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MONITORING THE PREVELENCE AND DEVELOPMENT OF MAJOR TOMATO DISEASES IN PROTECTED CULTIVATION

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Tomato (Solanum lycopersicum L.) is a key crop in protected cultivation, where closed-ground systems ensure high yields and year-round supply. However, intensive greenhouse practices – high plant density, stable microclimates, and continuous cultivation – create favorable conditions for pathogen development. This study investigated the prevalence, development, and harmfulness of major tomato diseases in greenhouses of LLC "Poltava-Sad" (Poltava Region, Ukraine) during 2024–2025. Phytopathological surveys identified fungal, bacterial, and mycoplasmal pathogens affecting tomatoes, including Cladosporium fulvum, Phytophthora infestans, Macrosporium solani, Pseudomonas lycopersicum, Fusarium oxysporum, and Verticillium alboatrum. Cladosporiosis exhibited the highest prevalence (21.7 %) and disease intensity (10.3 %), followed by blossom-end rot (14.9 % / 5.7 %), while late blight and verticillium wilt were less widespread due to controlled greenhouse conditions. Comparative assessment of substrate types showed higher infection levels on mineral wool compared to soil mixtures, highlighting the influence of root-zone moisture, condensation, and planting density on pathogen development. The efficacy of biological control agents was evaluated, demonstrating that biofungicides Fitosporin-M and Isokur significantly reduced the prevalence and intensity of leaf mold, late blight, and blossom-end rot, with technical efficacy ranging from 71.5 % to 79.4 %. Application of biofungicides improved physiological and biochemical processes, enhanced nutrient uptake, stimulated photosynthesis, and increased yield by 12.4–18.6 % compared to untreated controls. Results indicate that integrated disease management, combining biological agents with cultural practices and microclimate regulation, is effective, environmentally safe, and economically justified for maintaining stable yields and high-quality tomato production in protected cultivation systems.

Key words: *tomatoes, protected cultivation, pathogen, prevalence, development, biological control measures, technical efficacy.*

Носков О. С., Горяінова В. В., Станкевич С. В. Моніторинг поширеності та розвитку основних хвороб томатів у закритому ґрунті

Томат (Solanum lycopersicum L.) є ключовою культурою закритого ґрунту, де вирощування у тепличних господарствах забезпечує високі врожаї та постачання продукції продовж року. Однак інтенсивні тепличні практики – висока щільність посадок, стабільний мікроклімат та безперервне вирощування – створюють сприятливі умови для розвитку

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фітопатопатогенів. У результаті дослідження нами був проведений моніторинг поширеності та розвитку основних хвороб томатів у закритому ґрунті у ТОВ «Полтава-Сад» (Полтавський район, Полтавська область) у 2024–2025 роках. Фітопатологічні обстеження виявили грибні, бактеріальні та мікоплазмові патогени, що уражують томати, зокрема Cladosporium fulvum, Phytophthora infestans, Macrosporium solani, Pseudomonas lycopersicum, Fusarium oxysporum та Verticillium alboatrum. Найвищі показники поширеності (21,7 %) та інтенсивності розвитку (10,3 %) спостерігалися при кладоспоріозі, за яким слідувала верхівкова гниль (14,9 % / 5,7 %), тоді як фітофтороз та вертицильозне в'янення були менш поширеними завдяки контрольованим тепличним умовам. Порівняльна оцінка типів субстрату показала вищий рівень ураження томатів на мінеральній ваті порівняно з ґрунтосумішшю, що свідчить про вплив вологості зони коренів, конденсації та щільності посадки на розвиток патогенів. Оцінка ефективності біологічних засобів захисту показала, що біофунгіциди Фітоспорин-М та Ізокур значно знижують поширеність та інтенсивність розвитку кладоспоріозу, фітофторозу та верхівкової гнилі, із технічною ефективністю від 71,5 % до 79,4 %. Застосування біофунгіцидів сприяло покращенню фізіолого-біохімічних процесів у рослинах, підвищенню засвоєння елементів живлення, стимуляції фотосинтезу та формуванню зав'язей, що призвело до збільшення врожайності на 12,4–18,6 % порівняно з контролем. Результати свідчать, що інтегрована система захисту, яка поєднує біологічні засоби, агротехнічні практики та регулювання мікроклімату, є ефективною, екологічно безпечною та економічно обґрунтованою для забезпечення стабільних врожаїв і високоякісної продукції томатів у закритому ґрунті.

Ключові слова: *томати, закритий ґрунт, патоген, поширеність, розвиток, біологічні заходи захисту, технічна ефективність.*

Statement of the problem. Tomato (*Solanum lycopersicum* L.) is a key vegetable crop in protected cultivation systems, where closed ground production ensures high yields and year-round supply. However, intensive greenhouse practices – such as high plant density, stable microclimates, and limited crop rotation n– create favorable conditions for the rapid spread of plant diseases.

Fungal, oomycete, bacterial, and viral pathogens significantly reduce yield and fruit quality in closed ground conditions. Diseases including late blight, powdery mildew, gray mold, fusarium wilt, and bacterial spot are especially harmful due to high humidity and continuous cultivation cycles. Climate change, greenhouse intensification, and monoculture have further altered disease complexes and increased pathogen aggressiveness, while resistance to pesticides limits chemical control effectiveness.

At the same time, insufficient data on the prevalence and development of major tomato diseases under specific greenhouse conditions hinders the implementation of effective integrated management strategies. Therefore, systematic phytosanitary monitoring is necessary to identify dominant pathogens, track disease dynamics, and support the development of sustainable and efficient disease control measures in greenhouse tomato production.

Analysis of recent researches and publications. In recent years, significant attention has been given to the study of phytopathological conditions of tomato (*Solanum lycopersicum* L.) under protected cultivation systems, both in Ukraine and internationally. Ukrainian researchers have focused on the prevalence, development, and harmfulness of major tomato pathogens in greenhouses, as well as on integrated approaches to their control.

Serhienko and Blancard [1, p. 363–368; 2, p. p. 322–324] emphasized the dominant role of fungal and oomycete pathogens, such as *Phytophthora infestans*, *Botrytis cinerea*, and powdery mildew, in shaping the phytosanitary status of greenhouse tomatoes in Ukraine. Their studies highlight the necessity of integrated disease management systems combining chemical, biological, and agronomic methods to reduce pathogen spread and mitigate yield losses. Shattock [3, p. 944–950] and Ivanov et al. [4, p. 803–812] analyzed the epidemiology of major tomato diseases, noting that high plant density, continuous cultivation, and microclimatic stability significantly favor pathogen development and accumulation in closed systems.

Boiko [5, p. 65–72] studied the influence of greenhouse microclimate on fungal disease dynamics, demonstrating that temperature and relative humidity are critical factors affecting pathogen aggressiveness. Tkalenko and Kumar [6, 7, p. 112–119] stressed the importance of timely disease diagnosis and the use of protective measures, including fungicides, resistant cultivars, and agronomic practices, to maintain stable productivity.

International studies support these findings. Smith and Jones [8, p. 721–732] and Egel et al. [9, p. 90–97] demonstrated that controlled greenhouse microclimatic conditions, while beneficial for plant growth, can enhance pathogen development, necessitating precise monitoring and adaptive management. Petrova [10, p. 45–53] highlighted that changes in cultivation practices and climate variability are altering the structure and aggressiveness of tomato disease complexes under protected conditions. The FAO [11, p. 399–427] and Agrios [12, p. 398–401] provide comprehensive guidance on integrated pest and disease management, which remains highly relevant for greenhouse vegetable production worldwide.

Overall, both domestic and international studies underline the need for continuous monitoring of tomato diseases in closed-ground systems, the adaptation of integrated management strategies to local conditions, and the combination of chemical, biological, and cultural methods. Despite substantial progress, gaps remain in obtaining up-to-date, region-specific data on pathogen prevalence, disease dynamics, and economic impact, particularly under the evolving climatic and technological conditions of Ukrainian greenhouse production.

Objective. The aim of this study is to investigate the prevalence, development, and harmfulness of major tomato diseases in closed-ground cultivation systems. The research focuses on identifying the key fungal, oomycete, bacterial, and viral pathogens affecting greenhouse tomatoes, assessing the influence of microclimatic conditions and cultivation practices on disease dynamics, and quantifying their impact on plant growth, fruit quality, and yield. Additionally, the study evaluates the effectiveness of chemical, biological, and integrated disease management strategies and provides scientifically grounded recommendations for sustainable and region-specific approaches to disease control, ensuring stable productivity and profitability of protected tomato production.

Materials and methods. The study was conducted in experimental greenhouse facilities located in different regions of Ukraine during the 2024–2025 growing seasons in ”Poltava Sad” LLC. Commonly cultivated tomato varieties (*Solanum lycopersicum* L.) were used for all experiments. Field surveys were carried out periodically to assess the prevalence and intensity of major tomato diseases, including late blight (*Phytophthora infestans*), Cladosporium leaf spot (*Fulva fulva*), blossom-end rot (*bacterias Pseudomonas lycopersicum*), using standard phytopathological methods [13, p. 124–126; 14, p. 134–136; 15, p. p. 215–218].

Infected plant samples, including leaves, stems, and fruits, were collected and examined in the laboratory for pathogen identification based on morphological, cultural, and microscopic characteristics [16, p. 210–212; 17, p. 132–136]. Controlled experiments evaluated the effectiveness of selected fungicides, biological agents, and cultural practices such as plant spacing, irrigation regimes, and cultivar resistance for disease suppression. Treatments were arranged in a randomized complete block design with three replications, and standard agronomic practices were applied.

Disease severity was assessed at key growth stages using established disease rating scales, and yield parameters – including fruit number per plant, average fruit weight, total yield, and quality indices – were recorded. Statistical analyses were performed using correlation and regression methods to determine the relationships between disease severity and yield losses, and to assess the economic impact of pathogen infection on greenhouse tomato production [18, p. 120–122; 19, p. 26–30; 20, p. 433–437].

Summary of the main research material. In 2024–2025, studies on the species composition, prevalence, and development of tomato diseases in protected cultivation were conducted at LLC "Poltava-Sad," Poltava District, Poltava Region, Ukraine. The species composition of tomato pathogens, their distribution, and development dynamics were identified and clarified. The diseases recorded in the experimental plots are presented in Table 1.

According to the data in Table 1, a wide spectrum of pathogens affecting tomato crops was identified in the greenhouse complex of LLC "Poltava-Sad" in 2024–2025, with fungal and bacterial diseases predominating.

Cladosporiosis (*Cladosporium fulvum*) showed the highest prevalence (*P* – 21.7 %), indicating its widespread occurrence under greenhouse conditions. The high intensity of disease development (*D* = 10.3 %) reflects a significant impact on the photosynthetic leaf area, leading to reduced plant productivity.

Table 1

Species composition of major tomato diseases in protected cultivation at LLC "Poltava-Sad," 2024–2025

Disease	Causal agent	P, %	D, %
Late blight	*Phytophthora infestans*	7,8	4,0
Cladosporium leaf spot	*Cladosporium fulvum*	21,7	10,3
Macrosporiosis	*Macrosporium solani*	12,7	4,2
Damping-off	*Pythium debaryanum i Rhizoctonia solani*, bacteria *Erwinia*	9,8	2,8
Blossom-end rot	bacteria *Pseudomonas lycopersicum*	14,9	5,7
Stem	Mycoplasma organism	10,4	3,2
Verticillium wilt	*Fusarium oxysporum*, *Verticillium alboatrum*	5,6	1,5

The second most economically significant disease was blossom-end rot (*Pseudomonas lycopersicum*), with a prevalence of 14.9 % and disease development of 5.7 %, highlighting the important role of bacterial infections in reducing fruit quality, particularly under conditions of high humidity and temperature fluctuations.

Macrosporiosis (*Macrosporium solani*) – *P* = 12.7 %, *D* = 4.2 % – and stem mycoplasma infection – *P* = 10.4 %, *D* = 3.2 % – were also notable components of the phytopathological complex, indicating the significant negative effects of both fungal and mycoplasmal infections on plant health.

Damping-off, caused by fungi (*Pythium debaryanum, Rhizoctonia solani*) and bacteria (*Erwinia spp*.), and exhibited a prevalence of 9.8 % and disease development of 2.8 %, which is typical for early growth stages in dense plantings or under suboptimal microclimatic conditions.

Lower shares in the structure of phytopathogens were recorded for late blight (*Phytophthora infestans*) – 7.8 %/4.0 % and verticillium wilt (*Fusarium oxysporum, Verticillium alboatrum*) – 5.6 %/1.5 %. This is primarily explained by the controlled greenhouse environment, which suppresses the development of pathogens typical for open-field cultivation.

In conclusion, the overall phytosanitary situation in the greenhouses of LLC "Poltava-Sad" is characterized by the predominance of foliar fungal diseases (cladosporiosis, macrosporiosis) and bacterial fruit infections (blossom-end rot). To stabilize the phytosanitary condition of tomato crops, it is advisable to strengthen preventive measures aimed at regulating the microclimate, performing sanitary treatments of greenhouses, and applying biological control agents targeted against the main pathogens.

A comparative assessment was carried out to evaluate tomato infection by major diseases depending on the type of substrate used – soil mixture and mineral wool. The study aimed to determine how substrate type influences the prevalence and development of key pathogens in protected cultivation.

The data presented in Table 2 show a comparative assessment of tomato infection by major diseases depending on the type of substrate – soil mixture and mineral wool. The study allows evaluating the impact of cultivation conditions on the phytosanitary status of greenhouse crops and indicates a high infectious pressure, which, in our opinion, is likely to persist in the following years.

The highest disease prevalence and development were observed in the mineral wool variant, which may be associated with increased root-zone moisture, rapid condensation accumulation on leaves, and higher planting density.

Cladosporiosis (*Cladosporium fulvum*) was the dominant disease in both variants. Its prevalence in the soil mixture was 25.4 %, with a disease development of 15.2 %, while in the mineral wool variant it reached 29.4 % and 17.3 %, respectively. This indicates that the fungal pathogen actively develops under conditions of elevated air humidity and limited air circulation, typical of protected cultivation systems.

Late blight (*Phytophthora infestans*) had relatively low prevalence – 7.8 % in soil mixture and 9.3 % in mineral wool, with disease development of 4.0 % and 3.9 %, respectively. The minor differences suggest that this pathogen spreads less actively under a stable greenhouse microclimate, especially when humidity and ventilation are controlled.

Table 2

Prevalence and development of major tomato diseases in closed cultivation at LLC "Poltava-Sad," 2025

Disease	Soil mixture		Mineral wool	
	Prevalence, %	Development, %	Prevalence, %	Development, %
Cladosporiosis	25,4	15,2	29,4	17,3
Late blight	7,8	4,0	9,3	3,9
Blossom-end rot	15,6	3,3	16,9	4,2

Blossom-end rot (*Pseudomonas lycopersicum*) showed a moderate prevalence – 15.6 % in soil mixture and 16.9 % in mineral wool, with disease development of 3.3 % and 4.2 %, respectively. This indicates that bacterial rot is more pronounced in fruits grown on inert substrates, where nutrient imbalances, particularly calcium deficiency, can occur.

Overall, the results indicate that tomato cultivation on mineral wool is associated with a higher infectious load compared to traditional soil mixtures. This underscores the need to strengthen phytosanitary control, regularly monitor substrate moisture, conduct preventive treatments with biofungicides, and implement drip irrigation systems with microclimate control to prevent pathogen development.

One of the key directions in modern protected vegetable cultivation is the implementation of environmentally safe and energy-efficient technologies, which include the use of biological plant protection products. These preparations not only provide effective control of major tomato diseases but also help maintain the natural biocenotic balance, reduce chemical load on the environment, and improve the phytosanitary status of greenhouses.

The results of biofungicide efficacy studies are presented in Figure 1. Analysis of the data shows that treatment with biofungicidal products significantly reduced the prevalence and intensity of late blight (*Phytophthora infestans*) and leaf mold (*Cladosporium fulvum*) in tomato plants.

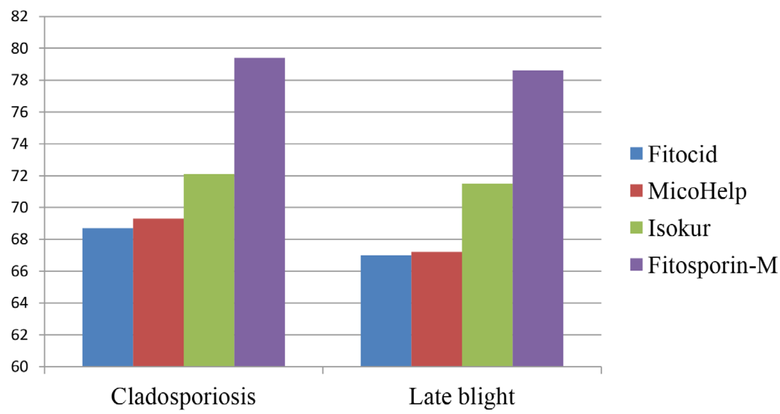

Fig. 1. Technical efficacy of biofungicides in the protection of tomatoes against major diseases, 2025

The highest technical efficacy was observed with the use of Fitosporin-M (0.5 kg/ha) and Isokur (2.5 l/ha). For leaf mold, the efficacy reached 79.4 % and 72.1 %, respectively, while for late blight it was 78.6 % and 71.5 %. This demonstrates the pronounced fungicidal activity of biological preparations, which is based on the antagonistic activity of beneficial microorganisms from the genera Bacillus and Trichoderma, suppressing pathogen development, activating plant immune responses, and stimulating growth.

The use of biofungicides reduces the number of chemical treatments required during the growing season, which is particularly important for greenhouse production, where intensive use of chemical agents may lead to the accumulation of toxic residues in the harvested produce.

Thus, the results of the study confirm that the biological preparations Fitosporin-M and Isokur exhibit high technical efficacy and can be recommended as part of an integrated tomato protection system in protected cultivation, aimed at producing environmentally safe and high-quality products.

The findings indicate that the application of biofungicides in tomato protection systems under closed-ground conditions is an effective agronomic measure, significantly reducing plant infection by major diseases compared to untreated control plots. Biological preparations contribute to the suppression of diseases such as late blight, leaf mold, and blossom-end rot by the antagonistic action of beneficial microorganisms, which inhibit pathogenic microflora, stimulate plant growth, and enhance plant immunity.

Improvement of the phytosanitary condition of crops positively affected tomato yield, as shown in Figure 2. The figure demonstrates that the use of biofungicides, particularly Fitosporin-M and Isokur, resulted in a yield increase of 12.4–18.6 % compared to the control.

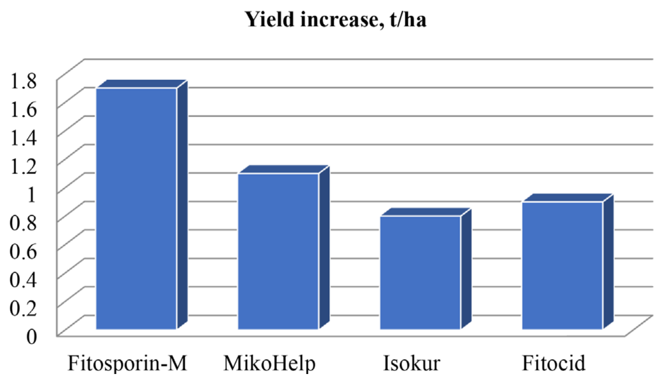

Fig. 2. Yield increase from the use of biofungicides in the protection of tomatoes against major diseases, 2025

This indicates that biological plant protection agents not only effectively suppress disease development but also contribute to the optimization of physiological and biochemical processes in plants, enhance nutrient uptake, stimulate photosynthesis, and promote fruit set. As a result, their application leads to increased productivity and improved fruit quality while reducing the pesticide load on the greenhouse ecosystem.

Thus, the use of biofungicides in greenhouse tomato production is scientifically justified and economically feasible as an integral component of integrated plant protection, ensuring stable yields and environmentally safe produce.

Conclusions. The conducted research demonstrates that tomato cultivation in protected systems is highly susceptible to a diverse range of fungal, bacterial, and mycoplasmal pathogens, with *Cladosporium fulvum, Pseudomonas lycopersicum, Macrosporium solani*, and *Phytophthora infestans* being the most prevalent and harmful. The study revealed that substrate type significantly influences disease prevalence and development, with mineral wool favoring higher infection levels due to increased root-zone moisture, condensation on leaves, and denser planting.

Application of biological control agents, specifically Fitosporin-M and Isokur, effectively suppressed major tomato diseases, reducing pathogen prevalence and intensity by up to 79.4 %, while also enhancing plant physiological and biochemical processes, nutrient uptake, and photosynthetic activity. This translated into a yield increase of 12.4–18.6 % compared to untreated controls, confirming the practical benefits of biofungicides in greenhouse tomato production.

Overall, the results indicate that integrated disease management – combining biological agents, cultural practices, and microclimate regulation – is a scientifically justified, economically feasible, and environmentally safe approach. Its implementation ensures the stabilization of phytosanitary conditions, improvement of fruit quality, and maintenance of high and sustainable yields in closed-ground tomato cultivation systems.

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