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Biological control of Alternaria and late blight of potatoes

Abstract. Infectious diseases, such as Alternaria and late blight, caused by the microorganisms *Alternaria solani* and *Phytophthora infestans*, often reduce potato yields and quality. Disease control involves the intensive use of chemical pesticides, which leads to pathogen resistance and various environmental challenges. Therefore, it is vital to investigate safe methods of plant protection. The purpose of the present study was to evaluate the effectiveness of various combinations of biological products against Alternaria and late blight of potatoes. The experiments were conducted at the Ukrainian Research Station of Plant Quarantine of the Institute of Plant Protection of the National Academy of Agrarian Sciences. Biofungicides based on micromycetes of the genera *Gliocladium* and *Trichoderm*a and bacteria of the genera *Pseudomonas* and *Bacillus* were used for the study. The use of combinations of different products included pre-planting treatment of tubers and three sprayings of vegetative plants at different stages of their growth and development. The use of biological products on potatoes reduced the spread of Alternaria by 38.7-51.2% and reduced the intensity of the disease development by 19.1-24.2% compared to the control. The technical efficiency ranged within 70.0-88.6%. The most effective combinations for disease control were Biospectrum BT + Vitastim BT, Bactofit BT + BioHibervit BT, Bactofit BT + Vitastim BT, which provided technical efficiency of 82.0-88.6%. The studied biological products also reduced the damage to plants by the pathogen of late blight. Technical efficiency under different variants of application of the preparations ranged from 61.6% (Trichopsin BT + BioHibervit BT, Fluorescin BT + BioHibervit BT) to 84.9% (Bactofit BT + Vitastim BT). The biological products had a positive effect on plant growth, yield formation, and overall productivity. The highest yield increase was observed in the variants with the use of Bactofit BT + BioHibervit BT, Trichopsin BT + Vitastim in Biospectrum BT + Vitastim BT. The studies confirmed the potential of biological products in the management of potato diseases

Keywords: biological products; fungal diseases; microorganisms-antagonists; efficiency; tubers; yield

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INTRODUCTION

Potatoes are one of the main crops and are essential for food security. Infectious diseases are among the factors that lead to lower crop yields and poorer product quality. Fungi often cause the most harmful plant pathologies. Specifically, potato plants are parasitised by the fungus *Alternaria solani* Sorauer and the oomycete *Phytophthora infestans* (Mont.) de Bary, which cause early dry spot or Alternaria and late blight, respectively (Hjelkrem *et al.*, 2021). M. Riolo *et al.* (2020) emphasised the great harmfulness of late blight worldwide, while K. Schiffer-Forsyth *et al.* (2023) estimated annual global potato yield losses and costs of late blight control at USD 3-10 billion.

R. Quds *et al.* (2023) pointed out that in potato cultivation technologies, pesticides must be used repeatedly during the growing season to control Alternaria and late blight. At the same time, according to C. Davies *et al.* (2021), the widespread use of numerous synthetic fungicides has led to the development of pathogen resistance to their active ingredients and a decrease in the effectiveness of the preparations. S. Juby *et al.* (2023) noted that to address a series of negative phenomena, the world is researching environmentally sustainable approaches to plant disease control based on biological agents. Specifically, the use of fungi of the genera *Trichoderma*, *Chaetomium*, *Pythium*, micromycetes *Gliocladium virens,* and *Coniothyrium minitans*, as well as yeast and other organisms is promising. The protective effect of biocontrol agents lies in direct antagonistic interaction or indirect interaction through induced changes in plant structure and physiology.

The findings of U. Alshimaysawe *et al.* (2024) suggest that the strains of micromycetes *T. hamatum* T8 and *T. harzianum* T5 have great potential as biocontrol agents for inhibiting the growth of pathogens in dual culture and culture filtrate methods, specifically, potato pathologies caused by *R. solani*. J. Hao *et al.* (2024) found an inhibitory effect of the fermentation broth of bacteria *Bacillus subtilis* ZWZ-19 (B) and fungus *Trichoderma asperellum* PT-29 (T) on the pathogen *Fusarium oxysporum*. The effect was better when co-cultivated with a 1:1 inoculation ratio (B1T1). M. Shuang *et al.* (2022) established the ability of the *Bacillus* sp. strain K-9 to inhibit *in vitro* the common potato scab pathogen (*Streptomyces scabies*). In addition, the studied strain K-9 inhibited the growth of the pathogen of black scab of potatoes at 70.39%. In field trials, the protective effect of the K-9 strain against potato scab did not differ significantly from the effectiveness of a mixture of bacteria or chemicals, but the disease index under K-9 treatment was significantly lower than in the control. The potato yield under the treatment with *Bacillus* sp. K-9 was 12.44% greater than in the control. H. Jabnoun-Khiareddine *et al.* (2023) found antifungal activity against a series of potato pathogens (*Fusarium oxysporum f. sp. tuberos*, *Rhizoctonia solani, Colletotrichum coccodes*) of strains SV39 and SV104 (*B. tequilensis*), SV41 (*B. subtilis*), SV44 (*B. methylotrophicus*) and SV65 (*B. amyloliquefaciens subsp. plantarum*). Field studies showed that soil treatment with *Bacillus* spp. strains provided substantial control of fungal diseases and improved potato growth and productivity parameters.

F. Fathi *et al.* (2021) investigated the ability of the bacterium *Pseudomonas fluorescens* VUPF506 to effectively suppress the causative agent of potato black scab, the fungus *Rhizoctonia solani*. X. Shi *et al.* (2024) established the growth stimulation and biological control of fungal diseases of another solanaceous crop, tomatoes, using the rhizobacterium *Pseudomonas chlororaphis subsp. aureofaciens* SPS-41. Specifically, the antifungal properties were manifested against the phytopathogenic fungi *Fusarium oxysporum* and *Botrytis cinerea*. S. Feng *et al.* (2021) identified a rare strain of the actinomycete *Saccharothrix texasensis* 6-C, which was isolated from the potato rhizosphere and proved its ability to inhibit *P. infestans.* L. Zhang *et al.* (2024) observed a reduction in Alternaria leaf spot index from 78.36 to 37.03% in potato plants treated with *Talaromyces muroii* strain SD1-4, along with significantly improved growth characteristics, including plant height, root length, fresh weight, dry weight, chlorophyll content, and photosynthetic rate.

Thus, considering the significance of potatoes as a valuable food crop in the world and in Ukraine and the harmfulness of Alternaria and late blight, it is vital to investigate the effectiveness of plant protection products based on biological control agents. The purpose of the present study was to investigate the effectiveness of various combination schemes of biological products against the main diseases of potatoes – Alternaria and late blight.

MATERIALS AND METHODS

Field studies were conducted during 2020-2021 at the Ukrainian Research Station of Plant Quarantine of the Institute of Plant Protection of the National Academy of Agrarian Sciences. The soil of the experimental plot was grey forest heavy loam. To protect potatoes from Alternaria and late blight, the technical effectiveness of a series of biological products was investigated. Gliocladin BT is a biological product based on mycelium and spores of a micromycete from the genus *Gliocladium* with a titre of at least 1.5×10^9 CFU/cm^3; biologically active substances. Trichopsin BT contains mycelium and spores of micromycetes of the genus *Trichoderma*; rhizosphere bacteria of the genus *Pseudomonas* with a titre of at least 2.0×10^{10} CFU/cm^3, biologically active substances. Fluorescin BT is a preparation based on a bacterium of the genus *Pseudomonas* with a titre of at least 5.0×10^9 CFU/cm^3; biologically active substances (phenazine-carboxylic acids, siderophores, cytokinins). Biospectrum BT consists of rhizosphere bacteria of the genus *Pseudomonas* with a titre of at least 5.0×10^9 CFU/cm^3, biologically active substances (acids of the genus phenazine-carboxylic, a complex of active pigments). Bactofit BT contains live cells and spores of bacteria of the genus *Bacillus* with a titre of at least 2.0×10^9 CFU/cm^3. BioHibervit BT consists of chlamydospores, mycelium, and conidia of *Trichoderma* micromycetes, as well as their metabolites. Vitastim BT is a preparation based on the joint deep cultivation of three strains of fungi and bacteria of the genera *Trichoderma* and *Pseudomonas* in liquid nutrient medium.

Field studies, disease diagnostics, evaluation of the technical effectiveness of biological preparations, and structural analysis of the crop were conducted according to generally accepted methods (Trybel *et al*., 2001; Kyryk *et al*., 2012). The potato variety Podolyanka was cultivated. The experimental design included the variants presented in Table 1. Tubers were treated before planting potatoes at the rate of 20 litres of working solution per 1 tonne. The vegetative plants were treated with a battery-powered backpack sprayer FORTE KF-16 during the following periods of plant growth and development: at the beginning of plant closure in the row; in the budding phase; in the flowering phase. Combinations of preparations were applied at the rate of 200 litres of working solution per 1 ha.

Table 1. Scheme of the experiment to investigate the effectiveness of combinations of biological products against potato diseases

No. of experiment variant	Treatment of tubers before planting	Spraying of plants during the growing season (3 times)
1	Control (without preparations)	
2	Gliocladin BT, 1.5 l/t + BioHibervit BT, 1.5 l/t	Gliocladin BT, 3 l/ha + BioHibervit BT, 3 l/ha
3	Trichopsin BT, 1.5 l/t + BioHibervit BT, 1.5 l/t	Trichopsin BT, 3 l/ha + BioHibervit BT, 3 l/ha
4	Fluorescin BT, 1.5 l/t + BioHibervit BT, 1.5 l/t	Fluorescin BT, 3 l/ha + BioHibervit BT, 3 l/ha
5	Biospectrum BT, 1.5 l/t + BioHibervit BT, 1.5 l/t	Biospectrum BT, 3 l/ha + BioHibervit BT, 3 l/ha
6	Bactofit BT, 1.5 l/t + BioHibervit BT, 1.5 l/t	Bactofit BT, 3 l/ha + BioHibervit BT, 3 l/ha
7	Gliocladin BT, 1.5 l/t + Vitastim BT, 1.5 l/t	Gliocladin BT, 3 l/ha + Vitastim BT, 3 l/ha
8	Trichopsin BT, 1.5 l/t + Vitastim BT, 1.5 l/t	Trichopsin BT, 3 l/ha + Vitastim BT, 3 l/ha
9	Fluorescin BT, 1.5 l/t + Vitastim BT, 1.5 l/t	Fluorescin BT, 3 l/ha + Vitastim BT, 3 l/ha
10	Biospectrum BT, 1.5 l/t + Vitastim BT, 1.5 l/t	Biospectrum BT, 3 l/ha + Vitastim BT, 3 l/ha
11	Bactofit BT, 1.5 l/t + Vitastim BT, 1.5 l/t	Bactofit BT, 3 l/ha + Vitastim BT, 3 l/ha

Source: developed by the authors based on the findings

Statistical processing of experimental data was performed using Microsoft Office® for Microsoft Windows®. The study followed the ethical standards specified in the Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973).

RESULTS AND DISCUSSION

One of the ways to protect potato plants from pests in an environmentally friendly way is to use biological products. Thus, during 2021-2022, the study investigated various schemes of combinations of biological products based on microorganisms, their metabolites, and biologically active substances against the most widespread potato diseases during the growing season – Alternaria and late blight. The treatment of potato tubers before planting and threefold spraying of plants led to a decrease in the spread and development of Alternaria on the aboveground organs in all variants of the experiment (Fig. 1). Specifically, the number of diseased plants was less by 38.7-51.2%, and the degree of damage decreased within 19.1-24.2% compared to the control, where these indicators were 65.8% and 27.3%, respectively. Preparations based on fungi of the genera *Gliocladium* and *Trichoderma* and bacteria of the genera *Pseudomonas* and *Bacillus* provided technical efficiency against Alternaria within 70.0-88.6%. Mixtures of Biospectrum BT + Vitastim BT, Bactofit BT + BioHibervit BT and Bactofit BT + Vitastim BT had the greatest effect on reducing the damage to potato plants by the pathogen (technical efficiency – 82.0-88.6%).

The studied biological products also had a fungicidal effect on potato late blight, which was manifested in a decrease in the spread of the disease by 23.3-37.2% and a decrease in its development within 11.4-15.7% (Fig. 2). In the variants with the use of mixtures of Bactophyte BT (*Bacillus* spp.) + Vitastim BT (*Trichoderma* spp., *Pseudomonas* spp.), Biospectrum BT (*Pseudomonas* spp.) + Vitastim BT (*Trichoderma* spp., *Pseudomonas* spp.), Trichopsin BT (*Trichoderma* spp., *Pseudomonas* spp.) + Vitastim BT (*Trichoderma* spp., *Pseudomonas* spp.) and Bactophyt BT (*Bacillus* spp.) + BioHibervit BT (*Trichoderma* spp.) showed the maximum effect on reducing the intensity of late blight development. Technical efficiency under different variants of application of the preparations ranged from 61.6% (Trichopsin BT + BioHibervit BT, Fluorescin BT + BioHibervit BT) to 84.9 % (Bactofit BT + Vitastim BT).

The use of biological products in the treatment of potato tubers and spraying of plants during the growing season positively influenced plant growth, yield formation, and generally increased crop productivity (Fig. 3). Depending on the biological products used, potato growth was stimulated. Specifically, compared to the control, the height of plants in different variants was 1.9-6.7 cm higher. Under the influence of the studied biological preparations, the total number of tubers increased by 0.4-8.5 per plant. Therewith, the marketable fraction increased, depending on the variant, from 1.3 to 4.5 pieces per plant. The greatest increase in potato yield was observed in the variants Bactophyt BT + BioHibervit BT – 14.0 t/ha, Trichopsin BT + Vitastim BT – 14.7 t/ha, and Biospectrum BT + Vitastim BT – 15.0 t/ha. The increase in potato yield in other variants with the use of biological products ranged within 4.4-12.8 t/ha.

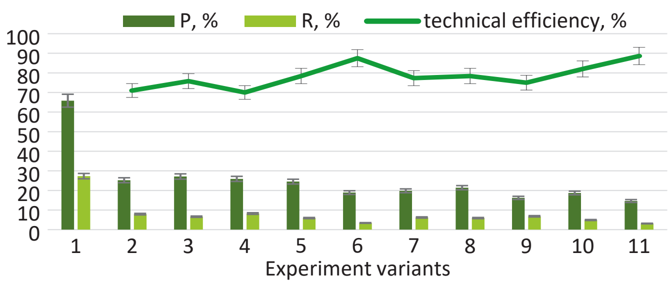

Figure 1. Efficiency of biological products against potato Alternaria (average for 2021-2022)
Note: P – disease spread; R – disease development
Source: developed by the authors based on the findings

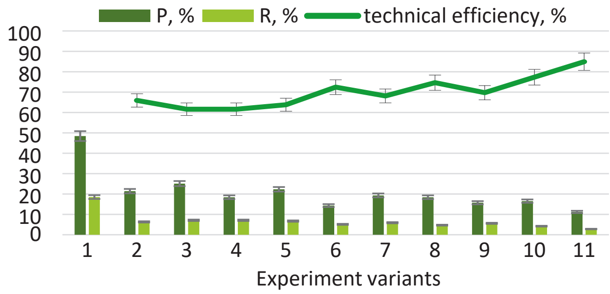

Figure 2. Efficiency of biological products against potato late blight (Podolyanka variety, average for 2021-2022)

Note: P – disease spread; R – disease development

Source: developed by the authors based on the findings

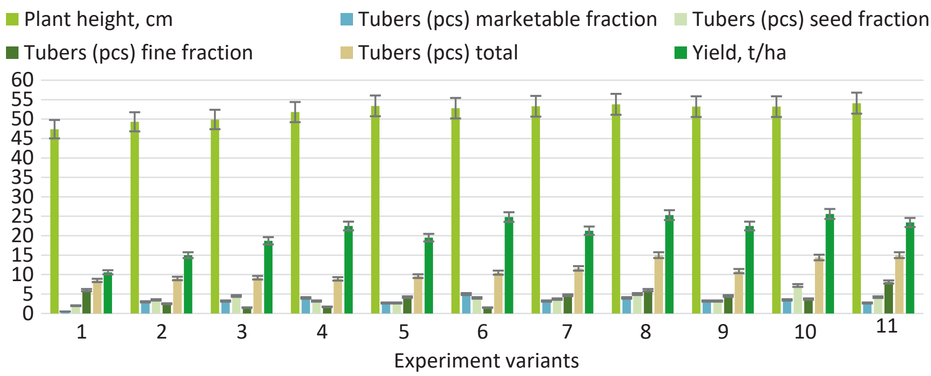

Figure 3. Influence of fungicidal and stimulating biological preparations on the indicators of structure elements and yield of potato tubers (average for 2021-2022)

Source: developed by the authors based on the findings

The conducted studies confirmed the results obtained in different regions of potato cultivation using biological products and antagonist microorganisms (Tleuova *et al.*, 2020). N. Rokaya *et al.* (2023) tested isolates of *Trichoderma* spp. against the potato late blight pathogen. Their effectiveness was manifested in a decrease in the size of the pathogen lesion area by 19-46% compared to the control. It was found that isolates of *Trichoderma* spp. together with the commercial product Sanjeevni (based on *T. viride*), in field experiments on a natural infection background stimulated plant growth, tuber yield, and reduced the development of late blight. Specifically, *Trichoderma* isolates TL1-2A, TL4-81A, and TL5-21A reduced the intensity of the disease by 37.3%, 37.2%, and 30.4%, respectively. According to the findings of two-year studies, isolate TL1-2A increased tuber yield by 46.4%. S. Kumar *et al.* (2023) found that biopriming of potato tubers by a microbial consortium (*T. viride*, *B. subtilis*, *P. fluorescens*) improved plant growth and induced defence responses against *A. solani*, which was conditioned by the induction of systemic resistance.

In laboratory experiments conducted by M. Sulaiman *et al.* (2020), the inhibition of the pathogen of soft rot of potato tubers – *Erwinia carotovora*, subsp. *carotovora* – by *Trichoderma* spp. isolates was proved. A decrease was also found in the damage of tubers treated with *T. viride* (TV3) and *T. harzianum* (TH2), respectively, by 20.27% and 16.47%, compared to the control. Yu. Kolomyets & L. Butsenko (2023) emphasised that soft rot pathogens are the primary reason for limiting potato production in many regions around the world. J. Leiminger & H. Hausladen (2012) noted that parasitism of potato plants by *A. solani* can lead to a 50% yield loss. M. Solomiychuk *et al.* (2024) used the biological product PhytoDoctor (*Bacillus subtilis*), 2 l/ha in combination with Humat Ultra, 60 g/ha in the conditions of Ukraine and noted a decrease in the development of Alternaria by 54.9% compared to the control.

I. Debez *et al.* (2024) found endophytes of *Bacillus* (*B. halotolerans* SpS5, *B. amyloliquefaciens* LiR9, *B. haynesii* ReR10, *B. velezensis* KnL15, *B. aryabhattai* FaR1) to have an antagonistic effect against the fungus *R. solani*, the causative agent of potato black scab. The vegetative and spore-forming strain SpS5, as well as 5 other *Bacillus* and their Sps5-based consortia were effective in reducing disease development and increasing the yield of healthy, high-quality potato tubers. The results of the study of the effectiveness of various biological products suggest the possibility of their use for the protection of potatoes against Alternaria and late blight. The studied biological agents had a protective effect on potato plants, which was manifested in a decrease in their damage by pathogens compared to the control. In addition, the mechanisms of plant growth and development were activated, and the yield increased.

CONCLUSIONS

As a result of the study, the use of combinations of various biological preparations based on microorganisms, their metabolites, and biologically active substances was found to decrease the spread and development of potato diseases on the aboveground organs of plants in all variants of the experiment. Treatment of potato tubers before planting and threefold spraying of plants during the growing season reduced the spread of Alternaria by 38.7-51.2% and reduced the intensity of plant damage within 19.1-24.2% compared to the control. Biological products provided technical efficiency against Alternaria in the range of 70.0-88.6%.

The investigated biological products reduced the spread of late blight within 23.3-37.2% and limited the intensity of the disease by 11.4-15.7%, while their technical efficiency ranged within 61.6-84.9%. The use of biological products positively influenced the growth of potato plants, the formation of the crop and, as a result, the overall productivity. Specifically, the height of plants in different variants was 1.9-6.7 cm higher compared to the control. Under the influence of the studied biological preparations, the total number of tubers increased by 0.4-8.5 per plant. The marketable fraction increased, depending on the experimental variant, from 1.3 to 4.5 pieces per plant. The highest increase in tuber yield was observed in the variants with the introduction of biological products Bactophyt BT + BioHibervit BT – 14.0 t/ha, Trichopsin BT + Vitastim BT – 14.7 t/ha and Biospectrum BT + Vitastim BT – 15.0 t/ha.

In further research, it will be significant to assess the technical effectiveness of biological products under different meteorological conditions, as well as on potato varieties with different resistance, which will allow establishing the best combinations of biological control agents and improve the scheme of their application. Overall, the findings of the study confirmed the ability of biological products to control Alternaria and late blight of potatoes, which is relevant in modern agrarian production.

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None.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Біологічний контроль альтернаріозу та фітофторозу картоплі

Анотація. Інфекційні хвороби – альтернаріоз і фітофтороз, викликані мікроорганізмами *Alternaria solani* і *Phytophthora infestans*, – часто знижують урожайність і якість картоплі. Контроль захворювань передбачає інтенсивне використання хімічних пестицидів, що призводить до виникнення резистентності патогенів і різних екологічних викликів. Тому актуальним є вивчення безпечних методів захисту рослин. Метою дослідження була оцінка ефективності різних комбінацій біологічних препаратів проти альтернаріозу та фітофторозу картоплі. Експерименти проводили в умовах Української науково-дослідної станції карантину рослин Інституту захисту рослин Національної академії аграрних наук. Для досліджень використовували біофунгіциди на основі мікроміцетів родів *Gliocladium* і *Trichoderma* та бактерій родів *Pseudomonas* і *Bacillus*. Застосування комбінацій різних препаратів включало передпосадкову обробку бульб і три обприскування вегетуючих рослин на різних етапах їх росту та розвитку. Використання біопрепаратів на картоплі зменшувало поширення альтернаріозу на 38,7-51,2 % та знижувало інтенсивність розвитку хвороби в межах 19,1-24,2 % порівняно з контролем. При цьому технічна ефективність становила від 70,0 до 88,6 %. Найбільш дієвими комбінаціями для обмеження хвороби були Біоспектр БТ + Вітастим БТ, Бактофіт БТ + БіоГіберввіт БТ, Бактофіт БТ + Вітастім БТ, які забезпечували технічну ефективність 82,0-88,6 %. Досліджувані біопрепарати також зменшували ураження рослин збудником фітофторозу. Технічна ефективність за різних варіантів застосування препаратів становила від 61,6 % (Трихопсин БТ + БіоГібервіт БТ, Флуоресцин БТ + БіоГібервіт БТ) до 84,9 % (Бактофіт БТ + Вітастим БТ). Біологічні препарати позитивно впливали на ріст рослин, формування врожаю та загальну продуктивність. Найбільший приріст урожаю спостерігали у варіантах із застосуванням Бактофіт БТ + БіоГібервіт БТ, Трихопсин БТ + Вітастим в Біоспектр БТ + Вітастім БТ. Проведені дослідження підтвердили потенціал біопрепаратів в управлінні хворобами картоплі

Ключові слова: біопрепарати; грибні хвороби; мікроорганізми-антагоністи; ефективність; бульби; урожайність