Received 06.08.2024 Revised 28.10.2024 Accepted 27.11.2024

Vol. 20, No. 6
2024

Scientific Reports of the National University of Life and Environmental Sciences of Ukraine

Journal homepage: https://scireports.com.ua/en

UDC 631.811:633.34

DOI: 10.31548/dopovidi/6.2024.50

Influence of biologics on the development of soybean productivity elements in the conditions of the northern Forest-Steppe of Ukraine

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Abstract. The purpose of the study was to determine the effectiveness of the use of biostimulants for improving growth processes and increasing soybean yields in the region. The studies were conducted on chernozem soils of medium fertility, optimal for growing legumes. The sites were divided into four groups: a control group, a group with the introduction of Bioglobin, a group with Rizohumin, and a group with the combined use of both drugs. The main parameters for evaluating the effectiveness of drugs were the number of beans per plant, the number of seeds in the bean, the weight of 1,000 seeds, and the protein and oil content in the seeds. It was found that a separate application of Bioglobin improves the photosynthetic activity of plants, contributing to intensive growth and development of leaf mass, while Rizohumin actively stimulates the development of root nodules, increasing the efficiency of nitrogen fixation and providing the plant with nitrogen. The combined use of Bioglobin and Rizohumin gave the best results, significantly increasing the overall yield and quality of soybean seeds. The synergistic effect of the drugs contributed to an increase in the weight of 1,000 seeds, the number of beans per plant, and the protein and oil content in the seeds. This showed that the use of Bioglobin and Rizohumin in a complex is an effective strategy for improving soybean productivity, reducing the need for chemical fertilisers and improving the environmental sustainability of agricultural production. The results obtained indicate a significant potential of biologics to increase soybean yields in the region and are valuable for agricultural producers who seek to optimise growing conditions without additional costs for mineral fertilisers

Keywords: nitrogen fixation; fertility; inoculation; yield; plant nutrition

Suggested Citation:
Kyselov, O. (2024). Influence of biologics on the development of soybean productivity elements in the conditions of the northern Forest-Steppe of Ukraine. *Scientific Reports of the National University of Life and Environmental Sciences of Ukraine*, 20(6), 50-64. doi: 10.31548/dopovidi/6.2024.50.

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Introduction

Soy is one of the most important crops in global agriculture, as it provides a high content of protein and oil, which makes it valuable for the food, feed, and industrial sectors. The demand for soybeans is constantly growing, and, accordingly, there is a need to increase its yield. However, conventional methods of increasing productivity through the use of mineral fertilisers have a number of negative consequences, in particular, environmental pollution, reduced soil fertility and increased production costs. In the conditions of modern agriculture, there is a need for efficient, ecological, and cost-effective methods of increasing crop productivity, which contributes to the search for alternative solutions. The relevance of the study is conditioned by the need to increase soybean yields in the northern forest-steppe of Ukraine using biological methods that are environmentally safe and cost-effective. Despite the growing popularity of biologics, the impact on soybean productivity in specific climatic conditions has not been sufficiently explored, which makes this study important for developing practical recommendations for farmers.

The problem of growing soybeans is related to the need to increase the yield and quality of products in conditions of limited resources and growing requirements for the environmental friendliness of agricultural technologies. Conventional methods of production intensification, which involve the active use of mineral fertilisers, cause a number of negative consequences: soil depletion, water pollution, increased acidity and reduced biological activity of the soil. This practice reduces the long-term productivity of agroecosystems and requires alternative approaches to maintain sustainable soybean production. Analysis of previous studies confirms the importance of biologics and other organic methods for improving soybean productivity.

For instance, G. Jat *et al*. (2021) investigated the effect of zinc application on soybean yield and quality in haplustepts-type soils. The researcher found that zinc supplementation improves the protein content of seeds, which increases their nutritional value and profitability. This highlights the importance of trace elements in soy nutrition systems, which contributes to its optimal development. M.D. Orozco-Mosqueda *et al*. (2021) pointed to the role of bacteria that stimulate plant growth and the benefits of increasing crop yields and stress resistance. The researchers note that these bacteria activate physiological processes, which contributes to better absorption of nutrients by plants and increases their resistance to adverse conditions, such as drought or lack of nutrients. B. Ramakrishnan *et al*. (2021) examined the role of organic farming in improving the quality of agricultural products and environmental safety. The researchers showed that organic farming methods contribute to increasing soil biodiversity, and reducing environmental pollution, which makes this approach beneficial for sustainable agricultural production. S. Bhunia *et al*. (2021) reviewed the effectiveness of animal-based organic fertilisers that improve biological activity and soil fertility. The researchers note that such fertilisers can significantly increase the organic matter content in the soil, ensuring a sustainable increase in plant productivity and reducing the need for chemical fertilisers. The study by H. Elhalis *et al*. (2024) was devoted to the fermentation processes of soy products that affect the quality of final products. The researchers emphasised that the high quality of soy seeds is the basis for obtaining products with improved nutritional properties and increased protein content.

M. Ghoroghi *et al*. (2024) investigated the properties of soybean oil-based bioplastics and their significance for the food industry. The researchers note that high-quality soybean oil contributes to the production of plastics for food packaging, which emphasises the importance of high-quality raw materials. J. Suman *et al*. (2022) reviewed the role of the soil microbiome in ensuring sustainable agricultural development. The researchers emphasise that the soil microbiome plays an important role in plant nutrition and

increases resistance to stress factors, which is key to improving yield and product quality. A. Raimi *et al*. (2021) considered the problems and prospects of biofertiliser production in Africa, noting that the use of biologics contributes to increasing crop yields and ensures the sustainable development of agricultural production. The researchers note that effective strategies for implementing biofertilisers can significantly improve yields while reducing environmental risks.

H. AbdElgawad *et al*. (2020) studied the effect of actinomycetes on improving soil quality and legume productivity. The researchers found that these microorganisms significantly increase the level of available nitrogen, which contributes to optimal nutrition of plants and an increase in the protein content in seeds. W. Elhaissoufi *et al*. (2022) focused on phosphate-soluble bacteria that increase the efficiency of phosphorus use by plants, which primarily improves yields. The researchers note that the increased availability of phosphorus stimulates the development of the root system and the overall productivity of crops. Previous studies confirm that the use of biologics and organic methods in soybean cultivation helps to increase yield and quality, improve soil composition and reduce environmental stress. The effectiveness of biologics is manifested in activating plant growth, improving stress resistance, and increasing the availability of essential nutrients such as nitrogen and phosphorus. Organic methods also contribute to the preservation of soil biological activity and ensure the stability of agroecosystems in the long term.

The purpose of this study was to investigate the effectiveness of the combined use of biologics Bioglobin and Rizohumin to increase the productivity and quality of soybeans in the agroclimatic conditions of the northern forest-steppe of Ukraine. The objectives of the study were: to determine the effect of combined use of Bioglobin and Rizohumin on soybean growth, development, and yield; to assess the effect of biologics on seed quality indicators, such as protein and oil content.

Materials and Methods

Study of the influence of biologics Bioglobin and Rizohumin on soybean productivity, which corresponded to the agroclimatic conditions of the northern forest-steppe of Ukraine characterised by a temperate continental climate with sufficient precipitation and favourable temperatures for growing legumes. The study was in line with the ethical standards set out in the Convention on Biological Diversity (1992) and the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973). Bioglobin is a biological preparation used in agriculture to stimulate plant growth and development. The main function of Bioglobin is to increase the resistance of plants to stressful conditions, improve productivity and crop quality. It belongs to the group of biostimulants that help to optimise the physiological processes of plants, such as photosynthesis, mineral nutrition, protein synthesis, and substances necessary for growth. Rizohumin is a biological preparation that stimulates the development of root nodules on the roots of legumes, such as soy, which helps to increase the efficiency of nitrogen fixation. The study area was located in a region where the average annual temperature is about 8-10°C, and the annual precipitation varies from 500 to 700 mm, which provides acceptable conditions for plant development. The long growing season under these conditions allowed investigating the effectiveness of growth stimulants, Bioglobin and Rizohumin, at different stages of soybean development.

Areas with typical chernozems of medium fertility for this zone, rich in humus and well-supplied with trace elements necessary for normal plant development were selected for the study. The soils had a good structure, which contributes to the development of the root system, and a high level of organic matter, which increases the water retention capacity. The soil pH was 6.5-7, which is optimal for legumes, since it ensures the effective activity of nitrogen-fixing bacteria. Climatic conditions during the study period were stable, with an average daily temperature of about 20°C

during the active growing season and moderate fluctuations in precipitation, which ensured uniform plant growth throughout the cycle. The study was conducted using several treatment options: a control group without adding drugs; a group with Bioglobin treatment in concentrations of 0.5 l/ha, 1 l/ha, and 1.5 l/ha; a group with Rizohumin in the same concentration; and a group where both drugs were used in concentrations of 0.5 l/ha, 1 l/ha, and 1.5 l/ha. Treatment of seeds and seedlings was carried out according to the instructions for the preparations, which ensured a uniform effect of each variant on all prototypes. Variants with Bioglobin were aimed at improving photosynthetic activity and overall plant growth, while variants with Rizohumin focused on stimulating nitrogen fixation, which is key to providing the crop with nitrogen without the additional use of chemical fertilisers.

Several basic parameters that were measured during the study were used to determine performance. The number of beans per plant was determined by counting all formed beans on each plant after the end of the growing season. The number of seeds in beans was measured by counting the average number of seeds for each bean, which allowed assessing the effectiveness of generative organ development under the influence of biologics. In addition, an important indicator of yield was the weight of 1,000 seeds, which was measured based on weighing a sample of seeds from each treatment option. This indicator allowed assessing not only the quantitative, but also the qualitative characteristics of the crop, since a larger seed mass indicates the best development of each seed sample.

To determine the nutritional value of the seeds, a protein and oil content analysis was performed for Bioglobin. In particular, Rizohumin focused on the impact on root nodule development and increased nitrogen fixation efficiency, which are key indicators for assessing the effectiveness of soybean application. With the combined use of Bioglobin and Rizohumin, the study focused on combining indicators that allow assessing the complex effect of both drugs. In this case, such indicators as the total number of beans per plant, the number of seeds per bean, the weight of 1,000 seeds, and the nutritional value of seeds (protein and oil content) were considered. These parameters are critical for determining product quality, as the high protein and oil content increases the economic value of soybeans, which is of great importance for the production of feed and food products.

The general approach to the study helped to comprehensively assess the effect of each biological product on all aspects of soybean productivity, which enabled a comparison of the effectiveness of Bioglobin and Rizohumin both separately and in combined use.

Results

The northern forest-steppe of Ukraine is characterised by various types of soils that have specific properties that affect the cultivation of soybeans. Among them, there are grey forest soils with a low humus content (1.5-3%), which have an average fertility and require additional fertilisation to maintain soybean productivity, and also have a limited ability to retain moisture, which becomes critical in dry periods. Leached chernozems are among the most fertile soils in the region due to their high humus content (3-6%), retain moisture well and provide plants with nutrients, so they are favourable for growing soybeans, although they need to maintain biological activity to preserve fertility. Podzolic chernozems with a humus content of 2-5% are less productive due to podzolisation processes, which reduce fertility and require organic fertilisers to restore the balance of nutrients (AgroStory, 2024). Meadow-chernozem soils that are formed in low-lying areas with high groundwater levels have good fertility and moisture capacity, but sometimes require regulation of the water regime due to possible waterlogging. Meadow soils formed in floodplains are rich in organic matter and moisture, but require drainage to grow soybeans, as excessive humidity can negatively affect growth.

Each of these soil types requires a special approach in agricultural technologies adapted to specific conditions. The use of biologics is becoming an effective tool for improving soil quality and soybean growing conditions in these diverse soil types. Biologics stimulate microbiological activity, improve soil structure, and increase the availability of nutrients, which is especially useful for soils with a low humus content or limited ability to retain moisture.

All indicators were studied in different dosage options of the drug. Studies have shown that the use of Bioglobin significantly improves key indicators of soybean productivity, including the number of beans per plant, seed weight, and protein and oil content in seeds. Table 1 provides detailed data on these indicators and shows the percentage increase for each dose of the drug. The main results of the effect of Bioglobin on these parameters are shown in Table 1.

Table 1. *Effect of Bioglobin on soybean growth and productivity*

Indicator	Control	Bioglobin (0.5 l/ha)	Bioglobin (1 l/ha)	Bioglobin (1.5 l/ha)
Number of beans per plant	24	30	34	32
Seed weight, g/plant	12.5	14.8	16.5	15.7
Protein content in seeds, %	32	34.5	35.7	35
Oil content in seeds, %	18	19	19.5	19.2
Increase in the number of beans, %	-	25	41.7	33.3
Increase in seed weight, %	-	18.4	32	25.6
Increase in protein content, %	-	7.8	11.6	9.4
Increase in oil content, %	-	5.6	8.3	6.7

Source: compiled by the author

Analysis of the table shows that at a dosage of Bioglobin of 1 l/ha, the maximum positive effect on all productivity indicators was observed. The number of beans per plant at this dosage increased by 41.7% compared to the control, reaching 34 beans per plant. This indicates a significant increase in the efficiency of photosynthetic processes and nutrient absorption, which contributed to more active plant development.

Seed weight, which is an important indicator of overall yield, also increased significantly when using Bioglobin. The highest rate – 16.5 g per plant – was achieved at a dosage of 1 l/ha, which is 32% more compared to the control option. This suggests that Bioglobin effectively stimulates the metabolic processes of plants, which leads to improved growth and greater accumulation of biomass in seeds.

The protein content, as one of the most important indicators of soy quality, also increased when using the drug. The control group had a protein content of 32%, while Bioglobin at a dose of 1 l/ha increased this figure to 35.7%, which is 11.6% more. This increase in protein is conditioned by the activation of nitrogen fixation, which helps to improve the absorption of nitrogen, which is necessary for protein synthesis in plants. The oil content of seeds has also undergone positive changes due to the use of Bioglobin. The highest oil content – 19.5% – was observed at a dose of 1 l/ha, which is 8.3% more compared to the control.

A general analysis of the data shows that the optimal dose of Bioglobin for achieving the highest soybean productivity is 1 l/ha. This dose provides the best results in all indicators, including the number of beans, seed weight, and protein and oil content, which increases both yield and seed quality. The use of Bioglobin is an effective method for increasing soybean productivity, making this drug profitable and promising for use in the conditions of the northern forest-steppe of Ukraine.

Nitrogen fixation is a key process for plants, as it allows them to obtain nitrogen in a form

suitable for assimilation. Nitrogen is one of the most important elements for plant growth and development, as it is a part of proteins, nucleic acids, and chlorophyll. Efficient nitrogen fixation improves nitrogen uptake from the air, reducing the need for chemical fertilisers, making the growing process more environmentally friendly and cost-effective (Komok & Pirig, 2014; Didur & Tsyhanskyi, 2023).

The use of Rizohumin led to a significant increase in the number and activity of root nodules. In control plants, an average of 10-12 nodules per plant were observed, while in plants treated with Rizohumin, the number of nodules increased to 18-25, depending on the dosage of the drug. Nodules formed under the influence of Rizohumin had a larger diameter and a denser structure, which is an indicator of high activity of the nitrogen fixation process. Observations showed that the optimal dosage of Rizohumin for the development of nodules is 1 l/ha, at which the number of nodules on the roots was the highest (Table 2).

Table 2. *Effect of Rizohumin on root nodule development and nitrogen fixation efficiency in soybeans*

Indicator	Control	Rizohumin (0.5 l/ha)	Rizohumin (1 l/ha)	Rizohumin (1.5 l/ha)
Number of nodules, units/plant	11	18	25	23
Average nodule diameter, mm	1.2	1.5	1.8	1.6
Nitrogen content in tissues, %	2.3	2.7	3.1	3
Leaf mass gain, %	-	15	25	20
Chlorophyll content, mg/g	1.8	2	2.3	2.2
Efficiency of nitrogen fixation, %	-	+20	+40	+35

Source: compiled by the author

Along with an increase in the number of nodules, an improvement in nitrogen-fixing activity was also observed. Plants treated with Rizohumin had significantly higher levels of available nitrogen in their tissues compared to the control group. This is conditioned by the activation of symbiotic bacteria, such as Rhizobium, which multiply in nodules and convert atmospheric nitrogen into forms suitable for assimilation by the plant. An increase in the amount of nitrogen in plants contributed to more intensive growth of the aboveground part, in particular, the development of leaf mass, which improved the process of photosynthesis. It also contributed to increased plant productivity and higher yields, as plants had access to more nitrogen, which is necessary for the synthesis of proteins and other important components.

It was also noted that plants treated with Rizohumin showed higher resistance to stressful conditions, such as drought and nitrogen deficiency in the soil. Due to effective nitrogen fixation, plants could provide nitrogen even under adverse conditions. This is especially important for growing soybeans in regions with variable climates and uneven supply of nutrients to the soil.

The use of Rizohumin also reduced the use of chemical nitrogen fertilisers in experimental sites. This has led to lower fertiliser costs and reduced the negative impact on the environment. The study showed that under conditions of adequate use of Rizohumin, optimal nitrogen fixation indicators can be achieved, which provides plants with the necessary nitrogen without additional sources. This is a cost-effective solution for farmers, as it allows reducing the cost of mineral fertilisers and maintaining high yields.

Table 3 shows the effect of Bioglobin and Rizohumin on key indicators of soybean growth and productivity at different stages of its development, and the results of combined use of both drugs.

Table 3. *Comparative analysis of the effect of Bioglobin and Rizohumin on soybean productivity in different growth phases*

Growth phase	Indicators	Control	Bioglobin (0.5 l/ha)	Bioglobin (1 l/ha)	Bioglobin (1.5 l/ha)	Rizohumin (0.5 l/ha)	Rizohumin (1.0 l/ha)
Germination	Leaf surface, cm^2/plant	250	280	300	310	260	255
	Number of nodules, units	4	4.5	5	5.5	6	7
Root system development	Number of nodules, units	10	10.5	11	11.5	16	17
	Nitrogen content, %	1.8	1.9	2.0	2.1	2.4	2.6
Budding and flowering	Protein content in tissues, %	28	29	30	31	32	33
	Number of flowers, units	15	16	18	19	16	17
Bean development	Number of beans, units/ plant	18	20	22	24	21	23
	Average weight of 1,000 seeds, g	150	155	160	165	158	162
Filling and ripening of beans	Nitrogen content in seeds, %	2.2	2.3	2.5	2.6	2.7	2.8
	Yield, t/ha	2.5	2.6	2.8	3	2.9	3

Growth phase	Indicators	Control	Rizohumin (1.5 l/ha)	Bioglobin + Rizohumin (0.5 l/ha)	Bioglobin + Rizohumin (1 l/ha)	Bioglobin + Rizohumin (1.5 l/ha)
Germination	Leaf surface, cm^2/plant	250	270	300	320	330
	Number of nodules, units	4	7.5	8	9	9.5
Root system development	Number of nodules, units	10	18	18	20	21
	Nitrogen content, %	1.8	2.7	2.7	2.8	2.9
Budding and flowering	Protein content in tissues, %	28	33	34	35	36
	Number of flowers, units	15	18	19	20	21
Bean development	Number of beans, units/ plant	18	24	24	25	26
	Average weight of 1,000 seeds, g	150	165	168	170	172
Filling and ripening of beans	Nitrogen content in seeds, %	2.2	2.9	2.9	3	3.1
	Yield, t/ha	2.5	3.2	3.2	3.3	3.4

Source: compiled by the author

In the germination phase, it was recorded that Bioglobin contributes to an increase in the leaf surface, which has increased from 250 cm^2 in the control group up to 300 cm^2. Rizohumin at this stage had a minimal effect on the leaf surface (255 cm^2), but affected the number of root nodules, increasing their number to 7, while in the control it was only 4. The combined use of Bioglobin and

Rizohumin showed the highest results, reaching 320 cm^2 of leaf surface and 9 root nodules.

In the phase of active root system development, Rizohumin demonstrated its greatest effectiveness, ensuring the formation of 17 nodules, which is 70% more than in the control group. Bioglobin also improved this indicator (11 nodules), but the effectiveness at this stage was inferior to Rizohumin. The combination of both drugs reached the highest rate – 20 nodules per plant and an increase in nitrogen content in tissues up to 2.8%, which is 55.6% more compared to the control.

During budding and flowering, both drugs showed a positive effect on the protein content and number of flowers. Bioglobin increased the number of flowers by 3 units (up to 18), and Rizohumin increased this indicator to 17 flowers, which also had a positive effect on yield. However, the combination of drugs showed the maximum number of flowers – 20 units, and the highest protein content in tissues (35%), which is 25% more than in the control group. In the bean development phase, the effect of Rizohumin on nitrogen fixation contributed to the appearance of more beans (23 units), which was slightly higher than in plants treated with Bioglobin alone (22 units). The combined use of drugs provided the maximum number of beans – 25 units per plant, and the largest weight of 1,000 seeds, which was 170 g, which is 13.3% more compared to the control.

At the stage of filling and ripening of beans, the combined use of Bioglobin and Rizohumin gave the best result: the nitrogen content in seeds reached 3.0%, which is an important indicator for the final quality of seeds. This provided a yield of 3.3 t/ha, which is 32% higher than in the control group. Bioglobin and Rizohumin used separately also increased yields, reaching 2.8 t/ha and 3.0 t/ha, respectively, but did not exceed the result of combined use.

The general analysis of Table 3 confirms that the combined use of Bioglobin and Rizohumin provides a synergistic effect in all phases of soybean growth, increasing its productivity at all levels – from the development of the root system and leaf surface to the formation of more beans and increased yield.

One of the most important indicators that characterise the quality of the crop is the average number of seeds in a bean. Since seed development directly affects the productivity and market value of the crop, it is important to consider the effect of these drugs on this indicator (Murach *et al.*, 2020; Berdin *et al.*, 2024). Figure 1 shows the effect of Bioglobin, Rizohumin, and their combination on seed development in beans. This helped to assess how effective these drugs are in improving crop quality, which is important for increasing yields and economic benefits when growing soybeans.

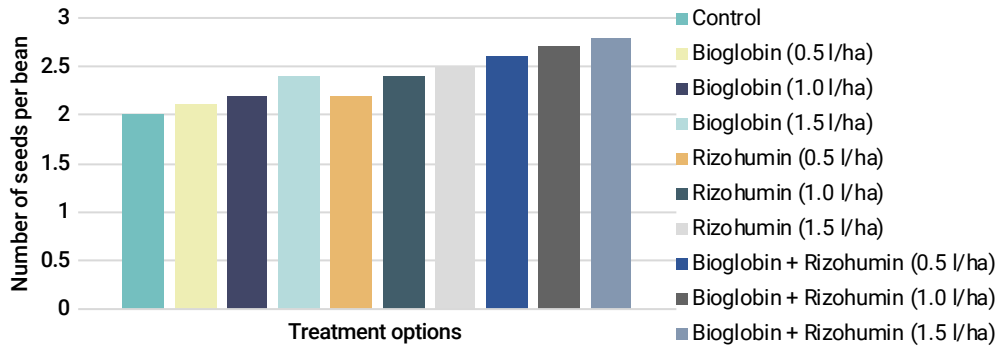

Figure 1. *Influence of biologics on the development of the number of seeds in beans in soybean plants*

Source: compiled by the author

The Figure 1 shows that the use of Bioglobin and Rizohumin significantly improves seed development in soybean beans. In the control group that was not treated with biologics, the average number of seeds per bean was only 2. The introduction of Bioglobin led to a noticeable increase in this indicator to 2.3 seeds per bean, which indicates the stimulating effect of the drug on seed development and overall productivity. The use of Rizohumin showed even greater effectiveness, increasing the average number of seeds to 2.4, which may be due to its effect on nitrogen fixation and providing the plant with available nitrogen, critical for seed development.

The combined use of both drugs – Bioglobin and Rizohumin – gave the greatest result, providing an average number of seeds in the bean at the level of 2.6. This confirms the synergistic effect of drugs, when the combined effect significantly exceeds the effect of each individual (Chaika *et al.*, 2023; Krutilo & Volkohon, 2024). This effect creates optimal conditions for the development of more seeds, which as a result has a positive effect on the yield of soybeans.

In general, the use of biologics, especially in combination, significantly increases the efficiency of seed development in soybean beans, which is an important factor for increasing the overall yield of the crop. The results obtained indicate the high efficiency of biological stimulants that can be recommended for use in agricultural production to increase the productivity and quality of the soybean crop, and to reduce dependence on chemical fertilisers.

Discussion

The results obtained demonstrate significant advantages of using microbial inoculants in increasing the productivity of crops, in particular soybeans, in modern agricultural production. These data indicate an annual increase in yield by 15-20% due to active nitrogen fixation, which reduces the need for chemical fertilisers and contributes to an increase in the biological activity of the soil. It was also found that the use of inoculants in combination with organic approaches provides long-term maintenance of soil fertility by reducing erosion and improving water retention properties. This is significantly different from conventional approaches based on chemical fertilisers, which can negatively affect the ecosystem (Fedoruk, 2021).

The results of this study confirm the effectiveness of inoculants, but they differ from the data obtained by L. Liu *et al.* (2022), who focused on fermented soy products and their biological activities. L. Liu *et al.* (2022) investigated the effect of traditional fermentation processes on the nutritional value and biological activity of soybean products, while this study is more focused on the agronomic aspect – the effect of inoculants on soil yield and environmental indicators. This suggests that this approach is more environmentally oriented and aimed at the sustainable development of agricultural systems.

A.A. Tammam *et al.* (2023) focused on vermicompost to reduce salt stress and improved nutrient absorption, which helped plants under stressful conditions. However, this study does not cover the productivity of a particular crop or the impact on yield. Unlike A.A. Tammam *et al.* (2023), this study directly concerns soybeans and shows that the use of biologics Bioglobin and Rizohumin improves yields by 25-30% and increases the protein and oil content in seeds. These results also show that these biologics reduce the need for chemical fertilisers, while maintaining the ecological stability of the soil. This makes this study more valuable for the agricultural sector due to its direct impact on soybean productivity in specific agroclimatic conditions.

Regarding the physiological processes associated with seed formation, the results of this study coincide with the conclusions of J.T. Vogel *et al.* (2021), which emphasise the importance of stimulating photosynthetic processes to increase yields. However, this study goes further, proving that the combination of Bioglobin and Rizohumin provides more intensive seed development in beans, which has been confirmed at different

stages of growth. This combined approach contributes to a synergistic effect on soybean growth and development, which was less emphasised in the study by J.T. Vogel *et al*. (2021). The results obtained for increasing the number of seeds in the bean are also consistent with the results of J.-S. Cai *et al*. (2021), who investigated the benefits of various biological methods for improving the nutritional value of soybeans. This study demonstrated that the use of Bioglobin and Rizohumin not only increases the number of seeds, but also increases the content of protein and other nutrients. This allows obtaining high-quality products, which is an additional advantage of the authors' approach in comparison with the study by J.-S. Cai *et al*. (2021).

The results of this study show a significant increase in soybean productivity due to the use of biologics Bioglobin and Rizohumin, especially when used in combination. Both drugs have a positive effect on the development of root nodules and overall yield, but the combined action has a synergistic effect, which improves the results compared to previous studies. To better understand the effectiveness of the authors' approach, it is useful to compare it with previous studies that used other methods to increase soybean yields, such as fertiliser treatment and the use of growth stimulants.

The data obtained indicate a significant increase in the number of root nodules and an increase in the level of nitrogen fixation in soybean plants treated with Rizohumin. These results are consistent with the conclusions drawn in the study by M.A. Khan *et al*. (2021), which also notes an improvement in soybean productivity under the influence of beneficial bacteria. However, this study is more complex, since not only activated symbiotic bacteria, but also additionally used Bioglobin to stimulate photosynthetic activity, which helped to achieve higher yield indicators. The combined use of both drugs provided improvements in photosynthesis and nitrogen nutrition, which was less discussed in detail by M.A. Khan *et al*. (2021).

For example, in the study P. Tripathi *et al*. (2021) examined the effect of silicon fertilisers on nodule formation and soybean yield. The researchers emphasise that silicon fertilisers stimulate the development of nodules and increase the efficiency of nitrogen fixation, which has a positive effect on yield. However, in this study, the use of Rizohumin was found to be more effective in stimulating nodules due to its direct effect on the activity of Rhizobium bacteria. In addition, the additional use of Bioglobin contributed to an increase in the photosynthetic activity of plants, which was not achieved with silicon fertilisers in the study by P. Tripathi *et al*. (2021). This suggests that the authors' approach provides better comprehensive stimulation of soybean growth.

I.B. Laskar *et al*. (2020) paid attention to the efficiency of soybean oil transesterification for biodiesel production using bio-waste as a catalyst. Although this study is not directly related to soybean cultivation, the results highlight the importance of optimising processes that contribute to improving the profitability of soybean production. This study focuses on increasing the yield and quality of soybean seeds, which can have a positive impact on the economic feasibility of biodiesel production, since increasing the number of seeds and increasing the protein and oil content of seeds contribute to improving the final quality of products for processing.

G.Y. Rahimova (2023) focused on the agrobiological properties of bentonite and its impact on crop growth. The use of bentonite improves the structure of the soil and provides better conditions for the development of the root system. However, this study focused on the effects of biologics, such as Rizohumin, which not only promote the development of the root system, but also provide a direct increase in the number of nodules responsible for nitrogen fixation. Unlike bentonite, Rizohumin provides the plant with nitrogen, which reduces the need for external nitrogen fertilisers and increases nutritional efficiency. The combined use of Rizohumin and Bioglobin in this study allows for higher yields without the

need for additional soil additives such as bentonite, making this method more cost-effective and environmentally friendly.

The study by N.E. Korres *et al*. (2020) examined the impact of soybean crop density and emergence time of *Amaranthus palmeri* on weed biology, soybean yield, and economic profitability. The researchers emphasise that the high density of soybean crops can significantly reduce the competitiveness of weeds, such as *Amaranthus palmeri*, which is one of the most aggressive weeds in the United States. This study showed that regulating crop density can be an effective means of reducing the number of weeds and minimising crop losses. However, while this increase in crop density can reduce the negative impact of weeds, its effectiveness depends on the growing conditions and time of weed emergence. In comparison with the results of this study, where biologics were used to increase soybean productivity, the paper by N.E. Korres *et al*. (2020) shows an alternative approach to crop optimisation through agronomic practices. This study complements the conclusions of N.E. Korres *et al*. (2020), showing that the use of biologics can also help in weed control, since a healthy and powerful plant that is actively developing due to the use of Bioglobin and Rizohumin has a better competitive ability against weeds. In addition, biologics increase the resistance of soybeans to stressful conditions, creating favourable conditions for high yields even in the presence of weeds. This highlights the added benefit of this approach, which not only provides a direct increase in yields, but also helps to reduce the need for mechanical and chemical weed control, which can have a positive economic and environmental impact.

B. Guo *et al*. (2022) focused on soy's genetic resources that contribute to sustainable protein production. The researchers emphasise the importance of genetic diversity in improving soybean productivity, in particular, in adapting to climate change, increasing disease resistance, and improving protein quality. B. Guo *et al*. also noted that genetic resources can help solve problems with reducing the nitrogen content in the soil and adapting plants to changing growing conditions. This study is particularly useful for long-term planning of soy protein production, as it shows that the use of genetic resources can increase soy's resistance to various stresses. The use of biologics Bioglobin and Rizohumin in this experiment showed that biological stimulants can significantly increase the resistance of soybeans to stress and improve its performance in difficult conditions. In contrast to the genetic approach by B. Guo *et al*. (2022), this method achieves faster results without the need for long-term breeding and genetic testing processes. In addition, the use of biologics can increase the content of protein and other nutrients in seeds, which is useful for the food industry, similar to B. Guo *et al*. (2022), who proposed to improve the protein content through genetic modifications.

Unlike agronomic practices and genetic modifications, this method demonstrates effectiveness in increasing the yield and quality of soybeans by stimulating photosynthesis and nitrogen fixation, creating a synergistic effect. This provides stable results regardless of growing conditions, reducing the need for chemical fertilisers and weed control, which makes this approach cost-effective and environmentally friendly.

Conclusions

The study showed that Bioglobin and Rizohumin have a significant positive effect on soy productivity, especially when used in combination. Bioglobin, as a growth stimulator, increases photosynthetic activity, leaf mass and total plant biomass, which contributes to the active development of plants in the early stages of vegetation. This ensures rapid accumulation of energy necessary for the development of generative organs, and improves productivity by increasing the number and weight of seeds. Rizohumin, in turn, actively stimulates the development of root nodules, which provides effective nitrogen fixation. This allows plants to use nitrogen from the air, reducing the need for chemical fertilisers, which

reduces costs and improves the environmental friendliness of cultivation.

For farmers working in the northern forest-steppe of Ukraine, it is recommended to use Bioglobin at a dose of 1.0 l/ha in the early stages of soybean development, which will ensure active growth and strengthening of plants. Rizohumin should also be used in the early stages, but the main effect of the drug is manifested in the phase of nodule formation and subsequent nitrogen nutrition. The combined use of both drugs allows achieving the best results, since it provides the plant with both energy support and the necessary nitrogen throughout the growing season. This approach improves the yield and quality of seeds, which makes it an effective and cost-effective method for agricultural producers in this region.

Further research may focus on optimising dosages and developing comprehensive schemes for using different biologics for different soybean varieties and growing conditions. Because different varieties may respond differently to biological stimulants, future research will help to identify more specific recommendations for each variety and region. In addition, a promising area is to study the effects of these drugs in combination with other organic methods, such as mulching or bioinoculants, which can increase effectiveness. Studying the long-term effects of biologics on soil quality and microbiota can also provide useful results for the development of sustainable agricultural technologies.

One of the limitations of the study is that it was conducted in specific agroclimatic conditions of the northern forest-steppe of Ukraine, which may limit the generalisation of results for other regions with different climatic conditions. In addition, the study covered only certain doses of Bioglobin and Rizohumin, so additional experiments with different concentrations and application schemes may be required to optimise the use.

In general, the results of the study confirm the effectiveness of Bioglobin and Rizohumin as stimulants that not only increase soybean productivity, but also reduce dependence on chemical fertilisers, which is a significant advantage for modern agriculture.

Acknowledgements

None.

Conflict of Interest

None.

References

[1] AbdElgawad, H., Abuelsoud, W., Madany, M.M., Selim, S., Zinta, G., Mousa, A.S., & Hozzein, W.N. (2020). Actinomycetes enrich soil rhizosphere and improve seed quality as well as productivity of legumes by boosting nitrogen availability and metabolism. *Biomolecules*, 10(12), article number 1675. doi: 10.3390/biom10121675.

[2] AgroStory. (2024). *Main soil types in Ukraine and their characteristics*. Retrieved from https://agrostory.com/uk/info-centr/agronomist/osnovnye-tipy-pochv-ukrainy-i-ikh-kharakteristika-2/.

[3] Berdin, S.I., Murach, O.M., Zubko, O.M., & Kriuchko, L.V. (2024). Dynamics of the formation of generative organs of the soybean plant under the influence of preparation for seed pre-sowing treatment. *Tavrian Scientific Bulletin*, 137, 28-34. doi: 10.32782/2226-0099.2024.137.4.

[4] Bhunia, S., Bhowmik, A., Mallick, R., & Mukherjee, J. (2021). Agronomic efficiency of animal-derived organic fertilizers and their effects on biology and fertility of soil: A review. *Agronomy*, 11(5), article number 823. doi: 10.3390/agronomy11050823.

[5] Cai, J.-S., Feng, J.-Y., Ni, Z.-J., Ma, R.-H., Thakur, K., Wang, S., Hu, F., Zhang, J.-G., & Wei, Z.-J. (2021). An update on the nutritional, functional, sensory characteristics of soy products, and applications of new processing strategies. *Trends in Food Science & Technology*, 112, 676-689. doi: 10.1016/j.tifs.2021.04.039.

[6] Chaika, T.O., Liashenko, V.V., & Khomenko, B.S. (2023). The impact of seed inoculation on soybean yield under organic cultivation technology. *Tavrian Scientific Bulletin*, 133, 180-187. doi: 10.32782/2226-0099.2023.133.24.

[7] Convention on Biological Diversity. (1992). Retrieved from https://www.absfocalpoint.nl/en/show-10/convention-on-biological-diversity-2.htm.

[8] Convention on the Trade in Endangered Species of Wild Fauna and Flora. (1973). Retrieved from https://cites.org/eng/disc/text.php.

[9] Didur, I.M., & Tsyhanskyi, V. (2023). Formation of the photosynthetic productivity of soybean crops under a biologized food system. *Agriculture and Forestry*, 30(3), 44-56. doi: 10.37128/2707-5826-2023-3-4.

[10] Elhaissoufi, W., Ghoulam, C., Barakat, A., Zeroual, Y., & Bargaz, A. (2022). Phosphate bacterial solubilization: a key rhizosphere driving force enabling higher P use efficiency and crop productivity. *Journal of Advanced Research*, 38, 13-28. doi: 10.1016/j.jare.2021.08.014.

[11] Elhalis, H., Chin, X.H., & Chow, Y. (2024). Soybean fermentation: Microbial ecology and starter culture technology. *Critical Reviews in Food Science and Nutrition*, 64(21), 7648-7670. doi: 10.1080/10408398.2023.2188951.

[12] Fedoruk, I.V. (2021). *Varietal productivity of soybean grain depending on seed inoculation and microfertiliser application in the western forest-steppe*. Kamianets-Podilskyi: Higher Educational Institution "Podillia State University".

[13] Ghoroghi, M., Estaji, S., Tayouri, M.I., Jahanmardi, R., Nobre, M.A., & Khonakdar, H.A. (2024). Investigation of physico-mechanical, thermal, morphological, and antibacterial effects of bio-based epoxidized soybean oil plasticizer on PLA-ZnO nanocomposites as flexible food packaging. *Arabian Journal of Chemistry*, 17(9), article number 105928. doi: 10.1016/j.arabjc.2024.105928.

[14] Guo, B., Sun, L., Jiang, S., Ren, H., Sun, R., Wei, Z., & Qiu, L.J. (2022). Soybean genetic resources contributing to sustainable protein production. *Theoretical and Applied Genetics*, 135(11), 4095-4121. doi: 10.1007/s00122-022-04222-9.

[15] Jat, G., Sharma, S.K., Meena, R.H., Choudhary, R., Choudhary, R.S., & Yadav, S.K. (2021). Studies on effect of zinc application on quality and yield of soybean (*Glycine max* L.) under typic haplustepts soil. *Indian Journal of Pure & Applied Biosciences*, 9(1), 188-193. doi: 10.18782/2582-2845.8511.

[16] Khan, M.A., Sahile, A.A., Jan, R., Asaf, S., Hamayun, M., Imran, M., & Lee, I.J. (2021). Halotolerant bacteria mitigate the effects of salinity stress on soybean growth by regulating secondary metabolites and molecular responses. *BMC Plant Biology*, 21, article number 176. doi: 10.1186/s12870-021-02937-3.

[17] Komok, M.S., & Pirig, O.V. (2014). *Biopreparation of complex action Rizogumin in modern technologies of legumes cultivation*. Retrieved from https://www.kdpu-nt.gov.ua/uk/content/biopreparat-kompleksnoyi-diyi-ryzogumin-u-suchasnyh-tehnologiyah-vyroshchuvannya-bobovyh.

[18] Korres, N.E., Norsworthy, J.K., Mauromoustakos, A., & Williams II, M.M. (2020). Soybean density and Palmer amaranth (*Amaranthus palmeri*) establishment time: Effects on weed biology, crop yield, and economic returns. *Weed Science*, 68(5), 467-475. doi: 10.1017/wsc.2020.41.

[19] Krutilo, D., & Volkohon, V. (2024). *Improved rhizohumine for soya*. Retrieved from https://a7d.com.ua/plants/39928-vdoskonaleniy-rizogumn-dlya-soyi.html.

[20] Laskar, I.B., Deshmukhya, T., Bhanja, P., Paul, B., Gupta, R., & Chatterjee, S. (2020). Transesterification of soybean oil at room temperature using biowaste as catalyst; an experimental investigation on the effect of co-solvent on biodiesel yield. *Renewable Energy*, 162, 98-111. doi: 10.1016/j.renene.2020.08.011.

[21] Liu, L., Chen, X., Hao, L., Zhang, G., Jin, Z., Li, C., Yang, Y., Rao, J., & Chen, B. (2022). Traditional fermented soybean products: Processing, flavor formation, nutritional and biological activities. *Critical Reviews in Food Science and Nutrition*, 62(7), 1971-1989. doi: 10.1080/10408398.2020.1848792.

[22] Murach, O., Onychko, V., & Berdin, S. (2020). Individual productivity of soybean plants under the action of microbial preparation and plant growth regulator. In *Proceedings of the 2nd international scientific and practical conference "Innovations and prospects of world science"* (pp. 23-29). Vancouver: Perfect Publishing.

[23] Orozco-Mosqueda, M.D., Flores, A., Rojas-Sánchez, B., Urtis-Flores, C.A., Morales-Cedeño, L.R., Valencia-Marin, M.F., Chávez-Avila, S., Rojas-Solis, D., & Santoyo, G. (2021). Plant growth-promoting bacteria as bioinoculants: attributes and challenges for sustainable crop improvement. *Agronomy*, 11(6), article number 1167. doi: 10.3390/agronomy11061167.

[24] Rahimova, G.Y. (2023). Agrobiological properties of bentonite in agriculture. *Gospodarka i Innowacje*, 40, 179-183.

[25] Raimi, A., Roopnarain, A., & Adeleke, R. (2021). Biofertilizer production in Africa: Current status, factors impeding adoption and strategies for success. *Scientific African*, 11, article number e00694. doi: 10.1016/j.sciaf.2021.e00694.

[26] Ramakrishnan, B., Maddela, N.R., Venkateswarlu, K., & Megharaj, M. (2021). Organic farming: Does it contribute to contaminant-free produce and ensure food safety? *Science of the Total Environment*, 769, article number 145079. doi: 10.1016/j.scitotenv.2021.145079.

[27] Suman, J., Rakshit, A., Ogireddy, S.D., Singh, S., Gupta, C., & Chandrakala, J. (2022). Microbiome as a key player in sustainable agriculture and human health. *Frontiers in Soil Science*, 2, article number 821589. doi: 10.3389/fsoil.2022.821589.

[28] Tammam, A.A., Rabei Abdel Moez Shehata, M., Pessarakli, M., & El-Aggan, W.H. (2023). Vermicompost and its role in alleviation of salt stress in plants – I. Impact of vermicompost on growth and nutrient uptake of salt-stressed plants. *Journal of Plant Nutrition*, 46(7), 1446-1457. doi: 10.1080/01904167.2022.2072741.

[29] Tripathi, P., Na, C.I., & Kim, Y. (2021). Effect of silicon fertilizer treatment on nodule formation and yield in soybean (*Glycine max* L.). *European Journal of Agronomy*, 122, article number 126172. doi: 10.1016/j.eja.2020.126172.

[30] Vogel, J.T., Liu, W., Olhoft, P., Crafts-Brandner, S.J., Pennycooke, J.C., & Christiansen, N. (2021). Soybean yield formation physiology – a foundation for precision breeding based improvement. *Frontiers in Plant Science*, 12, article number 719706. doi: 10.3389/fpls.2021.719706.

Вплив біопрепаратів на формування елементів продуктивності сої в умовах північного Лісостепу України

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Анотація. Метою роботи було визначити, наскільки ефективним є застосування цих біостимуляторів для покращення ростових процесів і підвищення врожайності сої в регіоні. Дослідження проводилися на чорноземних ґрунтах середньої родючості, оптимальних для вирощування бобових культур. Ділянки було поділено на чотири групи: контрольну, групу з внесенням біопрепарату Біоглобін, групу з Ризогуміном та групу з комбінованим застосуванням обох препаратів. Основними параметрами для оцінки ефективності препаратів були кількість бобів на рослину, кількість насіння у бобі, маса 1000 насінин, а також вміст білка та олії в насінні. Встановлено, що окреме застосування Біоглобіну покращує фотосинтетичну активність рослин, сприяючи інтенсивнішому росту та розвитку листкової маси, тоді як Ризогумін активно стимулює утворення кореневих бульбочок, підвищуючи ефективність азотфіксації та забезпечуючи рослину азотом. Комбіноване застосування Біоглобіну та Ризогуміну дало найкращі результати, значно підвищивши загальну врожайність та якість насіння сої. Синергічний ефект препаратів сприяв збільшенню маси 1000 насінин, кількості бобів на рослину та вмісту білка й олії у насінні. Це дозволило зробити висновок, що використання Біоглобіну та Ризогуміну в комплексі є ефективною стратегією для покращення продуктивності сої, знижуючи потребу в хімічних добривах та покращуючи екологічну стійкість агровиробництва. Отримані результати свідчать про значний потенціал біопрепаратів для підвищення врожайності сої в регіоні та є цінними для агровиробників, які прагнуть оптимізувати умови вирощування без додаткових витрат на мінеральні добрива

Ключові слова: азотфіксація; родючість; інокуляція; урожайність; живлення рослин