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RESEARCH ARTICLE

Efficiency of fertilizer products in sunflower cultivation under the conditions of the forest-steppe of Ukraine

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Abstract

The effect of Azotophyt and organic balance biological preparations on the productivity of the P64F66 sunflower hybrid under the conditions of the North-Eastern Forest-Steppe of Ukraine was investigated. It was found that foliar application of the preparations at the 2-3 pair leaf stage increased seed yield compared with the control treatment. The highest seed yield (3.55 t ha^{-1}) was obtained using organic balance, confirming the potential of biological preparations for sustainable sunflower cultivation.

Keywords: Sunflower, Yield, Soil, Organic fertilizer, Biologics, Foliar fertilizer, Hybrid

Introduction

Sunflower (*Helianthus annuus* L.) is one of the principal oilseed crops within the agricultural sector of both Ukraine and the global market. Its seeds constitute a valuable source of high-quality edible and industrial oil, while by-products of processing are widely utilized in animal husbandry as protein-rich feed additives (Tkachuk, et al. 2024, Sobko, et al. 2024). Over recent decades, the cultivation area of sunflowers in Ukraine has expanded considerably due to the high profitability of production and the sustained demand in international markets. However, the intensification of sunflower cultivation, particularly the excessive saturation of crop rotations, frequently results in soil depletion, deterioration of soil biotic potential, and accumulation of phytopathogens (Abdullaeva, 2024). Concurrently, at the global scale, and especially in regions characterized by unstable moisture supply, such as the Steppe zone of Ukraine, climate change exerts increasingly adverse effects manifested through rising air temperatures, uneven precipitation distribution, and a greater frequency of drought events during critical crop growth stages.

One of the major challenges of contemporary agriculture remains the development of balanced plant nutrition systems that ensure high productivity without causing ecosystem degradation (Kharchenko, et al. 2019, Datsko, et al. 2024). Excessive application of mineral fertilizers, although effective in increasing yields in the short term, is often associated with soil acidification, suppression of beneficial microbiota, and reduced plant resistance to abiotic stress (Hryhoriv, et al. 2024, Husssain, et al. 2025). In response to these challenges, the concept of sustainable agriculture emphasized the development and implementation of biological products capable of optimizing plant nutrition through the mobilization of natural soil resources (Didur, et al. 2026, Zhatova, et al. 2017).

Among modern agrotechnological solutions, fertilizers based on probiotic microbial strains, commonly referred to as Plant Growth-Promoting Rhizobacteria (PGPR), play a particularly important role. These preparations contain living microorganisms (e.g., *Bacillus* spp., *Azotobacter* spp., *Streptomyces* spp.) that colonize the rhizosphere or endosphere of plants. Their influence on soil functioning is multifactorial and includes several key mechanisms (Vessey, 2003). First, they improve plant trophic status through atmospheric nitrogen fixation, phosphate and potassium solubilization, and siderophore production. Second, they modulate plant stress responses by Inducing Systemic Resistance (ISR), synthesising phytohormones such as auxins and cytokinins, and activating antioxidant enzymes, including catalase and superoxide dismutase, thereby mitigating oxidative stress under moisture-deficient conditions. Third, these microorganisms exert phytosanitary effects through their antagonistic activity against phytopathogenic fungi and bacteria, reducing the incidence of root rot diseases (Tsekhmeistruk, 2022).

Nevertheless, the effectiveness of such biopreparations remains a matter of scientific debate. Numerous studies demonstrate considerable variability in performance across hydrothermal conditions, soil types, microbial strain specificity, and hybrid genotypes. For instance, investigations conducted in the Southern Steppe of Ukraine revealed a positive correlation between the application of bioagents, particularly those based on *Bacillus* spp., and sunflower productivity on low-fertility chernozems (Kovalenko, et al. 2020). However, in certain years, the observed effects were statistically insignificant. Moreover, some experimental treatments even resulted in slight yield reductions (e.g., application of HelpRost at the 5-6 leaf-pair stage), highlighting the necessity for optimization of application rates, timing, and methods, particularly when combined with mineral fertilization.

Therefore, the aim of the present study was to evaluate the effects of novel microorganism-containing fertilizers produced by Biotechnological University (BTU)-Center on the productivity of sunflower hybrids under Ukrainian agroecological conditions. Preliminary trials demonstrated that pre-sowing seed treatment and foliar applications of products such as Biocomplex-BTU may stimulate plant growth and enhance oil accumulation in seeds. However, comprehensive analyses of their effects on the soil water regime, nutrient translocation, and the taxonomic composition of the rhizosphere microbiome remain underexplored. Future research should therefore shift from solely evaluating gross yield parameters toward detailed analyses of the phylogenetic composition of microbial communities using Next-Generation Sequencing (NGS) approaches based on 16S rRNA profiling. Such strategies may facilitate the development of personalized biofertilizer formulations tailored to specific agroecological conditions.

Materials and Methods

The P64F66 sunflower hybrid was used in the experiment. The experimental plots were established under field crop rotation conditions within the Krasnopillia territorial community, Osoivka village, Sumy district, Ukraine. Field experiments were conducted in 2024-2025, and the biological preparations were applied as foliar treatments at the 2-3 pair leaf stage. 0.5 L of fertilizer products per ha was dissolved with water. Each treatment variant area was 56 m², and the field experiment was arranged in three replications. The soil of the experimental plots was classified as a typical medium-humus calcareous Chernozem developed on loess-like loam with a neutral soil reaction.

Results and Discussion

The weather conditions during the study period (April-September of 2024-2025) differed considerably from long-term averages and had a substantial influence on the growth, development, and productivity of sunflower plants in the North-Eastern Forest-Steppe of Ukraine. In 2024, the beginning of the growing season was characterized by relatively favourable thermal conditions. The average air temperature in April reached 12.0℃, exceeding the long-term average by 3.2℃, while precipitation totalled 30 mm, indicating a moderate moisture deficiency. May conditions were generally favorable, with 48 mm of rainfall and temperature close to the climatic norm. In June, precipitation decreases to 46 mm compared with the long-term average of 68,5 mm, while the mean temperature rose to 20.7℃. The most critical period occurred in July, when only 8 mm of precipitation was recorded against the climatic norm of 72 mm, accompanied by a mean temperature of 24℃. These conditions caused severe drought stress during flowering and seed filling. Warm, dry weather and a moisture deficit persisted in August (43 mm per month) and at the beginning of September (26 mm per month), which helped with the harvest of sunflower seeds.

The 2025 growing season was more favorauble in terms of summer moisture supply. April precipitation was 40 mm, ensuring sufficient soil moisture reserves for uniform emergence. Although May was relatively dry (34 mm), conditions improved during June and July, when precipitation reached 56 mm and 67 mm, respectively. These conditions led to better flowering and seed filling than in 2024. August and September of 2025 were moderately warm, with 45 mm and 35 mm of precipitation, respectively, and elevated air temperature. Such conditions favoured crop maturation and timely harvesting.

Thus, 2024 was marked by pronounced drought stress during the reproductive period, especially in July, which limited seed filling and yield realization. In contrast, 2025 provided more balanced hydrothermal conditions, contributing to improved formation of yield structure components and allowing a more complete realization of sunflower productivity potential. These contrasting weather conditions created favourable prerequisites for assessing hybrid adaptability and the effectiveness of biological treatments under variable environmental conditions (Tab. 1).

The results indicate a positive response of the P64F66 sunflower hybrid to biological treatments in both years of the study. The effect of the preparations was observed under contrasting weather conditions in 2024 and 2025, although the magnitude of the response varied with the treatment combination and the growing-season hydrothermal conditions.

In the control treatment, the yield of the hybrid amounted to 2.98 t ha^{-1} in 2024 and 3.41 t ha^{-1} in 2025, which confirms generally more favourable environmental conditions for sunflower productivity in 2025. The increase in control yield by 0.43 t ha^{-1} compared with 2024 suggests better realization of the biological potential of the hybrid due to more balanced moisture supply during the reproductive period.

Table 1. Yield of the P64F66 sunflower hybrid under different biological treatments in 2024-2025, t ha^{-1}.

No.	Treatment option	2024	2025
1	Control	2.98	3.41
2	Azotophyt	3.1	3.5
3	Organic Balance	3.17	3.55
4	Enposam	3.05	3.46
5	Organic Balance+Azotophyt	3.24	3.61
6	Organic Balance+Azotophyt+Enposam	3.31	3.68
7	Organic Balance+Enposam	3.2	3.58
8	Azotophyt+Enposam	3.13	3.52
9	LSD	0.142	0.118

Application of Azotophyt as a single treatment increased to 3.10 t ha^{-1} in 2024 and 3.50 t ha^{-1} in 2025, corresponding to yield increases of 0.12 and 0.09 t ha^{-1}, respectively, compared with the control. This indicated a moderate but stable stimulating effect of the preparation on plant growth and nutrient uptake.

Using organic balance produced a more pronounced effect. Yield reached 3.17 t ha^{-1} in 2024 and 3.55 t ha^{-1} in 2025, exceeding the control by 0.19 and 0.14 t ha^{-1}, respectively. This confirms the effectiveness of this multifunctional biological preparation in improving physiological activity and supporting productive processes.

The individual application of Enposam showed the smallest effect among the tested single-component treatments. Yield values were 3.05 t ha^{-1} in 2024 and 3.46 t ha^{-1} in 2025, exceeding the control by only 0.07 and 0.05 t ha^{-1}, respectively. Such results indicate that the independent effect of Enposam is limited, whereas its role is more likely to be associated with enhancing the efficiency of combined applications.

Combined treatments demonstrated significantly greater effectiveness than single-component applications. The combination of organic balance+Azotophyt increased yield to 3.24 t ha^{-1} in 2024 and 3.61 t ha^{-1} in 2025, representing increases of 0.26 and 0.20 t ha^{-1}, respectively. This confirms the synergistic interaction between these preparations.

The highest productivity was recorded for the three-component combination organic balance+Azotophyt+Enposam, with yields of 3.31 t ha^{-1} in 2024 and 3.68 t ha^{-1} in 2025. Compared with the control, the yield increase amounted to 0.33 t ha^{-1} (11.1%) in 2024 and 0.27 t ha^{-1} (7.9%) in 2025. These results indicate the highest biological and agronomical efficiency of the integrated treatment system.

The treatment organic balance+Enposam also demonstrated high effectiveness, yielding 3.20 and 3.58 t ha^{-1} in 2024 and 2025, respectively, while Azotophyr+Enposam yielded 3.13 and 3.52 t ha^{-1}.

Conclusion

Overall, the results indicate that all biological treatments positively affected sunflower productivity, but the magnitude of their influence depended on treatment composition and environmental conditions. The most effective treatment was the three-component combination, which ensured the highest yield in both years the study. This confirms the expediency of combining multifunctional biological preparations for improving the productivity of the P64F66 sunflower hybrid under the conditions of the North-Eastern forest-steppe of Ukraine.

References

Abdullaeva S. (2024). On the rhizosphere of field crops and factors influencing the dynamics of its microbiota. *Nat Sci Int Sci J*. **6**:10-13.

Akuaku J, Makarchuk AV, Melnyk TI, Trostenko VI. (2019). Productivity and quality of high-oleic sunflower seeds as influenced by foliar fertilizers and plant growth regulatorsin the left-bank forest-steppe of Ukraine. *Agro Life Sci J*. **8**:167-175.

Datsko O, Kovalenko V, Yatsenko V, Sakhoshko M, Hotvianska A, Solohub I, Horshchar V, Dubovyk I, Kriuchko L, Tkachenko R. (2024). Increasing soils fertility as a factor in the sustainability of agriculture and resilience to climate change. *Modern Phytomorphol*. **18**:110-113.

Didur I, Pantsyreva H, Polishchuk M, Aralova T, Matusyak M, Tsyhanska O, Palamarchuk I, Mostovenko V, Piddubna A, Pankova S. (2026). Research on the ecologization of soil cultivation technologies on the level of weed infestation in sunflower, soybean and grain corn crops. *Modern Phytomorphol*. **20**: 501-505.

Hryhoriv Y, Butenko A, Solovei H, Filon V, Skydan M, Kravchenko N, Masyk I, Zakharchenko E, Tykhonova O, Polyvanyi A. (2024). Study of the impact of changes in the acid-base buffering capacity of surface sod-podzolic soils. *J Ecol Eng*. **25**:73-79.

Hussain S, Khan M, Altaf MT, Shah MN, Alfagham AT. (2025). Deciphering the morpho-physiological and biochemical response of sunflower hybrids with the application of biochar and slow-release nitrogen fertilizers under drought stress. *Front Plant Sci*. **16**:1541123.

Kharchenko O, Zakharchenko E, Kovalenko I, Prasol V, Pshychenko O, Mishchenko Y. (2019). On problem of establishing the intensity level of crop variety and its yield value subject to the environmental conditions and constraints. *Agro Life Sci J*. **8**:113-120.

Kovalenko OA, Fedorchuk MI, Neroda RS, Donets JL. (2020). Sunflower cultivation using micro-fertilizers and bacterial preparations. *Sci Progress Innov*. **2**:26-35.

Sobko M, Zakharchenko E, Kolisnyk O, Medvid S, Kysylchuk A, Krokhin S, Rudska N, Amons S, Omelianenko O, Bondarets R, Surzhykov M. (2024). Yield and energy efficiency of sunflower cultivation under different primary soil tillage methods. *Modern Phytomorphol*. **18**:200-204.

Tkachuk O, Gucol G, Mazur O, Verhelis V, Titarenko O. (2024). Ecological safety of sunflower seeds in the conditions of agricultural intensification. *Sci Horiz*. **27**:71-79.

Tsekhmeistruk MH. (2022). Application of bacterial agents on sunflower. *Plant Breed Seed Sci*. **121**:105-112.

Vessey JK. (2003). Plant growth promoting rhizobacteria as biofertilizers. *Plant Soil*. **255**:571-586.

Zhatova GA, Trotsenko VI. (2017). Dynamics of sunflower rhizosphere microbiota. *Ukr J Ecol*. **7**:22-29.