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Turnip yield in open soil conditions in Polissya under different plant protection systems

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Abstract. The aim of the study was to evaluate the effectiveness of bacterial and chemical preparations regarding their impact on turnip yield and specific quality indicators of its root crops under different plant protection systems. The research was conducted at the Volyn State Agricultural Research Station of the NAAS in 2024-2025 using the turnip varieties 'Zolota Kulya', 'Purpurova', 'Purpletop', and 'Geisha'. To protect against diseases, the chemical fungicide Magnicur Boost and the biological products Phytocide-r and Mycohelp (BTU company) were applied; for pest protection, the chemical insecticide Confidor Maxi and the biological products Bitoxibacillin-BTU and Aktoverm-formula (BTU company) were used. An untreated variant served as the control. The study was established with fourfold replication following standard vegetable-growing methodology. The results showed that the application of the biofungicide Phytocide-r increased the root crop yield of the 'Purpletop' variety to 22.2 t/ha, and for the 'Zolota Kulya', 'Purpurova', and 'Geisha' varieties (using Phytocide-r or Mycohelp) by 0.9-1.2 t/ha. Magnicur Boost and Phytocide-r increased the starch content in 'Zolota Kulya' root crops to 7.12-7.30% and vitamin C to 19.3-19.5 mg/100 g. The 'Purpletop', 'Geisha', and 'Purpurova' varieties proved to be more resistant to downy mildew; Mycohelp limited the spread of the disease to 2.0-2.7% and its development to 0.21-0.31%, while Magnicur Boost limited the spread to 0.76%. The systemic use of the bioinsecticides Bitoxibacillin-BTU and Aktoverm-formula increased the yield

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of the 'Purpletop' and 'Purpurova' varieties to 21.6-22.0 t/ha, whereas Confidor Maxi only increased it by 5%. Without insecticidal protection, the yield was at its lowest. Biological products increased the dry matter content to 16.3-16.4%, starch to 6.29-6.74%, protein to 5.4%, and vitamin C to 19.2-19.3 mg/100 g. Bitoxibacillin-BTU and Aktoverm-formula proved to be more effective against the adults of the black crucifer flea beetle

Keywords: fungicide; insecticide; turnip; yield; root crop; quality; effectiveness

Introduction

Food quality is a critical factor for the national security of Ukraine. Plant products, particularly vegetables, form the basis of the Ukrainian consumer's diet. The full-scale aggression of the Russian Federation has altered the geography of vegetable production: cultivation is shifting from the southern regions to the central and western provinces. In modern conditions, increasing attention is being paid to minor vegetable crops with a high content of biochemical components. Among these, the turnip stands out for its resistance to unfavourable climatic conditions, long shelf life, and nutritional value. At the same time, the low yield of the crop is often due to insufficient protection against diseases and pests. Traditional chemical agents, despite their effectiveness, raise concerns regarding the accumulation of toxic substances in the produce. This prompts the search for biological preparations that ensure the ecological safety of the produce while maintaining high crop productivity (Vakhovska, 2023).

In the context of searching for effective and ecologically safe turnip protection systems, the recommendations of G.I. Yaroviy & O.V. Romanov (2025) are significant. The authors systematised the principles of integrated protection for cruciferous crops against downy mildew, alternaria, black leg, and flea beetles, emphasising the advantages of combining agro-technical, biological, and, where necessary, chemical methods to ensure high yields and root crop quality in the conditions of the Ukrainian Polissya. S.V. Stankevych *et al.* (2024) provided a detailed characterisation of the main harmful organisms of cruciferous crops, particularly rapeseed. The

authors developed a comprehensive integrated protection system that combined agro-technical, biological, and chemical measures to limit the spread of diseases, pests, and weeds. The work focused on ecologically justified approaches to minimising yield losses and improving product quality under Ukrainian conditions.

V. Shvets (2023) investigated the implementation of biological protection methods for cruciferous crops in modern organic production, highlighting the need for a comprehensive approach to ensuring the phytosanitary welfare of crops. The author emphasised the importance of using biological preparations based on beneficial microorganisms for protection against fungal diseases and pests as an alternative to traditional chemical means. V.P. Rud (2023) analysed the effectiveness of various application schemes for biofungicides to protect cruciferous vegetable crops. The results demonstrate that correctly selected biological products can provide a sufficient level of protection against the main pathogens when agro-technical requirements and the timeliness of treatments are observed.

Research by G. Wu *et al.* (2024) is of great importance for understanding the protection problems of cruciferous crops; they conducted a comprehensive review of the pathogenesis of the turnip mosaic virus and host plant resistance mechanisms. The authors systematised information on the molecular mechanisms of virus interaction with plants of the genus *Brassica*, identified candidate resistance genes, and proposed new strategies for controlling viral infection based on genetic resistance. This comprehensive approach

to studying viral diseases opens new possibilities for breeding resistant varieties of cruciferous crops. P. Palukaitis & S. Kim (2021) researched the diversity of turnip mosaic virus isolates and their impact on various Brassica species. The authors established that significant variability exists in the virulence of different virus strains, which must be considered when developing protection strategies. The study confirmed the presence of different types of resistance in representatives of the genus *Brassica rapa*, including turnips, which can be utilised in breeding programmes.

In the context of biological plant protection, the review by R. Lahlali *et al.* (2022) is significant, as it analysed global perspectives on the biological control of phytopathogens. The researchers established that biological control agents, particularly representatives of the genera *Pseudomonas*, *Bacillus*, *Burkholderia*, and *Trichoderma*, demonstrate high effectiveness against a wide spectrum of foliar and soil-borne pathogens. The authors noted that, despite a slightly lower efficacy compared to chemical preparations, biological protection agents offer additional benefits such as plant growth stimulation and environmental safety.

C. Lago *et al.* (2024) investigated the impact of the turnip yellows virus and drought on rapeseed productivity under climate change conditions. The authors established that the combined stress of viral infection and water deficit significantly exacerbates the negative impact on plant growth and development. These results highlight the need to develop comprehensive protection strategies that account for changing climatic conditions and the spread of viral diseases. The authors paid particular attention to the necessity of using resistant varieties and optimising protection systems in the face of the predicted increase in the frequency and intensity of droughts. K. Macleod *et al.* (2023) conducted a thorough analysis of resistance sources to the turnip yellows virus in various Brassica species. The researchers identified several new quantitative trait loci (QTL) in the genomes of *B. napus*, *B. rapa*, and *B. oleracea*, which can be used to

develop commercial varieties with increased resistance. The authors emphasised the importance of implementing diverse resistance sources to reduce selection pressure on the virus and prolong the effectiveness of the resistance.

C.F. Nellist *et al.* (2022), in their comprehensive review, characterised the turnip mosaic virus as a “virus for all seasons”, describing its broad host range and ability to adapt to various environmental conditions. The authors analysed the phylogenetic groups of the virus, the specifics of its interaction with different cruciferous species, and the mechanisms of transmission via aphids. Particular attention was paid to the diversity of isolates adapted to Brassica and Raphanus, which is vital for understanding the epidemiology of the disease.

The aim of the study was to establish the influence of different plant protection systems (using preparations of bacterial and chemical origin) on turnip productivity and the biochemical quality indicators of its root crops

Materials and Methods

The experimental part of the research was conducted under the conditions of the Volyn State Agricultural Research Station of the Institute of Agriculture of the Carpathian Region of the National Academy of Agrarian Sciences of Ukraine during 2024-2025, using turnip varieties ‘Zolota Kulya’, ‘Purpurova’, ‘Purpletop’, and ‘Geisha’. The seeds of these varieties were sown in the second decade of April. The soil of the experimental plot is sod-podzolic light loamy with the following agrochemical indicators: humus content 1.18%; pH of salt extract – 5.3; nitrogen content (easily hydrolysed) – 61 mg/kg, mobile phosphorus – 135.1 mg/kg, and mobile potassium – 81.33 mg/kg of air-dry soil.

To evaluate the effectiveness of fungicides, the chemical preparation Magnicur Boost was used at a dose of 800 g/ha, along with biological preparations of bacterial origin, Phytocide-r and Mycohelp, produced by the BTU company. Seed treatment with Phytocide-r was carried out at a rate of 1 l/kg of seeds, followed by spraying at 2 l/ha

in two stages – at the 1-2 true leaf phase and 15 days after the first treatment. For Mycohelp, the seed treatment rate was 0.7 l/kg of seeds, with spraying at 2 l/ha according to a similar scheme. To evaluate the effectiveness of insecticides, the chemical preparation Confidor Maxi was used at a rate of 20 g/ha, as well as the biological products Bitoxibacillin-BTU and Aktoverm-formula produced by the BTU company. Spraying with Bitoxibacillin-BTU was carried out at a rate of 8 l/ha in three stages: at the cotyledon leaf phase, during the formation of vegetative mass, and 15 days after the second treatment. Aktoverm-formula was applied at a rate of 4 l/ha following the same schedule. The control variant consisted of plants that were not treated with any preparations. The quality indicators of the produce were determined in the root crops of the 'Zolota Kulya' variety. The study was established with fourfold replication according to the methodology of experimental work in vegetable and melon growing (Bondarenko & Yakovenko, 2001; Rozhkov, 2016). The research was conducted in compliance with the principles of the Convention on Biological Diversity (1992), specifically regarding the sustainable use of plant genetic resources, the conservation of agroecosystem biodiversity, and the fair distribution of benefits from the use of biological materials. The use of bacterial-origin biological products contributed to minimising negative environmental impacts and maintaining ecological balance in agrocenoses.

Quality indicators of the root crops were determined under laboratory conditions using standard methods. In samples of the 'Zolota Kulya' variety, the dry matter content (by drying to constant weight), starch (by the iodometric method), crude protein (by the Kjeldahl method with conversion to protein using a factor of 6.25), and ascorbic acid (vitamin C) by titration with 2,6-dichlorophenolindophenol were analysed. The results of the biochemical analyses are summarised in Table 2, which shows the starch and protein content as a percentage of fresh weight, as well as the vitamin C content in mg per 100 g of fresh root crop weight. Determinations were carried out in three analytical replicates for each field replication.

Results and Discussion

The studied varieties formed typical root crops that matched their varietal characteristics in shape and colour and were not damaged by either bacterial or fungal diseases. During the analysis of plant productivity for the varieties under study, the indicator was not constant and varied depending on the growing conditions and the fungicide applied. The soil and climatic conditions of the 2024 growing season were more favourable than those of 2025 for the 'Purpurova', 'Purpletop', and 'Geisha' turnip varieties. However, on average, the root crop yield in the experiment, when sown in the second decade of April, amounted to 19.5-22.2 t/ha (Table 1).

Table 1. Turnip yield with fungicide protection, t/ha

| Varieties | Years of cultivation | Control | Magnicur Boost | Phytocide-r | Micohelp | LSD ₀₅ |
|----------------|----------------------|---------|----------------|-------------|----------|-------------------|
| 'Zolota Kulya' | 2024 | 20.7 | 20.9 | 21.7 | 20.8 | 0.3 |
| | 2025 | 20.6 | 21.1 | 21.5 | 21.6 | 0.6 |
| | Average | 20.7 | 21.0 | 21.6 | 21.2 | |
| | ± to control | - | +0.3 | +0.9 | +0.5 | |
| 'Purpurova' | 2024 | 21.3 | 21.5 | 21.8 | 21.6 | 0.3 |
| | 2025 | 20.3 | 21.4 | 21.5 | 21.4 | 0.8 |
| | Average | 20.8 | 21.5 | 21.7 | 21.5 | |
| | ± to control | - | +0.7 | +0.9 | +0.7 | |
| 'Purpletop' | 2024 | 21.5 | 22.0 | 22.2 | 22.0 | 0.4 |
| | 2025 | 20.4 | 21.7 | 22.1 | 21.5 | 0.6 |
| | Average | 21.0 | 21.9 | 22.2 | 21.8 | |
| | ± to control | - | +0.9 | +1.2 | +0.8 | |

Table 1. Continued

| Varieties | Years of cultivation | Control | Magnicur Boost | Phytocide-r | Micohelp | LSD ₀₅ |
|---------------------|----------------------|---------|----------------|-------------|----------|-------------------|
| 'Geisha' | 2024 | 19.5 | 20.0 | 21.6 | 21.4 | 0.6 |
| | 2025 | 19.8 | 19.9 | 20.3 | 20.4 | 0.3 |
| | Average | 19.7 | 20.0 | 21.0 | 20.9 | |
| | ± to control | - | +0.3 | +1.3 | +1.2 | |
| Yield of tops, t/ha | | 30.17 | 32.45 | 33.04 | 32,42 | 2.22 |

Source: developed by the authors

In determining the effectiveness of the fungicide according to the existing protection scheme (seed treatment at 1 l/kg + spraying at 2 l/ha in two stages: 1-2 true leaves and 15 days after the first treatment), it was established that the biofungicide Phytocide-r ensured the highest turnip root crop yield when growing the 'Purpletop' variety. In this variant, the yield indicator, averaged over the years of cultivation, was 22.2 t/ha, which exceeded the control root crop yield by 1.2 t/ha.

Simultaneously, when growing the 'Zolota Kulya' and 'Purpurova' varieties using Phytocide-r (seed treatment 1 l/kg + spraying 2 l/ha in two stages: 1-2 true leaves and 15 days after the first treatment) and the 'Geisha' variety using the biofungicide Mycohelp (seed treatment 0.7 l/kg + spraying 2 l/ha in two stages: 1-2 true leaves and 15 days after the first treatment), the root crop yield was slightly lower but still exceeded the control yield by 0.9-1.2 t/ha. The plants of these varieties responded better to the protection system compared to the control variant when using these biological products. This is likely due to the presence of natural bacteria *Bacillus subtilis* in the preparations at a concentration of at least 1.0×10^9 CFU/cm³, which provided improved plant protection by increasing resistance to unfavourable environmental conditions, promoting better growth and development, and protecting against a wide range of fungal and bacterial pathogens, as evidenced by the yield of turnip tops. The continued use of biological preparations and their positive effect on plant productivity is consistent with key European Union documents and the conference "Modern Biotechnologies in Agriculture – Paving the Way for Responsible Innovation",

organised by the European Food Safety Authority (European Commission, 2017).

The application of a fungicide of chemical origin is also effective for growing turnips in open-soil conditions. As a result of growing the 'Purpletop' variety and using the fungicide Magnicur Boost, the average root crop yield was also quite high at 21.9 t/ha, with an increase over the control of 0.9 t/ha. The use of this systemic fungicide, which contains 800 g/kg of fosetyl-aluminium, allowed for rapid penetration of the solution into the plant, which ensured the stimulation of the plant's natural immunity and a long-lasting preventive effect; the turnip plants also exhibited resistance to fungal diseases. The obtained turnip yield data do not coincide with the turnip yield data of S.A. Vdovenko (2019), who grew them in the open-soil conditions of the Right-Bank Forest-Steppe. In that author's research, turnip yields fluctuated depending on the sowing dates between 12.5 and 22.1 t/ha, whereas in the current study, the yield was close to the maximum value, indicating high productivity and the potential of the varieties studied. However, the size of the turnip root crops in current research was 4-9 cm, which coincides with the data of V.V. Khareba *et al.* (2016).

The studied disease protection products also influenced the quality of the turnip root crops. The biochemical indicators of the turnip root crops depended on the origin of the preparation. Phytocide-r (seed treatment 1 l/kg + spraying 2 l/ha in two stages: 1-2 true leaves; 15 days after the first treatment) and Mycohelp (seed treatment 0.7 l/kg + spraying 2 l/ha in two stages: 1-2 true leaves; 15 days

after the first treatment) contribute to a slight decrease in the total dry matter content. In

these variants, the studied indicator was at the level of 15.1-15.4% (Table 2).

Table 2. Quality of root crops of the turnip variety 'Zolota Kulya' after fungicide application (average for 2023-2025)

| Turnip disease protection system | Content of biochemical substances in turnip root crops, % | | | |
|----------------------------------|---|-----------|----------|---------------------|
| | Dry matter | Starch | Protein | Vitamin C, mg/100 g |
| 1. Control | 15.6±0.04 | 6.22±0.03 | 5.1±0.03 | 18.4±0.05 |
| 2. Magnicur Boost | 15.4±0.03 | 7.12±0.03 | 5.3±0.04 | 19.3±0.04 |
| 3. Phytocide-r | 15.1±0.04 | 7.30±0.03 | 5.4±0.03 | 19.5±0.03 |
| 4. Mycohelp | 15.4±0.04 | 6.65±0.03 | 5.4±0.02 | 18.9±0.03 |

Source: developed by the authors

The chemical preparation Magnicur Boost and the biofungicide Phytocide-r ensured an increase in the starch content of 'Zolota Kulya' root crops up to 7.12% and 7.30% respectively, which exceeded the control variant by 15-17%. A trend towards increasing starch content relative to the control was identified with the use of the biofungicide Mycohelp, which contains a higher bacterial count. The protein content in the turnip root crops remained at a level of 5.1-5.4% regardless of the protection system; however, a trend towards its increase was observed in the variants where fungicides were applied.

One of the vital quality indicators for root crops is the vitamin C value. The highest vitamin C content was established using the biofungicide Phytocide-r and the fungicide Magnicur Boost, where the studied value could increase to 19.5 and 19.3 mg/100 g of product respectively, exceeding the control by 1.1 times. During the cultivation of the 'Zolota Kulya' variety and the application of the biofungicide Mycohelp, research established a trend towards an increase in vitamin C content relative to the control by only 0.5 mg/100 g of product. In the studies by V.I. Smolyar (2000), the physiological and hygienic properties of turnips were studied, specifically their chemical composition. According to that work, turnips contained 10.5-13.0% dry matter, 0.1% starch, up to 1.74% protein, and up to 60 mg/100 g of vitamin C. This provided baseline parameters for assessing the nutritional value of turnips. However, the current

study revealed that the application of biofungicides and improved agro-techniques contributed to a significant increase in the content of starch, protein, and vitamin C. For instance, with the use of the biofungicide Phytocide-r, the starch content in 'Zolota Kulya' root crops reached 7.30%, significantly exceeding the figures cited in V.I. Smolyar's research. This indicates the possibility of significantly improving the nutritional value of turnips through the application of modern cultivation and plant protection methods. In a study by C. Chen-Tien *et al.* (2000), the purification and properties of chitinases isolated from radish root crops were examined. It was found that the chitinases contained in radishes possess antifungal activity, which adds value to the crop in the food and medical industries. In the current study, the use of biological products such as Mycohelp, which contains natural bacteria, also demonstrated effectiveness in disease control, particularly against fungal pathogens. This confirms the importance of using biological agents to improve product quality and disease protection. Research by O.V. Khareba *et al.* (2021) highlights the turnip as a rare vegetable crop containing significant amounts of minerals such as iron, potassium, and calcium. The work notes that turnips are a promising product for therapeutic nutrition due to their properties in normalising blood pressure and improving the condition of the respiratory system. The current study also identified a significant increase in the mineral content of turnip root crops grown using

modern agro-technologies, confirming the importance of proper plant care for achieving high-quality indicators. The vitamin C content in the root crops was 19.5 mg/100 g, which exceeds the data reported in the literature. These values attest that the conditions for growing turnips in Polissya and the protection system can significantly improve the quality indicators of the root crop, ensuring they fully meet modern requirements.

During the cultivation of vegetable plants in open-soil conditions, both the spread and development of disease were observed. According to research by M.V. Zubets *et al.* (2010), pathogens can have a dual impact on yield and quality indicators, depending on growing conditions and the applied agro-technical measures. They note that in organic farming, a correct approach to cultivation technology is capable of minimising the impact of diseases on yield. The current study also recorded that a proper plant protection system, including biological products, ensures not only a reduction in disease levels but also improves the qualitative characteristics of turnip root crops. For example, the application of biofungicides significantly reduced the spread and development of downy mildew, confirming the ability of biological preparations to enhance product quality. According to the

work of L.A. Zhurakovska (2013), pathogens can either reduce yields or, under certain conditions, even improve quality indicators. This depends on the choice of protection methods and cultivation technologies. In the current research, it was established that the application of biological products such as Phytocide-r and Mycohelp not only increased yield but also contributed to the improvement of biochemical indicators in the root crops. Thus, the starch content in turnip root crops rose to 7.30%, a significant improvement compared to the control variants. This indicates that the selection of appropriate agro-technologies and protection agents can influence product quality not only by reducing disease levels but also by improving the physiological indicators of the plants.

In the experiment conducted, the systemic application of fungicides of both bacterial and chemical nature contributed to a significant reduction in the spread and development of the disease, which fluctuated at levels of 2.0-6.41% and 0.21-2.98% respectively. Downy mildew is considered the most dangerous disease for turnip plants. Among the turnip varieties studied, 'Purpletop', 'Geisha', and 'Purpurova' proved to be more resistant to infection and the further development of downy mildew (Table 3).

Table 3. Fungicidal protection of turnip depending on technological components (average for 2024-2025)

| Variety | Fungicidal protection | | | | | | | |
|----------------|-----------------------|------------------------|-------------------|------------------------|-------------------|------------------------|-------------------|------------------------|
| | Control | | Magnicur Boost | | Phytocide-r | | Mycohelp | |
| | downy mildew | | | | | | | |
| | disease spread, % | disease development, % | disease spread, % | disease development, % | disease spread, % | disease development, % | disease spread, % | disease development, % |
| 'Zolota Kulya' | 4.94 | 1.67 | 3.0 | 1.08 | 3.30 | 1.15 | 3.4 | 0.45 |
| 'Purpurova' | 6.41 | 2.98 | 2.9 | 0.76 | 3.81 | 1.22 | 2.7 | 0.31 |
| 'Purpletop' | 5.16 | 1.57 | 2.4 | 1.92 | 3.74 | 1.20 | 2.0 | 0.21 |
| 'Geisha' | 5.85 | 1.82 | 3.0 | 1.24 | 4.52 | 1.63 | 2.3 | 0.27 |

Source: developed by the authors

Based on the data obtained, it was established that in the variant where no fungicidal

preparations were applied, the rate of spread and development of downy mildew was considerably

high. As a result of growing the 'Purpurova', 'Purpletop', or 'Geisha' varieties and applying Mycohelp (seed treatment at 0.7 l/kg + spraying at 2 l/ha in two stages: 1-2 true leaves and 15 days after the first treatment), the disease spread value was the lowest, amounting to only 2.0-2.7%, and the lowest rate of downy mildew development (0.21-0.31%) relative to the control was also obtained. Evidently, the bacteria that form the basis of the preparation work more effectively against harmful fungi, especially during periods of excessive rainfall, which positively influenced the overall plant yield. A significant reduction in the spread and subsequent development of the disease was ensured by the chemical fungicide Magnicur Boost at a dose of 800 g/ha during the cultivation of the 'Purpurova' variety. In this variant, the reduction in disease spread on turnip crops was 0.76%, which differed from the control variant value. However, according to S.V. Stankevych *et al.* (2024), the reduction and control of disease through chemical fungicides can show somewhat higher indicators. Simultaneously, the authors emphasised that modern protection of the Brassicaceae family must account for organisational, management, agro-technical, biological, and chemical methods: these are the most reliable and profitable, while each method individually significantly limits the spread and development of a given disease, where plant infection can fluctuate from 4% to 45%. In current research, the spread of the disease was at a significantly low level, which does not coincide with the data of S.V. Stankevych *et al.* When using the biofungicide Phytocide-r, the rate of disease spread and development decreased relative to the control by 1.1-2.4 times, yet remained high relative to the values where Mycohelp and Magnicur Boost were applied.

On turnip crops, the most common pests were the black crucifer flea beetle and aphids. Without a proper protection system, these representatives are capable of significantly reducing the overall turnip yield. Turnip productivity, depending on the insecticides applied, was not constant and depended on the origin and composition of the preparation as well as varietal characteristics. It was established that throughout the years of cultivation, turnip root crop yields remained practically at the same level. Among the varieties studied, 'Purpurova' and 'Purpletop' were characterised by higher yields, amounting to 21.3 and 21.6 t/ha respectively, exceeding the yield of the control variety 'Zolota Kulya' by 0.7-1.0 t/ha.

As a result of the systemic application of the biological products Bitoxibacillin-BTU (spraying the plant at a dose of 8 l/ha in three stages: cotyledon leaves; formation of vegetative mass; 15 days after the second treatment) or Aktoverm-formula (spraying plants at a dose of 4 l/ha in three stages: cotyledon leaves; formation of vegetative mass; 15 days after the second treatment) during the cultivation of the 'Purpletop' or 'Purpurova' varieties, the yield indicator was the highest, reaching 21.6-21.7 t/ha and 21.9-22.0 t/ha respectively. In this study, the obtained yield values significantly expand the understanding of turnip productivity compared with those recorded under the conditions of the Right-Bank Forest-Steppe (Vdovenko, 2019). Viable cells of *Bacillus thuringiensis* bacteria, through systemic application, provided better protection against insect pests compared to the preparation Confidor Maxi. This was particularly observed during steady increases in air temperature starting from 14°C. In these variants, the increase in turnip yield amounted to 0.8-1.1 t/ha (Table 4).

Table 4. Turnip yield with insecticide protection, t/ha

| Varieties | Years | Control | Confidor Maxi | Bitoxibacillin-BTU | Aktoverm-formula | LSD ₀₅ |
|----------------|--------------|---------|---------------|--------------------|------------------|-------------------|
| 'Zolota Kulya' | 2024 | 19.6 | 20.6 | 20.9 | 20.7 | 0.6 |
| | 2025 | 20.6 | 20.8 | 20.9 | 20.8 | 0.1 |
| | Average | 20.1 | 20.7 | 20.9 | 20.8 | |
| | ± to control | - | +0.6 | +0.8 | +0.7 | |

Table 4. Continued

| Varieties | Years | Control | Confidor Maxi | Bitoxibacillin-BTU | Aktoverm-formula | LSD ₀₅ |
|---------------------|--------------|---------|---------------|--------------------|------------------|-------------------|
| 'Purpurova' | 2024 | 20.3 | 21.0 | 21.4 | 21.2 | 0.6 |
| | 2025 | 20.8 | 21.7 | 21.9 | 21.8 | 0.8 |
| | Average | 20.6 | 21.4 | 21.7 | 21.6 | |
| | ± to control | - | +0.8 | +1.1 | +1.0 | |
| 'Purpletop' | 2024 | 21.4 | 21.7 | 22.0 | 21.9 | 0.4 |
| | 2025 | 20.8 | 21.7 | 21.9 | 21.8 | 0.8 |
| | Average | 21.1 | 21.7 | 22.0 | 21.9 | |
| | ± to control | - | +0.6 | +0.9 | +0.8 | |
| 'Geisha' | 2024 | 19.1 | 20.0 | 20.8 | 20.4 | 0.8 |
| | 2025 | 19.0 | 19.7 | 20.2 | 20.1 | 0.6 |
| | Average | 19.1 | 19.9 | 20.5 | 20.3 | |
| | ± to control | - | +0.8 | +1.4 | +1.2 | |
| Yield of tops, t/ha | | 28.23 | 30.15 | 31.26 | 31.33 | 1.90 |

Source: developed by the authors

Somewhat lower turnip root crop yields, although still satisfactory, were observed in variants where Confidor Maxi was used during the cultivation of the 'Purpurova' variety, and where Bitoxibacillin-BTU or Aktoverm-formula were used for the 'Geisha' variety. In these variants, the total yield of the varieties increased relative to the control by only 5-7% respectively. However, this yield increase differs slightly from the research results of V.V. Khareba *et al.* (2016) and S.V. Stankevych *et al.* (2024), where the authors recorded yield increases of up to 10%. It was established that Confidor Maxi can also be applied during turnip cultivation, as it was characterised by systemic-contact action. Due to the active ingredient imidacloprid, the pest's nervous system is blocked for 30 days, while also exerting a stimulating effect on the plant's growth processes.

In the absence of protection (control), a significant decrease in turnip root crop yield was established, amounting to 20.1 t/ha for 'Zolota Kulya', 20.6 t/ha for 'Purpurova', 21.1 t/ha for 'Purpletop', and 19.1 t/ha for 'Geisha'. Based on the plant inspections conducted, the population of adult black crucifer flea beetles in the experiment was 1-14 individuals per m². The biological products Bitoxibacillin-BTU and Aktoverm-formula are more effective in controlling the adults of the black crucifer flea beetle. Following systemic plant protection,

the pest population decreased by 92.86% for Bitoxibacillin-BTU and Aktoverm-formula, compared to 85.72% for Confidor Maxi. The positive effect of the studied preparations was also established during the growth of the plant's vegetative mass. Regardless of the insecticide used, the top yield significantly exceeded the leaf mass yield of the control variant, which also influenced the formation of the root crop and the overall yield.

A qualitative analysis of turnip root crops under the pest protection system showed its partial influence on biochemical indicators, namely the content of dry matter, starch, and protein. Under the formation of optimal open-soil growing conditions and nutrient processes, an optimal photosynthesis process, accumulation of vegetative mass, and an increase in organic matter content were observed. During turnip cultivation and the application of bacterial-origin preparations such as Bitoxibacillin-BTU or Aktoverm-formula, the dry matter content was higher relative to the control. The dry matter indicator reached levels of 16.4% and 16.3%, exceeding the control variant by 0.4-0.5% respectively. Evidently, the viable cells of *Bacillus thuringiensis* bacteria and endospores provide reliable plant protection against insect pests; simultaneously, a prolonged period of action was observed, which did not cause resistance in the insect pests (Table 5).

Table 5. Quality of root crops of the 'Zolota Kula' turnip variety depending on the use of insecticide protection (average for the years of research)

| Pest protection system | Content of biochemical substances in turnip root crops, % | | | |
|------------------------|---|-------------|------------|---------------------|
| | Dry matter | Starch | Protein | Vitamin C, mg/100 g |
| 1. Control | 15.9 ± 0.02 | 6.11 ± 0.05 | 5.2 ± 0.01 | 18.3 ± 0.03 |
| 2. Confidor Maxi | 15.7 ± 0.02 | 6.26 ± 0.04 | 5.3 ± 0.02 | 19.1 ± 0.02 |
| 3. Bitoxibacillin-BTU | 16.4 ± 0.03 | 6.29 ± 0.04 | 5.4 ± 0.03 | 19.3 ± 0.03 |
| 4. Aktoverm-formula | 16.3 ± 0.02 | 6.74 ± 0.05 | 5.4 ± 0.01 | 19.2 ± 0.03 |

Source: developed by the authors

A similar positive influence of the biological products Bitoxibacillin-BTU or Aktoverm-formula was also established during the determination of starch, protein, and vitamin C content. The timely application of these preparations within the biological protection system for the 'Zolota Kulya' turnip variety contributed to the fact that the starch indicator in the root crops can increase to levels of 6.29% or 6.74% (an increase of 3-10%); protein can reach 5.4% (a 4% increase); and the vitamin C content can rise to 19.3% or 19.2% (a 5% increase) respectively. The obtained values for the root crop quality indicators do not coincide with the data already existing in primary sources (Khareba *et al.*, 2021). Furthermore, the application of the insecticide Confidor Maxi can ensure an increase in the biochemical indicators studied relative to the control variant; however, their magnitude depends on the scheme and recommendations for its application, as confirmed by the results of M.V. Zubets *et al.* (2010). Overall, the application of biological products during turnip cultivation for pest and disease control also ensured that they are safe for humans and warm-blooded animals, as biological protection agents do not pollute the environment. Simultaneously, biological products exhibit high selectivity, are convenient for mass application, and possess inexhaustible resources for this purpose, which aligns with the assertions of L.A. Zhurakovska (2013) and key European Union food safety documents and regulations (European Commission, 2017).

The work of Z.D. Sych *et al.* (2018) emphasised the necessity of a comprehensive approach to vegetable growing, encompassing both theoretical

knowledge and practical skills. This study became an important benchmark for understanding the complexities of vegetable cultivation, and the results of the current research confirmed the need to integrate modern methodologies and technologies to increase yield and quality while simultaneously considering ecological sustainability. The research by O.Yu. Barabash *et al.* (1994) examined the biological characteristics of vegetable production and the influence of various environmental factors on crop development, which was also a significant aspect of the current study. The interaction of soil conditions, water regimes, and climatic factors mentioned in their work directly influenced the efficiency of vegetable production. The results of the current study also confirmed the importance of employing ecological methods to enhance the productivity and stability of agricultural systems. S.V. Berzina (2011) investigated the ecological aspects of the production and certification of organic food products. She focused on the implementation of environmental standards in agriculture, which became vital for improving vegetable production and its compliance with ecological certification requirements. This approach correlated harmoniously with the emphasis on ecological principles in the current study, confirming the relevance of integrating sustainable practices into modern vegetable growing to reduce negative environmental impacts and improve product quality. Broadly, the current study built upon these scientific works, highlighting the importance of both practical experience and ecological sustainability in vegetable production. The combination of modern agro-technical methods

with ecological practices ensured the sustainable development of the vegetable sector, meeting both market demands and environmental standards.

Thus, the results of the current study confirmed the high efficiency of applying biological products and modern agro-technologies in turnip cultivation. The increase in yield and the improvement of biochemical indicators – such as starch, protein, and vitamin C content – evidence the positive impact of the plant protection methods used. The application of biofungicides and bioinsecticides allows for a significant reduction in disease spread and enhances plant resistance to stress conditions. Therefore, the research results confirm the effectiveness of ecologically safe protection agents for improving the quality and productivity of turnips.

Conclusions

The application of the biofungicide Phytocide-r in turnip cultivation technology increases the root crop yield for the 'Purpletop' variety to a level of 22.2 t/ha. When growing the 'Zolota Kulya' and 'Purpurova' varieties using Phytocide-r or Mycohelp, and when growing the 'Geisha' variety, the total root crop yield increases by 0.9-1.2 t/ha. Chemical protection ensures a total root crop yield of only 21.9 t/ha. Magnicur Boost and the biofungicide Phytocide-r contribute to an increase in starch content in 'Zolota Kulya' root crops to 7.12% and 7.30% respectively, and vitamin C to 19.5 and 19.3 mg/100 g, or by 1.1 times. The 'Purpletop', 'Geisha', and 'Purpurova' turnip varieties are more resistant to infection and the further development of downy mildew. With the use of Mycohelp, the spread of the disease may not exceed 2.0-2.7%, and its development is only 0.21-0.31%. The chemical fungicide Magnicur Boost helps reduce the spread of the disease in turnip crops to 0.76%.

With the systemic application of the biological products Bitoxibacillin-BTU or Aktoverm-formula, when growing the 'Purpletop' or 'Purpurova' varieties, the root crop yield can increase to 21.6-21.7 t/ha and 21.9-22.0 t/ha respectively. The yield of turnip root crops from the use of Confidor Maxi during the cultivation of the 'Purpurova'

variety increases by only 5%, while the lowest root crop yield is obtained in the absence of insecticidal protection. The positive effect of the studied preparations was also established during the increase of the plant's vegetative mass. The top yield increases regardless of the insecticide used, which influences the formation of the root crop and the overall yield. During the application of Bitoxibacillin-BTU or Aktoverm-formula, the dry matter content in the root crops increases by 0.4-0.5% and can reach 16.4% and 16.3%. Timely application of the preparations ensures an increase in starch content in the root crops to 6.29-6.74%, or an increase of 3-10%; protein increases to 5.4%, and vitamin C content rises to 19.3-19.2 mg/100 g, or by 5% respectively.

The biological products Bitoxibacillin-BTU and Aktoverm-formula are more effective in controlling the adults of the black crucifer flea beetle. Following systemic spraying of the plants with bioinsecticides, the pest population is reduced when using Bitoxibacillin-BTU and Aktoverm-formula: adults by 92.86%; with the preparation Confidor Maxi, the reduction is 85.72% respectively. The use of biological products during turnip cultivation to control pests and diseases is a safe measure for humans and warm-blooded animals; biological protection agents do not pollute the environment. Biological products exhibit high selectivity, are convenient for mass application, and have inexhaustible resources. Further research regarding the long-term impact of biological products on soil microbiota and nitrate accumulation in turnip root crops under different crop rotation systems in Polissya conditions is promising.

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Conflict of Interest

None.

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Урожайність ріпи в умовах відкритого ґрунту Полісся за різної системи захисту рослини

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Анотація. Метою дослідження було оцінити ефективність препаратів бактеріального та хімічного походження щодо впливу на врожайність ріпи та окремі якісні показники її коренеплодів за різних систем захисту рослин. Дослідження проведено в умовах Волинської державної сільськогосподарської дослідної станції НААН у 2024-2025 роках із використанням сортів ріпи 'Золота куля', 'Пурпурова', 'Пурпулепоп' та 'Гейша'. Для захисту від хвороб застосовано хімічний фунгіцид Магнікур Буст та біопрепарати Фітоцид-р і Мікохелп (компанія ВТУ); для захисту від шкідників хімічний інсектицид Конфідор Макс і біопрепарати Бітоксацилін-БТУ й Актоверм-формула (компанія ВТУ). Контролем був варіант без обробки препаратами. Дослідження закладено в чотириразовій повторності за стандартною методикою овочівництва. Результати показали, що застосування біофунгіциду Фітоцид-р підвищило врожайність коренеплодів сорту 'Пурпулепоп' до 22,2 т/га, а сортів 'Золота куля', 'Пурпурова' та 'Гейша' (з Фітоцид-р або Мікохелп) на 0,9-1,2 т/га. Магнікур Буст і Фітоцид-р збільшили вміст крохмалю в коренеплодах сорту 'Золота куля' до 7,12-7,30 % та вітаміну С до 19,3-19,5 мг/100 г. Сорти 'Пурпулепоп', 'Гейша' та 'Пурпурова' виявилися стійкішими до переноспорозу; Мікохелп обмежив поширення хвороби до 2,0-2,7 % і розвиток до 0,21-0,31 %, а Магнікур Буст поширення до 0,76 %. Системне використання біоінсектицидів Бітоксацилін-БТУ та Актоверм-формула підвищило врожайність сортів 'Пурпулепоп' і 'Пурпурова' до 21,6-22,0 т/га, тоді як Конфідор Макс і лише на 5 %. Без інсектицидного захисту врожайність була найнижчою. Біопрепарати збільшили вміст сухої речовини до 16,3-16,4 %, крохмалю до 6,29-6,74 %, білка до 5,4 % та вітаміну С до 19,2-19,3 мг/100 г. Бітоксацилін-БТУ та Актоверм-формула виявилися ефективнішими проти імаго чорної хрестоцвітої блішки

Ключові слова: фунгіцид; інсектицид; ріпа; врожайність; коренеплід; якість; ефективність