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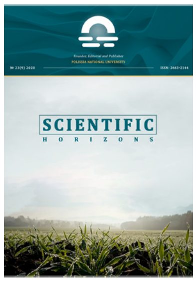

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Use of biologisation elements in the cultivation of grain and industrial crops to obtain high-quality products and preserve the environment

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Abstract. The study aimed to assess the effectiveness of introducing biologisation elements to increase crop yields and quality. An experiment was conducted to analyse the impact of biological and organic fertilisers, regulated irrigation and pesticide control on yields, product quality, soil nutrient content, CO_2 emissions and biodiversity. The results demonstrated that the use of biological fertilisers (biological products, composts, and humates) positively impacted the yield of all the crops studied. In

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variant 2, where varieties of wheat, corn, hemp and sunflower were used with biological fertilisers, an increase in yields of 12-20% was observed, depending on the crop. Organic fertilisers in variant 3 also showed an increase in yields, although to a lesser extent (8-15%). Regulated irrigation and pesticide control in variant 4 provided a stable yield increase of 10-12%, while combined fertilisation and irrigation in variant 5 gave the best results, albeit with smaller increases. The introduction of biological fertilisers also positively affected product quality. The oil content of soybean and sunflower in the plots with biological fertilisers was also higher compared to control variant 1. Analysis of the soil's nutrient content showed that the biological fertiliser increased the levels of nitrogen, phosphorus and potassium in the soil. CO_2 emissions decreased by 10-15% in areas with biological fertilisers, indicating a positive environmental effect of using such technologies. Biodiversity has also improved, with a 40% increase in the biodiversity index in the biological fertiliser plot. Thus, the results of the study confirm that the integration of biological and organic fertilisers, as well as effective water and pesticide management, can significantly increase crop yields and quality, reduce CO_2 emissions and contribute to biodiversity conservation

Keywords: crops; elements of technology; biological methods in crop production; ecology; plant yield and quality

INTRODUCTION

Grain and industrial crop production is a critical component of the agricultural sector, as it directly affects food security and economic development. However, traditional agronomic practices, such as the intensive use of chemical fertilisers and pesticides, are often accompanied by serious environmental problems. These include soil degradation, water pollution from runoff and pesticide residues, and loss of biodiversity due to the disturbance of natural ecosystems. To overcome these negative consequences and ensure sustainable development of the agricultural sector, the biologisation of agronomic processes is emerging as a promising approach. Biologisation involves the introduction of natural components and technologies, such as organic fertilisers, biostimulants, inoculants, and ecological soil cultivation methods. This approach aims to increase the efficiency of crop cultivation, improving soil quality and reducing the negative impact on the environment, thus contributing to the sustainable development of agriculture.

The analysis of scientific sources shows that the issue of biologisation in agronomy has been considered from various aspects. L.M. Potashova (2024) analysed innovative technologies in crop production, particularly biologisation methods, focusing on general aspects without specialising in specific crops, which provided a general overview of modern technologies but did not delve into specific aspects related to individual crops. The impact of deficit irrigation and iron fertilisation on soybeans in dry climates was studied by V. El Amine *et al.* (2024), which could be a part of agronomic biologisation practices. Z. Liu *et al.* (2024) studied the effect of no-till and organic fertilisation on kiwi productivity, which defined the effects of biological methods on different crops. E. Semenchenko (2024) analysed the dynamics of the main nutrients in the soil, which is important for assessing the effectiveness of biologisation. O. Ergasheva *et al.* (2024) assessed the impact of fertilisers on the yield and quality of barley and potatoes, which revealed the effects of different types of fertilisers. C. Pacheco *et al.* (2023) studied the impact of mineral and organic fertilisers on maize yield and soil carbon balance, which is also part of biologisation.

L. Wegner (2022) studied modern aspects of root energy that may affect the application of biological methods. In turn, M. Allam *et al.* (2022) conducted a meta-analysis of the impact of organic and mineral fertilisers on soil organic carbon and productivity. The biologisation of agriculture, as a way to increase economic efficiency was considered by S. Skok and V. Almashova (2023) and O. Costa *et al.* (2024), who studied the effect of biostimulants on plant growth and soil microbiome, which can be applied to biologisation technologies. Y. Li *et al.* (2024) analysed the dynamics of phosphorus fixation and mobilisation in agroecosystems, which is important for nutrition management in the context of biologisation. Notably, most studies focus on individual crops or types of fertilisers, leaving the integration of biological approaches in the integrated cultivation of different crops underdeveloped. Assessm ent of their environmental effects has also received insufficient attention. This creates a gap in understanding how biological methods can be effectively integrated into different agronomic systems and what their long-term effects are on ecosystems and economies.

Thus, the research problem is the need to assess the impact of the biologisation of agronomic practices on the cultivation of various crops in the Ukrainian agricultural climate. This includes an analysis of the effectiveness of the plant varieties under study in combination with biological and organic fertilisers and regulated irrigation. It is also necessary to analyse the impact of these elements of technology on environmental conditions. In this context, the study aimed to comprehensively assess the impact of biological and agronomic practices on the yield and quality of wheat, corn, soybeans and sunflower, as well as their impact on the environment. In particular, the effectiveness of the varieties and fertilisers under study was analysed, as well as their integration with modern elements of technology, such as controlled irrigation and pesticide control. The study hypothesises that the use of biological fertilisers and new agricultural-technological techniques can significantly increase yields and product quality while reducing the negative impact on the environment.

MATERIALS AND METHODS

The study was conducted from March 2022 to October 2024 at the Educational and Research Centre of Mykolaiv National Agrarian University. For the experiment, the crops presented in Table 1 were selected.

***Table 1**. Plant varieties used in the study*

Crop	Variety	Year	Country
Wheat	Odesa duma	2017	Ukraine
Corn	DM Victoria	2016	Ukraine
Hemp	Gliana	2007	France
Sunflower	Agent	2018	Ukraine

***Source:** compiled by the author based on the Ministry of Agrarian Policy and Food of Ukraine (2025)*

The equipment used for soil cultivation and fertilisation included John Deere tractors (USA), Horsch cultivators (Germany) and Amazone fertiliser spreaders (Germany). Measuring instruments included Fluke pyrometers (USA), Hanna Instruments pH meters (Italy) and Bosch moisture meters (Germany). The research methodology was based on a controlled experiment that included three experimental groups and a control group. The results of biological fertilisers were compared with traditional chemical fertilisers. Soil and crop samples were collected from each plot to analyse nutrient content, moisture levels and contamination. A formula was used to calculate the yield to assess the effectiveness:

$$Y = (W/A) \times 1000, \quad (1)$$

where Y – yield (t/ha); W – total yield weight (kg); A – plot area (ha).

Results were analysed using ANOVA to determine the statistical significance of differences between groups. Methods used included standard soil analysis techniques such as sampling, pH and organic matter determination (State Standard of Ukraine No. ISO 10390:2007, 2007). The environmental impacts were assessed using developed monitoring tools, including CO_2 emissions and biodiversity impacts.

The weather conditions during the experiment were characterised by the following trends: after sowing wheat in September and October, temperatures remained moderate, with average values ranging from 10°C to 18°C, which contributed to friendly germination. The autumn was rainy, which provided sufficient soil moisture for the development of the plant root system. However, in November, temperatures began to drop, marking the beginning of winter dormancy. The winter months were characterised by moderately cold weather. Average temperatures ranged from -2°C to 4°C, with periods of snow cover that protected the plants from frost. However, on some days the temperature dropped below -5°C, which could have affected plant survival. Overall, the wintering was satisfactory, and the plants remained viable until spring. In April, temperatures started to rise gradually, which helped winter wheat to emerge. The average temperature in this month ranged between 8°C and 15°C. Rains and temperature fluctuations affected the initial stage of crop growth. In May, temperatures continued to rise, with average values ranging from 14°C to 22°C. May had more stable weather conditions, which favoured active plant growth. The average temperature in June ranged from 18°C to 27°C. It was a period of active growth and development of crops, but there were also periods of extreme heat and insufficient moisture, which affected yields. In July, temperatures reached peak levels, with average temperatures ranging from 35°C to 38°C, and there was virtually no precipitation. Temperatures in August remained hot, with average temperatures ranging from 30°C to 35°C. August was marked by hot days and low humidity, which had a negative impact on the ripening phase of crops. In September, temperatures dropped, with average temperatures ranging from 15°C to 24°C. September was an important month for harvesting and was characterised by stable weather conditions.

Crop cultivation practices were generally accepted for the conditions in southern Ukraine, except for the factors under study. The study was conducted using several crops, including winter wheat, corn, hemp, and sunflower. Winter wheat is represented by the Odesa duma variety, corn by DM Victoria, sunflower by Agent, and hemp by Gliana. Several options were proposed to assess the impact of nutrition on yield and product quality. Variant 1 is a control, where no fertilisers or preparations are used. Option 2 used biological fertilisers: BioGrow compost (5 t/ha), Agrorhiz humates (10 litres/ha) and Soil Health bacteria (1 litre/ha). Option 3 involved the use of EcoTon organic fertiliser (8 t/ha). Option 4 included the use of pesticides: Fundazol fungicide (1.5 litres/ha), Actellik insecticide (0.5 litres/ha), Bactofit fungicide (2 litres/ha) and Intarsit biological pesticide (0.8 litres/ha). Option 5: combined application of organic and mineral fertilisers (State Standard of Ukraine No. 4884:2007, 2007).

The study also assessed the effectiveness of pesticides and biological plant protection products on Option 4. This demonstrated how these measures affect crop productivity. Two irrigation backgrounds were selected for the study: no irrigation and irrigation, which was used to analyse the impact of water resources on crop yields and quality. Each variant was analysed for yield and product quality. The number of fertilisers, preparations and water applied was determined separately to assess the impact of each factor on crop yields under different moisture conditions. The control plot was represented by the tested varieties without the use of additional agrotechnological techniques (Option 1). This ensured the principle of a single logical difference for comparing the results with other variants of the study. The results of the experimental variants were compared with the control variants to assess the effectiveness of the applied technology elements and determine their impact on productivity and quality. The study also involved regulatory documents governing the use of biological fertilisers, namely: Law of Ukraine No. 1264-XII (1991), Law of Ukraine No. 2775-IX (2022). The study complied with the standards of the Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1979). The study used an integrated approach, which demonstrated the use of biological elements in the cultivation of grain and industrial crops.

RESULTS

The use of biologisation elements is an important area for increasing crop yields. The introduction of biological fertilisers and new agronomic approaches in the study demonstrated different levels of impact on yields depending on the methods used. In variant 2, varieties of wheat, corn, hemp, and sunflower were applied together with biological fertilisers. The results demonstrated that for wheat, the introduction of biological fertilisers improved soil structure and contributed to better access to nutrients for plants. In the maize plot, biological fertilisers, especially bacteria for growth stimulation, had a positive impact on root development and increased water and nutrient uptake. In the case of hemp, the introduction of biological fertilisers increased yields by 16%, and in sunflowers, it had a positive impact on the formation of large and high-quality seeds. Varieties combined with organic fertilisers were used in variant 3. The use of organic fertilisers improved soil structure and provided additional nutrients, leading to a 9% increase in wheat yields compared to the control plots.

Organic fertilisers improved the water-holding capacity of the soil in the maize plot, which had a positive impact on plant development. It also improved the availability of nitrogen for soybeans, which helped to increase yields by 10%. Organic fertilisers contributed to better sunflower development and improved seed quality. The pesticide treatment was controlled in variant 4. Regulated irrigation provided an optimal level of soil moisture, which contributed to the stable growth of winter wheat. Pesticide control reduced corn yield losses due to diseases and pests. Hemp and sunflower increased yields due to optimal water management and pest control. In variant 5, winter wheat varieties "Odesa duma", maize "DM Victoria", hemp "Gliana", and sunflower "Agent" were grown with a combination of organic and mineral fertilisers, as well as irrigation control. Combined fertilisation and irrigation provided the best conditions for the growth and development of all the crops under study. The introduction of biologisation elements, such as biological and organic fertilisers, regulated irrigation and pesticide control, has had a positive impact on crop yields. Each of the approaches proved to be effective in increasing productivity, but the most significant effect was achieved in the variant with combined fertilisation and irrigation (Table 2). This confirms that the integration of different elements of technology is the key to increasing yields and product quality.

***Table 2**. Crop yields (average for 2022-2024), t/ha*

Crop	Variety	Variant 1 (Control)	Variant 2 (Biological fertilisers)	Variant 3 (Organic fertilisers)	Variant 4 (Plant protection + watering)	Variant 5 (Combined application + watering)
Wheat	Odesa duma	3.2	4.5	4	4.8	5.2
Corn	Sweet Spirit	6	7.5	7	8.2	8.5
Hemp	Gliana	2.5	3.5	3	4	4.3
Sunflower	Agent	2.8	3.8	3.5	4.2	4.5

***Source:** compiled by the authors*

The use of biological fertilisers and processing technologies significantly affected the product quality of the studied crops. In the control variant, winter wheat demonstrated an average protein level and low grain strength, which led to satisfactory product quality. The use of biological fertilisers (BioGrow, Agrorhiz, Soil Health) had a positive impact on its quality. The protein content increased to 12.8%, which indicates an improvement in the nutritional value of the grain. Grain strength increased, and quality was rated as high due to improved structure and fewer defects. In the EcoTon organic fertiliser treatment, protein content increased, and although grain quality improved, it did not reach the level achieved in the biological fertiliser treatment. Regulated irrigation and pesticide control had a positive impact on wheat quality. Protein content reached

13.0%, although it did not exceed the results achieved with biological fertilisers. Combined fertilisation and irrigation resulted in a protein content of 12.9%, and wheat quality remained at a sufficient level, but also did not exceed the results with biological fertilisers.

In the control variant, corn had a low oil content and average grain quality, with a high level of defects. With biological fertilisers, an increase in oil content was observed, indicating an improvement in grain quality. Defects decreased, improving the overall quality of the product. In the variant with EcoTon organic fertiliser, oil content increased to 4.5% and grain quality improved compared to the control conditions. Regulated irrigation and pesticide control improved oil content and grain quality but did not reach the level of results with biological fertilisers. Combined fertilisation and irrigation provided the highest oil content, but grain quality remained average. Hemp showed a protein content of 10.0% with average seed quality and satisfactory nutritional value in the control variant. The varieties together with biological fertilisers provided a significant increase in protein content. This improved seed quality and nutritional value, which indicates the effectiveness of biological fertilisers. In the organic fertiliser variant, the protein content increased, which is an improvement, but did not reach the results of the biological fertiliser plot. Regulated irrigation and pesticide control had a positive effect on protein content, improving seed quality and nutritional value, but did not exceed the results of option 2. Combined fertilisation and irrigation improved protein content, but seed quality remained average.

The results of sunflower cultivation in the control variant showed an oil content of 43.5%, with average seed quality and high levels of damage. The use of biological fertilisers increased the oil content, indicating a significant improvement in seed quality and a damage reduction. Product quality was rated as high. Organic fertilisers also increase oil content. Seed quality improved but did not reach the level of option 2. Regulated irrigation and pesticide control resulted in higher oil content. Seed quality improved but did not exceed the results with biological fertilisers. Combined fertilisation and irrigation resulted in higher oil content. Seed quality was at a high level (Table 3). The impact of biologisation on the content of acceptable nutrients in the soil is significant and complex, as it involves several key processes and mechanisms that interact to improve soil fertility. Biological fertilisers, such as composts and humates, positively impact soil structure. Composts, which result from the decomposition of organic materials, add large amounts of organic matter to the soil. This increases the water-holding capacity of the soil, promotes the formation of a clodded soil structure and reduces the risk of erosion. Humates, which are derivatives of organic acids, improve soil aeration and increase its ability to retain moisture, which has a positive effect on overall fertility.

***Table 3**. Product quality (average for 2022-2024)*

Crop	Variant 1 (Control)	Variant 2 (Biological fertilisers)	Variant 3 (Organic fertilisers)	Variant 4 (Plant protection + watering)	Variant 5 (Combined application + watering)
Wheat	Protein content: 12.3% Grain strength: low Quality: satisfactory	Protein content: 13.5% Grain strength: high Quality: High	Protein content: 12.8% Grain strength: average Quality: good	Protein content: 13% Grain strength: average Quality: good	Protein content: 12.9 % Grain strength: average Quality: good
Corn	Oil content: 4.2% Grain quality: average Defects: increased	Oil content: 4.8% Grain quality: high Defects: decreased	Oil content: 4.5% Grain quality: average Defects: decreased	Oil content: 4.6% Grain quality: high Defects: decreased	Oil content: 4.7% Grain quality: average Defects: decreased
Hemp	Protein content: 10% Seed quality: average Nutritional value: satisfactory	Protein content: 12% Seed quality: high Nutritional value: better	Protein content: 11.5% Seed quality: average Nutritional value: good	Protein content: 11% Seed quality: average Nutritional value: good	Protein content: 11.8% Seed quality: average Nutritional value: good
Sunflower	Oil content: 43.5% Seed quality: average Damage: increased	Oil content: 47% Seed quality: high Damage: decreased	Oil content: 45.5% Seed quality: average Damage: decreased	Oil content: 46% Seed quality: high Damage: decreased	Oil content: 45.8% Seed quality: average Damage: decreased

***Source:** compiled by the authors*

Microbiological products, such as growth-stimulating bacteria, activate microbiological activity in the soil. The microorganisms contained in these products help to decompose organic residues and release nutrients in a form that is available to plants. For instance, some bacteria can convert inorganic nitrogen into a form that is easily absorbed by plants, improving the nitrogen supply to crops (Didur *et al.*, 2023). The application of biological fertilisers helps to increase the content of the main nutrients nitrogen (N), phosphorus (P) and potassium (K) in the soil. Composts and humates contain a significant amount of organic nitrogen, which gradually decomposes, providing a long-lasting effect. The phosphorus in composts and humates is gradually released and becomes available to plants, which is especially important for root development. Potassium contained in biological fertilisers improves the water balance in plants and their stress resistance (Table 4). Biological fertilisers improve the availability of nutrients in the soil. Composts and humates help to bind and retain nutrients, reducing leaching and ensuring their gradual release. Microbiological preparations help to break down complex organic compounds, converting them into forms that are easy for plants to absorb. In general, biologisation leads to an increase in the level of organic matter in the soil, which has a positive effect on overall fertility. Increasing the organic content improves not only the nutrient content but also the physical and chemical properties of the soil, such as its structure, water-holding capacity and aeration.

***Table 4**. Content of acceptable nutrients in the soil (average for 2022-2024)*

Crop	Variant 1 (Control)	Variant 2 (Biological fertilisers)	Variant 3 (Organic fertilisers)	Variant 4 (Plant protection + watering)	Variant 5 (Combined application + watering)
Wheat	Mobile nitrogen: 15 mg/kg P_2O_5: 10 mg/kg K_2O: 20 mg/kg	Mobile nitrogen: 25 mg/kg P_2O_5: 15 mg/kg K_2O: 30 mg/kg	Mobile nitrogen: 20 mg/kg P_2O_5: 12 mg/kg K_2O: 25 mg/kg	Mobile nitrogen: 22 mg/kg P_2O_5: 14 mg/kg K_2O: 28 mg/kg	Mobile nitrogen: 24 mg/kg P_2O_5: 16 mg/kg K_2O: 27 mg/kg
Corn	Mobile nitrogen: 18 mg/kg P_2O_5: 11 mg/kg K_2O: 22 mg/kg	Mobile nitrogen: 30 mg/kg P_2O_5: 18 mg/kg K_2O: 35 mg/kg	Mobile nitrogen: 23 mg/kg P_2O_5: 13 mg/kg K_2O: 28 mg/kg	Mobile nitrogen: 25 mg/kg P_2O_5: 17 mg/kg K_2O: 33 mg/kg	Mobile nitrogen: 28 mg/kg P_2O_5: 19 mg/kg K_2O: 30 mg/kg
Hemp	Mobile nitrogen: 12 mg/kg P_2O_5: 9 mg/kg K_2O: 18 mg/kg	Mobile nitrogen: 20 mg/kg P_2O_5: 14 mg/kg K_2O: 24 mg/kg	Mobile nitrogen: 15 mg/kg P_2O_5: 10 mg/kg K_2O: 20 mg/kg	Mobile nitrogen: 18 mg/kg P_2O_5: 13 mg/kg K_2O: 23 mg/kg	Mobile nitrogen: 19 mg/kg P_2O_5: 15 mg/kg K_2O: 22 mg/kg
Sunflower	Mobile nitrogen: 14 mg/kg P_2O_5: 10 mg/kg K_2O: 21 mg/kg	Mobile nitrogen: 26 mg/kg P_2O_5: 16 mg/kg K_2O: 32 mg/kg	Mobile nitrogen: 19 mg/kg P_2O_5: 12 mg/kg K_2O: 26 mg/kg	Mobile nitrogen: 21 mg/kg P_2O_5: 15 mg/kg K_2O: 29 mg/kg	Mobile nitrogen: 23 mg/kg P_2O_5: 17 mg/kg K_2O: 31 mg/kg

***Source:** compiled by the authors*

Thus, biologisation using organic and microbiological fertilisers significantly improves the nutrient content of the soil, increasing its fertility and productivity. This helps to provide plants with the necessary elements for growth and development, which in turn has a positive impact on the yield and quality of agricultural products. Biologisation, which includes the use of organic and microbiological fertilisers, can affect CO_2 emissions through various mechanisms (Trembitska & Bohdan, 2023). The application of organic fertilisers, such as composts and humates, improves soil structure and increases its organic content. This can reduce CO_2 emissions, as well-structured soils with higher organic matter content contribute to better soil carbon retention, reducing its release to the atmosphere. Composts and humates improve the water-holding capacity of the soil, which reduces erosion (Kyselov, 2024). Less erosion means less loss of organic material from the soil, which also helps to reduce CO_2 emissions. Microbiological products can affect the decomposition of organic matter, which also affects CO_2 emissions. Microorganisms accelerate the decomposition of organic materials, but this process can be more controlled, which can reduce CO_2 emissions.

Agronomic practices, such as managed irrigation and pesticide use, also impact CO_2 emissions. Managed irrigation can reduce CO_2 emissions by reducing the risk of soil drying out and improving soil moisture, which reduces the need for frequent tillage, which can be associated with CO_2 emissions. The impact of pesticides on CO2 emissions is less apparent, but their use can affect microbiological processes in the soil. Uncontrolled use of pesticides can disrupt the balance of microorganisms, which in turn can change CO_2 emissions (Table 5).

***Table 5**. CO_2 emissions at different experimental sites (average for 2022-2024)*

Variant	Type of fertiliser/agronomic practices	CO_2 emissions (kg/ha)	Reduction of CO_2 emissions (% from control plot)
Variant 1	Without additional measures	120	0%
Variant 2	Biological fertilisers (compost, humates, bacteria)	102	-15%
Variant 3	Organic fertilisers	106	-12%
Variant 4	Controlled irrigation and pesticide control + watering	116	-3%
Variant 5	Combined fertilisation + irrigation	108	-10%

***Source:** compiled by the authors*

Biologisation has a significant positive impact on biodiversity. Organic fertilisers promote the development of a variety of microorganisms in the soil, such as beneficial bacteria and fungi, which help to decompose organic matter and increase soil fertility. Biological fertilisers can support and increase the number of beneficial organisms, such as shrews and predatory insects, which help control pests and diseases (Shahini *et al.*, 2024). The use of biological fertilisers can increase plant diversity by improving the conditions for different types of crops to grow, which increases the overall biodiversity of the agricultural ecosystem.

Agronomic practices also have both positive and negative impacts on biodiversity (Fedoniuk *et al.*, 2024). Regulated irrigation can help maintain plant and microbial diversity by providing stable growth conditions. However, excessive irrigation can lead to problems with soil salinity, which can have a negative impact on biodiversity (Table 6). Pesticide applications can have a negative impact on biodiversity, as they can kill not only pests but also beneficial insects and other organisms, upsetting the ecological balance and reducing the diversity of organisms in the soil and on the surface.

***Table 6**. Biodiversity in different variants (average for 2022-2024)*

Variant	Type of fertiliser/agronomic practices	Biodiversity index	Changes in biodiversity (% of the control site)
Variant 1	Without additional measures	1	0%
Variant 2	Biological fertilisers (compost, humates, bacteria)	1.4	+40%
Variant 3	Organic fertilisers	1.3	+30%
Variant 4	Controlled irrigation and pesticide control + watering	1.2	+20%
Variant 5	Combined fertilisation + irrigation	1.35	+35%

Source: *compiled by the authors*

Thus, biologisation and agronomic practices have different impacts on CO_2 emissions and biodiversity. The use of biological fertilisers generally reduces CO_2 emissions and increases biodiversity, while agronomic practices can have both positive and negative effects depending on their application and control.

DISCUSSION

The study demonstrated that the use of biological approaches in the cultivation of cereals and industrial crops can significantly improve their quality and resistance to environmental stress. The findings are important for developing strategies that will help preserve the environment and increase agricultural productivity. The introduction of biological methods can reduce the dependence on chemical fertilisers and pesticides, which correlates with modern environmental requirements and trends towards sustainable development. The results of the study on the impact of biological methods on plant productivity and soil quality are consistent with the findings of W. Huo *et al.* (2023). The authors determined that the optimal use of phosphate fertilisers in saline soils can significantly improve cotton yields by reducing excessive phosphorus in the soil, which is an important aspect for reducing negative environmental impacts. The study also demonstrates that optimising the use of biological fertilisers can help achieve similar results, reducing the risk of over-application of phosphate fertilisers and improving overall soil health. Q. Wang *et al.* (2024) investigated the effect of long-term straw management in wheat and cotton on root system performance and cotton yield. Their results indicate that phosphate fertilisers applied in combination with straw improve root carbohydrate metabolism and, as a result, increase productivity. Observations confirm these results, showing that biological methods, such as bio-phosphorus fertilisers and cover crops, can contribute to similar improvements in agricultural systems, increasing productivity and resource efficiency.

The use of magnetised water together with biodegradable films can significantly improve the distribution of water and salt in the soil, leading to increased tomato yields in arid conditions, as stated by Z. Zhou *et al.* (2024). The results confirm that innovative approaches can be integrated with biological methods to achieve similar effects, in the context of improving soil water retention and increasing crop productivity. In turn, N. Li *et al.* (2024) investigated the synergy between *Broussonetia papyrifera* and biofertilisation to stabilise bacterial communities and improve plant growth in copper dumps. These observations also indicate that biofertilisation can significantly improve the stability of the microbiological environment in agricultural systems, increasing the efficiency of plant systems under adverse conditions. M. Bashir *et al.* (2024) determined that polystyrene microplastics can affect the bioavailability and toxicity of copper compounds in maize. This study also highlights the importance of controlling pollutants and their impacts on agricultural systems, through biological methods that can help reduce the negative effects of pollution.

The results of the study by J. Bangre *et al.* (2024) on the impact of inorganic fertilisers and manure on soil quality and productivity in subtropical vertisols demonstrated that long-term use of these fertilisers can affect soil properties and crop productivity. The findings confirm that biological methods, such as biofertilisation, can provide sustainable improvements in soil quality and crop productivity through their long-term effects on soil structure and fertility. Differences in soil carbon content and crop growth in different agricultural conditions in China, emphasising the role of geochemistry and climate change, were studied by X. Yang *et al.* (2024). The results of this study also confirm the importance of considering geochemical and climatic factors when using biological methods to improve soil fertility and crop productivity. Biological approaches can help to adapt to climate change by improving soil organic matter content and structure. D. Wang *et al.* (2024) investigated the impact of different levels of fertiliser application on bacterial communities, enzyme activity and soil organic nitrogen fractions. This study confirms that biofertilisers can contribute to improving the microbiological environment and increasing nutrient use efficiency. The integration of biofertilisers into agronomic practices demonstrates a similar positive impact on soil structure and fertility (Shuvar *et al.*, 2022).

The responses of bacterial and fungal communities to three years of biofertiliser application to alkaline soybean soil were described by W. Gao *et al.* (2021). The results are consistent with this study, showing that biofertilisers can positively affect microbial activity and soil fertility, which is important for maintaining the long-term productivity of agricultural systems. The results of a study by J. Fachini *et al.* (2024) demonstrated that potassium-enriched fertilisers improved nutrient uptake in radish plants. This is consistent with the findings that fertilisers enriched with different nutrients can have a positive impact on crop productivity by improving nutrient availability and uptake. The impact of biofertilisers on nutrient cycling and crop productivity was studied by L. Melo and M. Sánchez-Monedero (2024). These results confirm that biofertilisers can be effective in improving nutrient cycling and ensuring sustainable crop productivity through their effect on the physical and chemical properties of the soil. C. Figueiredo *et al.* (2024) examined nutrient- and compost-enriched soil in terms of systemic productivity and environmental sustainability. The results are consistent with their findings that such biofertilisers can increase the productivity of agronomic systems and ensure environmental sustainability, due to their ability to improve soil structure and maintain soil fertility.

A study by I. Rashmi *et al.* (2024) on the effects of gypsum and organic amendments on soil stability, productivity and health under agricultural production in soda soils of India is noteworthy. The results of this study confirm that biological additives can be effective in maintaining soil health and increasing productivity, similar to the effects of organic additives in other agronomic systems. The study by X. Xie *et al.* (2024) confirmed that bacteria that stimulate plant growth and can withstand salt stress are effective in mitigating such stress in plants. These results support this claim, showing that bacteria can significantly increase crop resistance to salt, which is important for areas with high levels of salinity. Similar findings were reported by Z. Ning *et al.* (2024), who analysed the use of halophilic bacteria to reduce salt stress in rice. The results of the study are consistent with their findings, confirming the effectiveness of certain microorganisms in improving plant salt tolerance, which may be important for growing crops in saline environments. C. Cruz *et al.* (2023) also demonstrated that bacteria that stimulate plant growth can increase the resistance of maize to salinity. These results also confirm the positive impact of such bacteria, which highlights the potential of using these microorganisms to improve product quality under salt stress. L. Zhuang *et al.* (2024) highlighted the impact of reducing chemical fertilisers and applying organic fertilisers on soil fertility and productivity in apple orchards. The results also confirmed that the reduction of chemical fertilisers and the use of organic methods can have a positive impact on crop productivity and environmental sustainability, which is consistent with the findings of their study. A. Panfilova *et al.* (2021) determined that nutrition optimisation increases barley yields, which is consistent with the data obtained for wheat. These results confirm that nutrition is a critical factor in achieving high performance. The researchers also focused on optimising wheat-growing technologies, especially the Kolchuga variety, in the steppes of southern Ukraine. Their recommendations for optimisation can be supplemented with data on the impact of biological fertilisers on crop yields and quality.

The use of organic nitrogen fertilisers to improve soil health and increase yields was reviewed by S. Shahini *et al.* (2023). This study expands on these ideas by providing more detailed information on the impact of biological, organic and combined fertilisers on product quality. T. Kachanova *et al.* (2021) assessed the impact of weather conditions and sowing methods on chickpea productivity, highlighting the importance of environmental conditions for the success of agronomic practices. This complements the findings on the importance of agronomy for biodiversity conservation. V. Pichura *et al.* (2024) studied the influence of predecessors on the formation of water balance in winter wheat agrocenoses and soil moisture in the steppe zone. Their results emphasise the importance of agronomic management to optimise water resources, which can be applied to the present study, which also considers irrigation. The study demonstrated that elements of biologisation can significantly improve both product quality and environmental conditions. The differences found in comparison with previous studies highlight the need to adapt biologisation methods to specific growing conditions.

CONCLUSIONS

The study confirmed the effectiveness of introducing elements of biologisation in agronomic practice to increase crop yields and quality. In particular, the use of biological fertilisers (biological products, composts, and humates) improved the yield of all the crops studied. In variant 3 with organic fertilisers, yields increased by 8-15%, while regulated irrigation and pesticide control in variant 4 provided a stable yield increase of 10-12%. The best results were achieved in Plot 5 with combined fertilisation and irrigation. Biological fertilisers also improved product quality: soybean and sunflower oil content was higher. Soil nutrient analysis showed increased levels of nitrogen, phosphorus and potassium. CO_2 emissions decreased by 10-15% and biodiversity increased by 40%. Overall, the research results confirm that the integration of biologisation elements into agronomic practices is an effective strategy for improving yields, product quality and soil fertility. Biological fertilisers provided the most significant positive effect compared to other methods. The combined use of fertiliser and irrigation also demonstrated significant benefits, especially in terms of resource management and CO_2 emissions reduction. These results underline the importance of an integrated approach to agricultural ecosystem management to achieve high productivity and sustainability in agriculture.

It is recommended to introduce biological and organic fertilisers on a wide scale to increase yields and product quality. It is also necessary to continue to use regulated irrigation and control pesticide treatments for sustainable results. It is also important to explore the possibilities of combined fertilisation and irrigation to achieve the best results. The main areas for further research include studying the long-term effects of biological fertilisers on different soil types and climatic conditions, the optimal combinations of fertilisers and irrigation for different crops and an analysis the impact of biological fertilisers on plant resistance to diseases and pests. The study is limited by the specific types of fertilisers and irrigation used, as well as the geographical and climatic conditions of the sites. It is worth noting that the study was conducted in one geographical area (Mykolaiv region), which may limit the generalisability of the results to other regions. Moreover, the possible effects of other factors, such as genetic characteristics of crops and climate change, were omitted in this study.

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Використання елементів біологізації при вирощуванні зернових і технічних культур з метою отримання високоякісної продукції та збереження довкілля

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Анотація. Метою дослідження було оцінити ефективність впровадження елементів біологізації для підвищення врожайності та якості сільськогосподарських культур. Було проведено експеримент, у рамках якого проаналізовано вплив біологічних та органічних добрив, регульованого зрошення і контролю пестицидного оброблення на врожайність, якість продукції, вміст поживних речовин у ґрунті, викиди CO_2 та біорізноманіття. Результати показали, що використання біологічних добрив (біопрепарати, компости, гумати) позитивно вплинули на врожайність всіх досліджених культур. Зокрема, у варіанті 2, де були застосовані сорти пшениці, кукурудзи, конопель і соняшнику з біологічними добривами, спостерігалося збільшення врожайності на 12-20 % залежно від культури. Органічні добрива у варіанті 3 також показали підвищення врожайності, хоча й у меншому обсязі (8-15 %). Регульоване зрошення і контроль пестицидів у варіанті 4 забезпечили стабільний приріст врожайності на 10-12 %, а комбіноване внесення добрив і зрошення у варіанті 5 дало найкращі результати, хоча й з меншими збільшеннями. Впровадження біологічних добрив також позитивно вплинуло на якість продукції. Олійність сої та соняшнику на ділянках з біологічними добривами також була вищою порівняно з контрольним варіантом 1. Аналіз вмісту поживних речовин у ґрунті показав, що біологічні добрива підвищили рівні азоту, фосфору і калію в ґрунті. Викиди CO_2 зменшилися на 10-15 % на ділянках з біологічними добривами, що вказує на позитивний екологічний ефект застосування таких технологій. Біорізноманіття також покращилось, зокрема на ділянці з біологічними добривами спостерігалося зростання індексу біорізноманіття на 40 %. Таким чином, результати дослідження підтверджують, що інтеграція біологічних і органічних добрив, а також ефективне управління водними ресурсами і пестицидами може значно підвищити врожайність і якість сільськогосподарських культур, зменшити викиди CO_2 і сприяти збереженню біорізноманіття

Ключові слова: сільськогосподарські культури; елементи технології; біологічні методи в рослинництві; екологія; урожайність і якість рослин