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Effect of foliar application of biological products on sunflower productivity in the north-eastern part of the forest-steppe of Ukraine

Abstract. Sunflower production required new technological approaches that involve not only the use of intensive hybrids, fertiliser systems, and innovative equipment, but also ensuring a comprehensive interaction of the main agrotechnological factors. The purpose of the study was to

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establish the effect of foliar application of biological products due to their stimulating and protective effect on the development of the productivity of sunflower plants embedded in the genotype. A field method was used to investigate the interaction of research objects with natural, laboratory, and mathematical and statistical factors. It was found that foliar application of biological products showed a tendency to stimulate plant growth. The highest plant height (+5 cm) in the five leaf phase over the years of research was observed in the variant treated with Azotohelp. Foliar dressing with Organic Balance biologics affected an increase in the basket diameter by 3.25 cm compared to the control version, Organic Balance Monophosphorus – by 3.55 cm, and Azotohelp – by 3.8 cm. The weight of 1,000 grains with the use of Organic Balance increased by 5.2 g, Organic Balance Monophosphorus – 3.2 g, Azotohelp – 3.7 g. Foliar applications of biologics increased the weight of seeds from the basket by 4.9, 6.9, and 9.7 g, respectively. However, an increase in the diameter of the basket, the number and weight of seeds in it, and the weight of 1,000 grains, led to an increase in yield, which was confirmed by a high correlation (r – 0.80-0.99) between these indicators. Notably, the greater influence of Organic Balance Monophosphorus biologics on the development of sunflower yield was found in hot weather conditions in 2021 compared to more favourable conditions in 2022-2023. On average, over three years of research, the biological yield of sunflower seeds with foliar application of biologics exceeded the control option by 0.3-0.54 t/ha. The highest productivity of sunflower was formed by foliar dressing with Azotohelp biologics and amounted to 3.7 t/ha with a control level of 3.16 t/ha, an increase of 0.54 t/ha, or 17.1%. These results can be used to optimise intensive sunflower cultivation technology, which will contribute to better plant nutrition, reduce the pesticide load, and increase sunflower yield

Keywords: oilseeds; yield; fertilisers; Azotohelp; Organic Balance; Organic Balance Monophosphorus

INTRODUCTION

Sunflower is one of the most important oilseeds in Ukraine, in particular in the left-bank forest-steppe, where it occupies a leading place among agricultural crops in terms of profitability. However, intensive sunflower cultivation, crop rotation violations, climate changes, and anthropogenic impact lead to soil degradation, reduced fertility, and disruption of water and nutrient regimes, which makes it difficult to obtain stable and high yields. Simultaneously, in the context of increasing climate risk, especially droughts and high temperatures, there is an urgent need to introduce effective and environmentally friendly approaches to plant nutrition (Adeleke *et al.*, 2022; Pavlichenko *et al.*, 2023). V. Pichura *et al.* (2023) noted that one of the promising areas is the use of biological preparations containing growth stimulants, anti-stress agents, amino acids, and other active components that can increase plant resistance to adverse conditions, activate physiological and biochemical processes, and improve crop productivity. Therefore, the study of the impact of foliar application of biologics is extremely relevant, both for science and for practice, since it is aimed at reducing the risks of agricultural production, improving the efficiency of using natural resources.

A. Rozhkov & V. Roenko (2025) emphasised the growing role of applying biologics to vegetative plants, which reduces the dependence of the crop on environmental factors, allows optimising resource-saving cultivation technologies and using the natural potential of this oilseed crop. They suggested that the introduction of biologics do not pollute the environment, showing a high selective effect, are convenient for production and has inexhaustible resources for constantly increasing production volumes. O. Laslo (2022) and O. Kovalenko *et al.* (2022) noted that foliar dressing acts as an additional method to root nutrition and ensures that nutrients are instantly absorbed and distributed inside plants through the leaves. O. Averchev & N. Vasylenko (2023) emphasised the importance of using biologics with protective and growth-stimulating functions that contribute to the implementation of potential opportunities inherent in the crop, including certain immune responses, increases plant productivity, and the implementation of genotypic makings of varieties and hybrids. O. Tsyliuryk *et al*. (2021) emphasised that the treatment of plant seeds with growth-regulating drugs has established an effect on the growth and development of sunflower and revealed the possibility of reducing the duration of stressful conditions with a versatile degree of adverse effects. The researchers also noted that one of the measures to increase plant resistance is the use of biologics that are environmentally safe, intensify physiological processes in plants, increase resistance, and increase the yield of agricultural crops.

According to the observations of J. Akuaku *et al*. (2020), B. Basile *et al*. (2021), the physiological effect of using biologics consists in the activation of the vital activity of plant cells, increase in the permeability of intercellular membranes, and acceleration of their biochemical reactions, which contributes to the intensification of nutrition, respiration, and photosynthesis. The high efficiency of using drugs for regulating the growth and development of plants of biological origin is determined, purposefully reducing stressful situations by reducing their duration, rational use of natural resources, and the development of a larger amount of dry mass, which, accordingly, leads to an increase in productivity and an improvement in product quality. However, the versatile effect of microbial preparations with foliar application is poorly investigated.

The purpose of the study was to establish the influence of foliar use of biologics, Azotohelp, Organic Balance and Organic Balance Monophosphorus in sunflower crops on the development of crops and individual plant productivity in the conditions of the north-eastern part of the forest-steppe of Ukraine.

MATERIALS AND METHODS

The research was conducted in the grain-row crop rotation of the Department of Agriculture of the Institute of Agriculture of the North-East of the National Academy of Agrarian Sciences in 2021-2023. The soil in the area under study was typical low=humus, slightly leached, coarse-grained, medium-loamy chernozem with the following agrochemical indicators of the arable layer: humus according to D. Tyurin – 4.2-4.8%; salt pH – 6.0; water pH – 7.9; easily hydrolysed nitrogen content according to D. Kornfeld – 107; mobile P_2O_5 and K_2O according to N. Chirikov, respectively, 62.7 and 67.5 mg per 1 kg of soil. Granulometric composition of the soil according to J. Kaczynski – coarse-grained, medium loamy: physical clay (particles 0.05-0.01) – 49.1-52.1%, silt (particles less than 0.001 mm) – 23.4-25.5% in a layer of 0-20 cm weight

The research was conducted according to generally accepted methodological approaches in the field of agronomy (Rozhkov *et al*., 2016). The area of the sowing plot in one repetition of each individual variant was 94.5 m^2, the area on which the harvest was recorded (without side and end protective strips) was 45.5 m^2, the repetition was four times, and the plots were arranged using the randomised repetition method. Crop accounting was carried out by continuous threshing of grain from each site, followed by recalculation to 8% of the basic humidity. The weight of 1,000 grains was determined by DSTU 4138-2002 (2004). The obtained results were processed by variance and correlation methods of analysis using Excel-16.0 software suite.

The cultivation technology was generally accepted for this zone, except for the techniques that were studied. Mineral fertilisers were applied in the spring, under pre-sowing cultivation with the rate of $N_{32}P_{32}K_{32}$ on all variants. The effectiveness of foliar application of biologics was studied in sunflower crops of the 'Esman' variety. Treatment of plants was carried out in the phase of 2-3 pairs of true leaves in a crop with a working solution consumption rate of 200 l/ha according to the following scheme: control (treatment of plants with water); Organic Balance 0.5 l/ha; Organic Balance Monophosphorus 0.5 l/ha; Azotohelp 0.5 l/ha.

Organic Balance – biologics based on bacteria with nitrogen-fixing, phosphorus and potassium mobilising and fungicidal properties, the action of which is to provide plants with an immunostimulating and protective effect. Composition of the biological product: *Bacillus velezensis*, *Agrobacterium pusense*, *Paenibacillus polymyxa*, *Enterococcus hirae*, *Lactobacillus delbrueckii* sp. *Bulgaricus*. Organic Balance Monophosphorus – biologics based on phosphorus mobilising bacteria, the action of which consists in providing prolonged nutrition of plants with mobile forms of phosphorus, fungicidal and bactericidal plant protection. Composition of the biological product: live cells of phosphorus mobilising and fungicidal and bactericidal properties of bacteria, biologically active substances: phytohormones, amino acids, and vitamins. The total number of viable producer microorganisms was not less than 1.0×10^9 CFU/cm^3. Azotohelp KS – a biological product based on associative nitrogen-fixing bacteria, which consists in fixing molecular nitrogen from the atmosphere by nitrogen-fixing bacteria and transferring it to a form accessible to plants, synthesising growth-stimulating substances. Composition of biologics: live cells of *Agrobacterium pusense*, vitamins, phytohormones, amino acids, and other physiologically active substances. Total number of viable cells – not less than 1.0×10^9 CFU/cm^3.

Weather conditions during the research years were satisfactory for plant growth and development. The spring was somewhat colder than usual. A decrease in air temperature was observed in April 2021-2022 and May in 2022. Summers during the research years were hotter compared to the long-term average. Thus, the excess temperature in the summer was from 0.5 to 4.9°C. At the beginning of autumn in September, it got slightly colder in 2021-2022 (respectively -0.6°C and -1.8°C below normal) In April, there was an excessive amount of precipitation during the research years, (+14...+67 mm), and May turned out to be dry in 2022-2023, the hydrothermal coefficient (HC) was 0.7, 0.4, respectively. The availability of plants with available moisture in the soil was formed due to precipitation that took place in April. In summer, dry conditions were observed in 2021, in July (HC – 0.1), and in 2022 in August (HC – 0.3). The summer of 2023 was characterised by a sufficient supply of moisture to plants. In early autumn 2021, 2023, in September, high air temperatures and low precipitation contributed to the harvest, and in 2022, harvesting was difficult due to heavy rains in the second and third ten days of September, the excess of precipitation was 75.6 mm. The contrast of weather conditions during the growing season during the years of research (decrease and increase in temperatures, lack of moisture) in the north-eastern part of the forest-steppe of Ukraine helped to more fully investigate the effectiveness of foliar application of biologics in sunflower crops. The study was conducted in accordance with the ethical standards of Convention on Biological Diversity (1992) and Convention on the Trade in Endangered Species of Wild Fauna and Flora (1976).

RESULTS AND DISCUSSION

The growth and development of plants took place without any special deviations and corresponded to the varietal characteristics of sunflower. Thus, full shoots appeared on day 12 after sowing on all variants of the experiment in 2021, on day 21 in 2022 and on day 9 in 2023. The negative impact of a decrease in the average daily air temperature (by 2.3°C) in May 2022 on the duration of seed germination and the uniformity of seedlings. The duration of interphase periods of germination – the first pair of true leaves – five leaf phase – flowering – maturation depended on climatic conditions and amounted to 5, 29, 19, 63 days on all variants of the experiment in 2021; in 2022 – 6, 28, 26, 75 days; in 2023 – 11, 29, 28, 50 days, respectively. Under these conditions, it was found that the use of biologics did not change the duration of the passage of plants, both individual phases of growth and development, and the growing season as a whole, which in 2021 was 116, in 2022 – 135, and in 2023 – 118 days (Table 1).

Table 1. Dates of the main phases of growth and development of sunflower plants

Phases of plant growth and development	Years of research		
	2021	2022	2023
Sowing	10.05	06.05	15.05
Germination	22.05	27.05	24.05
First pair of true leaves	27.05	03.06	05.06
Five leaf phase	25.06	01.07	03.07

Table 1, Continued

Phases of plant growth and development	Years of research		
	2021	2022	2023
Flowering	14.07	27.07	31.07
Maturation	15.09	10.10	19.09

Source: compiled by the authors

In the process of studying the effect of treating the vegetative mass of plants with biologics, observations of growth processes were carried out. The height of sunflower plants in the five leaf phase in 2021 ranged from 68 to 74 cm in 2022 from 70 to 73 cm, and in 2023 – 60-65 cm (Fig. 1). Foliar dressing with biologics showed a tendency to stimulate plant growth. In 2021, this trend was more pronounced due to a warmer and wetter spring, compared to 2022 and 2023. The highest height of plants in the five leaf phase over the years of research was observed in the variant where Azotohelp treatment was performed, the increase compared to the control was 2-5%. The best development of the photosynthetic apparatus of plants at this stage was one of the significant factors in the development of their productivity. The difference in plant height persisted until the end of the growing season (maturation phase): plants of the control variant in 2021 and 2023 were lower by 3-9% and 3-8%, and in 2022 by 1-4%, compared to treated biologics.

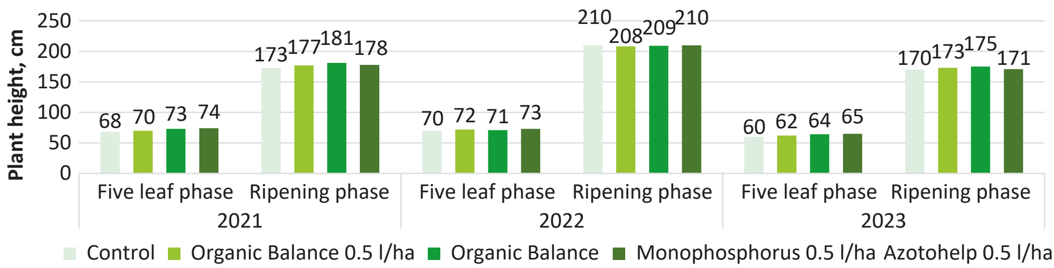

Figure 1. Height of sunflower plants with the foliar application of biologics
Source: compiled by the authors

One of the main indicators that affect the development of sunflower productivity was the basket diameter, the weight of seeds from the basket, and the weight of 1,000 grains. The results of experimental data indicate that foliar dressing with biologics increased the diameter of the basket. Thus, the introduction of Organic Balance on average for three years of research increased this indicator compared to the control version by 3.25 cm, Organic Balance Monophosphorus – by 3.55 cm, and Azotohelp – by 3.8 cm.

A significant role in the development of yield was played by the weight of 1,000 grains, which characterises the fullness of seeds and directly affects the weight of grain in the basket and plant productivity. It was found that on average for three years, the weight of 1,000 grains in the version using Organic Balance increased by 5.2 g, Organic Balance Monophosphorus – 3.2 g, Azotohelp – 3.7 g, compared to the control. Naturally, an increase in the weight of 1,000 grains due to foliar application of biologics led to an increase in the weight of seeds from the basket by 4.9, 6.9, and 9.7 g, respectively (Table 2).

Table 2. Structural indicators of sunflower yield with the foliar application of biologics (average for 2021-2023)

Option	Basket diameter, cm	Weight of grains from the basket, g	Weight of 1,000 grains, g
1. Control	18.6	53.9	54.8
2. Organic Balance 0.5 l/ha	21.1	58.8	59.1

Table 2, Continued

Option	Basket diameter, cm	Weight of grains from the basket, g	Weight of 1,000 grains, g
3. Organic Balance Monophosphorus 0.5 l/ha	21.1	60.8	58.0
4. Azotohelp 0.5 l/ha	21.9	63.6	58.5

Source: compiled by the authors

The results obtained demonstrate that the treatment of plants with Organic Balance, Organic Balance Monophosphorus, Azotohelp preparations, improving biological and economic productivity indicators, had a positive effect on sunflower yield, which was confirmed by the close relationship between these indicators. Thus, an increase in the diameter of the basket, the number and weight of seeds in it, and the weight of 1,000 grains, is highly correlated with yield (r – 0.80-0.99) (Table 3). An integral indicator of the effectiveness of a particular element of technology is the yield of the crop. However, the weather conditions of the year also have a significant impact on the crop development. Thus, according to the results of accounting in 2021, a mathematically significant increase (+0.3, +0.7, +0.64 t/ha, respectively) to the control variant was obtained at all variants of the experiment where foliar dressing with biologics was carried out (Table 4).

Table 3. Correlation coefficients of valuable biological and economic characteristics of sunflower with the foliar application of biologics (average for 2021-2023)

Indicators	Basket diameter, cm	Number of seeds in the basket, units	Weight of grains from the basket, g	Weight of 1,000 grains, g
Number of seeds in the basket, units	0.77	-	-	-
Weight of grains from the basket, g	0.96	0.91	-	-
Weight of 1,000 grains, g	0.93	0.49	0.8	-
Yield, t/ha	0.96	0.9	0.99	0.8

Source: compiled by the authors

Table 4. Sunflower yield with the foliar application of biologics

No.	Option	Yield, t/ha					Lewis stability coefficient, Ksfn
		2021	2022	2023	Average for 2021-2023	± to control, t/ha	
1	Control	3.05	3.27	3.16	3.16	-	1.07
2	Organic Balance 0.5 l/ha	3.35	3.57	3.41	3.44	0.28	1.07
3	Organic Balance Monophosphorus 0.5 l/ha	3.75	3.33	3.42	3.5	0.34	1.13
4	Azotohelp 0.5 l/ha	3.69	3.7	3.78	3.72	0.56	1.02
LSD_{05}		0.28	0.21	0.21			

Source: compiled by the authors

In the climatic conditions of 2022, a significant increase in yield was formed when plants were treated with Organic Balance (+0.3 t/ha) and Azotohelp (+0.43 t/ha) biologics. The use of biologics in 2023 significantly increased this indicator in all variants (+0.25 t/ha, +0.26 t/ha, and +0.62 t/ha, respectively). Notably, the advantage of the positive effect of Organic Balance Monophosphorus on the development of sunflower yield under hot weather conditions in 2021 (+0.6 t/ha) compared to favourable conditions for agricultural crops in 2022-2023 (+0.06, +0.26 t/ha, respectively). On average, over three years of research, the biological yield of sunflower seeds with the foliar application of biologics exceeded the control option by 0.3-0.54 t/ha. The highest productivity of sunflower was formed by foliar dressing with Azotohelp and amounted to 3.7 t/ha at the control level of 3.16 t/ha, respectively, the increase was 0.54 t/ha, or 17.1%. This option, according to the Lewis coefficient (1.02), turned out to be the most stable in terms of yield.

It was determined that similar patterns regarding the positive use of biologics were confirmed by studies on other cultures. In particular on winter wheat, A. Bahan & V. Gurba (2025) noted that the use of microbiological preparations in technologies for growing winter wheat helped to increase the supply of nutrients to plants, which stimulated the development of plants during the growing season, and, as a result, increased the length of the ear to the control option by 4.1%, and productivity by 3-12%. A. Datsko *et al.* (2022) noted that the productivity of winter wheat increased compared to the control variant by 2-7% with the use of Azotohelp, by 8% with Organic Balance, and by 10% with Organic Balance Monophosphorus. According to V. Polishchuk *et al.* (2025), foliar application of biologics in 'Granada' potato crops contributed to higher yields compared to the control option when using biologics, the yield increase against the background of 50 tonnes of manure was 6-11%, and with the mineral fertiliser system $N_{50}P_{40}K_{70}$ – 3-8%. V. Bilyi & V. Knysh (2021) noted that double foliar application of biologics increased corn yield relative to control by 26-30%.

The findings by K. Geetha *et al.* (2018) and A. Bahan *et al.* (2023) showed that the treatment of sunflower seeds with biologics had a significant impact on its sowing qualities, there was an increase in the length of the root and sprout, and the weight of 100 sprouts during germination in hybrids, compared with the control. D. Chuyko *et al.* (2020) indicated a positive effect of double foliar application of biologics on the line-sterile analogues of the Sh808A genotype, increasing yield by 19%, plant productivity – by 17%. O. Kovalenko *et al.* (2020) noted that the foliar application of biologics contributes to the mobilisation and optimisation of plant nutrition elements, improvement of growth processes, and high sunflower seed productivity, an increase relative to control by 5-13%. A. Panfilova *et al.* (2024) noted that the use of biologics Azotofit and Organic Balance on various sunflower hybrids improved biological performance, which, in turn, increased productivity by 5-10 and 3-12%, respectively, and the oil content – by 0.9-1.8%.

The study investigated the use of biologics specifically for foliar application, which is important in increasing the biological potential of the crop, considering the weather features of the growing season. The proposed agricultural measure is effective and necessary in contemporary agricultural technologies; however, in the context of climate change, it requires further scientific research.

CONCLUSIONS

In the conditions of the north-eastern part of the forest-steppe zone of Ukraine, on typical low-humus medium loamy chernozems, it is advisable to use foliar application of biological products to increase the efficiency of intensive sunflower cultivation technology. Foliar application of biologics contributed to the activation of physiological and biochemical processes, stimulation of plant growth and development, which was manifested in an increase in the height of sunflower plants by 3-7%, the diameter of the basket by 16.9-19.8% of the weight of 1,000 grains by 8.4-12.1%, and an increase in yield by 9.5-17.1% compared to the control. A high correlation (r – 0.80-0.99) was obtained between the elements of productivity (basket diameter, number and weight of grains, weight of 1,000 grains) and yield, which confirms their decisive role in the development of the level of crop productivity.

The greatest increase in the yield of sunflower plants was provided by foliar application of Azotohelp, which increased productivity by 0.54 t/ha (17%) relative to the control (3.16 t/ha) and was characterised by the highest stability according to the Levis coefficient (1.02). Organic Balance Monophosphorus showed a particularly positive effect in arid conditions in 2021, which indicates an increase in plant resistance to abiotic stresses and the prospects for using biologic preparations in the context of climate change.

The use of biologics not only increased the yield of sunflower, but also allowed optimising plant nutrition, reducing the pesticide load, and increasing the efficiency of intensive sunflower cultivation technology, which meets the requirements of contemporary ecological farming. The use of biologics contributed not only to increasing yields, but also to improving environmental sustainability and reducing the impact of sunflower cultivation on the environment. The results of the study showed the potential of integrating biologics into precise and sustainable farming systems, which increases both productivity and resource efficiency. In further studies of foliar application of biologics on sunflower, it is advisable to expand the research of the growth-regulating effect of biologics, their role in reducing the duration of stress states, influence on photosynthetic activity, and features of the development of productivity of agrophytocoenoses.

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CONFLICT OF INTEREST

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Вплив фоліарного внесення біопрепаратів на продуктивність соняшника в умовах північно-східної частини Лісостепу України

Анотація. Виробництво соняшнику вимагає нових технологічних підходів, що передбачають не лише використання інтенсивних гібридів, систем удобрення й інноваційної техніки, а також забезпечення комплексної взаємодії основних агротехнологічних чинників. Метою дослідження було встановити вплив фоліарного внесення біопрепаратів завдяки їх стимулюючій та захисній дії на реалізацію продуктивності рослин соняшнику закладених в генотипі. У дослідженні було застосовано польовий метод для вивчення взаємодії об'єктів досліджень з природними факторами, лабораторний, а також математико-статистичний. Встановлено, що за фоліарного підживлення біопрепаратами простежилась тенденція до стимуляції росту рослин. Найбільша висота рослин (+5 см) у фазу зірочки за роки досліджень спостерігалася на варіанті, де проводили обробку Азотохелпом. Позакореневі підживлення біопрепаратом Органік баланс вплинули на збільшення діаметра кошика порівняно до контрольного варіанту на 3,25 см, Органік баланс монофосфор – на 3,55 см, а Азотохелп – на 3,8 см. Водночас маса 1000 зерен, за застосування Органік баланс зростала на 5,2 г, Органік баланс монофосфор – 3,2 г, Азотохелп – 3,7 г. Фоліарні внесення біопрепаратів підвищували масу насіння з кошика відповідно на 4,9, 6,9 та 9,7 г. Втім, збільшення діаметру кошика, кількості та маси насінин в ньому, а також маси 1000 насінин, зумовило підвищення врожайності, що підтвердилось високою кореляцією (r – 0,80-0,99) між даними показниками. Слід відмітити, що більший вплив біопрепарату Органік баланс монофосфор на формування урожайності соняшника виявлено за спекотних погодних умов 2021 р. порівняно з більш сприятливими умовами 2022-2023 рр. В середньому за три роки досліджень біологічна урожайність соняшника за фоліарного внесення біопрепаратів перевищила контрольний варіант на 0,3-0,54 т/га. Найвища продуктивність соняшника формувалася за позакореневого підживлення біопрепаратом Азотохелп і складала 3,7 т/га за рівня на контролі 3,16 т/га, приріст склав 0,54 т/га, або 17,1 %. Дані результати можуть бути використані для оптимізації інтенсивної технології вирощування соняшника, що сприятиме кращому живленню рослин, зниженню пестицидного навантаження та підвищення врожайності соняшника

Ключові слова: олійні культури; урожайність; добрива; Азотохелп; Органік баланс; Органік баланс монофосфор