, it was found that the use of different fertilizer systems and the application of biopreparations had a significant impact on sunflower productivity. However, another important component of evaluating the production of this crop is the economic efficiency of the studied agricultural measures.

The economic efficiency of using different fertilizers in sunflower cultivation was determined using commonly accepted methodological recommendations and standard provisions. The calculations took into account direct monetary and material costs, including labor costs, seed, fertilizers, fuel and lubricants, as well as payments to social insurance funds, pension and other contributions, depreciation and current repairs. The calculations of economic efficiency were based on prices for agricultural and industrial products that were established on the exchange market of Ukraine in the second decade of July 2023.

It was found that more than 30 % of the expenses were attributed to the use of mineral fertilizers, which led to a significant increase in this indicator in sunflower cultivation. In the variant without fertilizers, the lowest production costs were recorded at 19,910 UAH/ha (Table 5). The use of biopreparation for pre–sowing inoculation of sunflower seeds increased costs to the level of 20,033 UAH/ha. The highest production costs for sunflower cultivation were observed under the mineral fertilizer system and amounted to 30,360 UAH/ha, while under the same fertilizer system with the use of biopreparation, it was 30,587 UAH/ha. When using the organo–mineral fertilizer system, both with and without the biopreparation, it was found that the costs were lower compared to the mineral fertilizer system and amounted to 29,877 and 29,924 UAH/ha, respectively.

The lowest net profit and level of profitability were obtained in sunflower cultivation under the mineral fertilizer system without biopreparation, which amounted to 9491 UAH/ha and 31.3 %, respectively.

The highest indicators of economic efficiency in sunflower cultivation, namely net profit and profitability, were achieved when using the biological active

Table 5: Economic efficiency of sunflower cultivation depending on biopreparation and different fertilizer systems, t/ha, 2018–2022.

The biopreparation, factor A	Fertilization system, factor B	Production costs, UAH/ha	Gross product value, UAH/ha	Net profit, UAH/ha	Profitability, %
Without seed treatment with biopreparation	No fertilizers	19,910	35,499	15,588	78.3
	Mineral	30,360	39,851	9491	31.3
	Organomineral	29,877	42,435	12,558	42.0
Seed treatment with biopreparation	No fertilizers	20,033	38,355	18,322	91.5
	Mineral	30,587	42,027	11,440	37.4
	Organomineral	29,924	43,931	14,007	46.8

[a]Author's calculations.

preparation for seed inoculation without fertilizers, which amounted to 18,322 UAH/ha and 91.5 %, respectively.

Therefore, having a sunflower yield at the level of 3.12–3.23 t/ha, which was achieved among the studied factors by applying mineral fertilizers and using the by–product of the predecessor as organic fertilizer, is less profitable than cultivating sunflower without fertilizers. Due to the high costs of mineral fertilizers that need to be applied to avoid nutrient imbalance in the soil ecosystem, it is necessary to use a biopreparation that contributes to an increase in sunflower yield by 0.21 t/ha according to the maximum indicators of economic efficiency.

6 Conclusions

Based on the results of five years of research, elements of sunflower cultivation technology have been developed in the conditions of the Northern Steppe of Ukraine. The analysis of our data provides a scientifically justified approach to determining the fertilizer system and the use of a biopreparation to achieve high yields and quality sunflower production.

It has been established that in conditions of sharp fluctuations in weather conditions over many years, the organo-mineral fertilizer system provided higher seed yields of sunflower – 3.12 t/ha. In combination with seed treatment with a biopreparation, the yield increased to 3.23 t/ha. The fertilizer system factor contributed more to the yield increase, adding an additional 0.31–0.50 t/ha of seeds (NIR0.5 0.11 t/ha). Increasing the amount of nutrients in the soil neutralized the activity of the biopreparation, resulting in a yield increase of 0.12–0.21 t/ha, with the lowest yield increase observed with the organo-mineral fertilizer system.

The productivity of sunflower seeds significantly depended on the application of fertilizers and the action of the biopreparation. The highest dry matter output from the production was obtained through the treatment of sunflower seeds with a biopreparation and the use of an organo-mineral fertilizer system: 6.47 t/ha of grain units, 3.56 t/ha of feed units, and 1.23 t/ha of digestible protein. The most significant increase in crop productivity was due to the action of nutrient elements, namely mineral and organo-mineral fertilizer systems. As the nutrient content in the soil increased, the activity of the biopreparation decreased but remained significant.

The highest indicators of economic efficiency in sunflower cultivation were achieved under the conditions of seed treatment with a biopreparation without the application of fertilizers, resulting in a net profit of 18,322 UAH/ha and a profitability of 91.5 %.

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