# TECHNOLOGY EFFICIENCY OF BIOLOGICAL CONTROL OF PLUM PESTS BY COMPLEX MICROBIAL PREPARATION

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**Abstract.** In the article the research results are presented on the efficiency of a biological control technology of plum trees, infected with the dominant plum pests, using a complex microbial preparation. The preparation was based on microbial strains with fungicidal (*Pseudomonas aureofaciens*) and insecticidal (*Streptomyces avervitilis*) properties, which were stored in the Microbial Culture Collection of the Engineering Technological Institute "Biotekhnika" of the National Academy of Agrarian Sciences of Ukraine. Both microbial strains were cocultured on a liquid growth medium for the complex microbial preparation. The field trials were carried out in 2021-2023 on the right-bank side of the Western Forest-Steppe of Ukraine in the plantations of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine on plum trees of the Stanley variety against the main pests: gray bud weevil *Sciaphobus squalidus*, plum codling moth *Grapholita funebrana*, plum pollinated aphid *Hyalopterus pruni*, and black plum sawfly *Hoplocampa minuta*. The technology was to be affected as 2-6 sprayings of the plum plants with the complex microbial preparation, depending on the type of the pest. Counting of the pest distribution was made before and after the treatment. The test results showed that applying the complex preparation significantly reduced the number of major plum pests. The efficiency of the technology ranged from 57.1% to 89.4% depending on the type of the pest. This confirms its practicability for biological control of fruit pests by a novel complex microbial preparation under the conditions of organic gardening. The high efficiency of the preparation can be explained by synergic action of the microorganisms with different taxonomic status on pests. The application of the complex preparation makes it possible to expand the range of the biological plant protection products and save the natural environment.

**Keywords:** complex microbial preparation, technical efficiency, protection technology, plum pests, fruit damage, shoot infestation, phenophases.

## Introduction

Growing plant products in Europe is a traditional activity, practised not only by large agro-industrial enterprises but also by small farms and private people, and plant protection is a priority for all those working on the land. Plant protection is a top priority. Unfortunately, farmers use chemical protection for this purpose without thinking about the negative consequences. And this leads to the fact that excessive enthusiasm for chemical methods of plant protection entails an increase in threatening phenomena in agrocenoses, associated with the pollution of plants, soils, water and the food products with the residues of chemical pesticides, a decrease in the resistance of harmful objects to protective agents, and violation of the stability of ecosystems because of the loss of a part of the microbiota as a result of the action of chemicals [1; 2].

This has a direct and negative impact upon the human health and the environment. Biological preparations may be an alternative to chemical plant protection against diseases and pests. They are based on living microorganisms, isolated from nature and/or their metabolites, which are harmless to the environment, humans, warm-blooded animals and beneficial fauna [3-6].

Among the biological agents that have found the most practical application for biocontrol of the plant diseases in the home country and abroad, the leading role belongs to such fungi as: *Trichoderma viride, Ampelomyces Artemisia, Gliocladium rozeum* and others, which are capable of stimulating the plant growth, inducing their resistance to phytopathogens, and competing with nutrients [7].

Fungi have the widest range of antagonistic properties against other groups of microorganisms. Bacterial microorganisms compete with fungal microorganisms. There is known the ability of the oil bacteria of the genus *Pseudomonas* to synthesize a wide range of substances that stimulate the plant root formation, in particular, cytokinins, vitamins, polysaccharides, free amino acids, etc. [8]. In addition, the microorganisms of this group are natural antagonists that are capable of activating the natural non-specific resistance of plants to phytopathogens and unfavorable climatic conditions, ensuring the polyfunctionality of biological preparations, based on these bacteria [6]. Many researchers pay attention to the use of bacteria of the genus *Pseudomonas* as a means of controlling the plant pathogens [8]. Of particular interest among bacteria of this genus is *Pseudomonas aureofaciens* Kluyv since this bacterium combines both an antagonistic effect upon a number of bacterial and fungal pathogens of plants and an insecticidal effect upon insects [9-11]. Work is currently underway in Latvia and Ukraine to create microbial preparations, using this bacterium. The result of such work was the creation of a microbiological preparation of complex action *Trichopsin BT*, capable of affecting the codling moth and a complex of pathogens, found in the agrocenosis of the apple orchards [4].

Many researchers are attracted also by the ray fungus *Streptomyces avermitilis*, which is classified as a soil actinomycete, capable of producing a complex of natural avermectins with a toxigenic effect. Avermectins block the transmission of the nerve impulses in insects, which, in turn, causes their paralysis [12]. This property of the ray fungus *Streptomyces avermitilis* is used to protect the plants from harmful insects and may serve as the basis for the creation of complex microbial preparations [5].

Plum is one of the most productive and widespread fruit crops, and it occupies the leading place in modern intensive plantations. Increasing the yield and quality of fruits is possible by reducing the losses caused by a complex of pests [13-14].

According to a FAO research report on the impact of climate changes upon the pest distribution in 2020 in Central Asia, the Caucasus and South-Eastern Europe, the losses of yield of major agricultural crops due to the pests are estimated at 40%. The losses of crops because of the climate changes are predicted to increase by 10-25% [15].

In Germany in 2001-2003 the losses of wheat, rice, corn, potatoes, soybeans and cotton due to the pests amounted to 18% [16].

**Materials and methods**

Research is currently underway to create a complex preparation of an insecticidal-fungicidal effect. The basis of the preparation is a strain of microorganisms with fungicidal properties (*Pseudomonas aureofaciens*) and a strain of microorganisms with pronounced insecticidal properties (*Streptomyces avervitilis*), stored in the Collection [4].

Investigations of the efficiency of a complex microbial preparation (CMP) were conducted in various regions to assess the efficiency of the preparation against the main pests in diverse soil and climatic conditions in the plum plantations of the *Stanley* variety. This CMP was developed by combining the strains of *Pseudomonas aureofaciens* and *Streptomyces avermitilis*. The plantations were divided into the control (reference) and the experimental groups. The control group was treated with the traditional chemical pesticides but the experimental group with the developed CMP. Regular observations and data collection were made about the spreading of the pests and diseases, as well as about the quality and quantity of the crop.

It should be noted that gardening is an industry where chemical pesticides are used intensively. However, in order to obtain ecologically safe fruit products, the strategy for protecting orchards should be based on strengthening the ecological approach to the development and implementation of protective measures with the maximum use of biological agents [17-18].

One of the most common stone fruit species is the plum which is widely distributed in Latvia and Ukraine. Due to the early fruiting and adaptation to diverse soil and climatic conditions, the plum plantations are located in all regions [19].

The weather conditions significantly affect the population density, harmfulness and distribution of pests. The low temperatures (+0-5°C) cause temporary rigor mortis in the insect pests. At low temperatures the physiological processes proceed slowly, and the development period of the preimaginal stages is noticeably extended. A small increase to +7-10°C raises their motor activity, and with a further increase they feed and reproduce.

Among the main weather conditions, average air temperature and precipitation are of decisive importance in the development of the plum pests [20]. To fully understand the weather conditions, we will disclose their significance for the area where these investigations are being conducted. In April the air temperatures were close (2021) or exceeded the norm in 2022 and 2023 (Table 1).

Table 1

**Meteorological factors in 2021-2023**

| Year | Basic indicators | Month | | | | | |
|---|---|---|---|---|---|---|---|
| | | **April** | **May** | **June** | **July** | **August** | **September** |
| 2021 | Average air temperature, °C | 7.9 ± 0.6 | 14.7 ± 0.5 | 21.7 ± 0.7 | 25.0 ± 0.4 | 21.4 ± 0.6 | 13.4 ± 0.7 |
| | Total precipitation, mm | 2.6 | 34.8 | 16.7 | 33.6 | 57.6 | 11.2 |
| 2022 | Average air temperature °C | 8.2 ± 0.7 | 14.8 ± 0.5 | 22.1 ± 0.6 | 21.0 ± 0.5 | 22.6 ± 0.4 | 12.7 ± 0.4 |
| | Total precipitation, mm | 19.0 | 26.3 | 23.5 | 24.0 | 21.2 | 36.5 |
| 2023 | Average air temperature °C | 9.7 ± 0.5 | 16.7 ± 0.7 | 20.1 ± 0.7 | 21.0 ± 0.5 | 24.0 ± 0.6 | 19.2 ± 0.3 |
| | Total precipitation, mm | 59.2 | 0.6 | 38.1 | 72.7 | 8.6 | 7.1 |
| Medium perennial 1991-2020 | Average air temperature °C | 7.8 | 14.9 | 18.3 | 20.0 | 18.8 | 13.9 |
| | Total precipitation, mm | 47.0 | 53.0 | 76.0 | 84.0 | 63.0 | 47.0 |

The amount of precipitation during this period exceeded long-term indicators in 2023, and a deficit was noted in 2021 and 2022. During the summer period, from June to August, the amount of precipitation was 22, 40 and 91, and the air temperature increased by 119, 125 and 114%, compared to the long-term indicators.

## Results and discussion

The trees were sprayed twice against the black plum sawfly, before flowering in the phenophase BBCH 59 and after flowering BBCH 69. The results of the investigations showed that the ovary damage ranged from 0.6 to 11.7% (Table 2).

Higher technical efficiency was observed in 2023 with a biopreparation consumption of 6.5 $l \cdot ha^{-1}$ and varied over the years from 34.0 to 66.5% (Table 3). A low protective effect against the phytophage of 24.5% was obtained in 2021 at a rate of 5.0 $l \cdot ha^{-1}$. Analysis of variance showed that the population density and harmfulness of the phytophage depended 62.7% on the preparation and only 11.3% on the weather conditions (Fig. 1).

The interaction of the investigated factors is 18.9%, and it is manifested because of the fact that with an increase in precipitation, regardless of the rate of application of the preparation, the complex influence of the weather upon the efficiency of the use of CMP essentially increases.

Among the plum insects-pests, the new biopreparation best controls *H. pruni*, which has a sucking mouth apparatus. The highest mortality of larvae (89.4%) was observed in 2021 when using 8.0 $l \cdot ha^{-1}$ of the product. The lowest efficiency of 48.2% was shown by the preparation in 2023 at a consumption rate of 5 $l \cdot ha^{-1}$. As a result of the dispersion analysis, it was established that the preparation influences the population density of the phytophage, its share is 52.3%, the weather factors 18.5%. The interaction of the factors is 23.2%, and this is due to the weather conditions against the background of the consumption rates of the preparation when in 2021 and 2023 the technical efficiency against aphids was noted at the level of 72.5-75.8 and 48.2-67.2%.

Table 2

**Distribution and harmfulness of the dominant plum phytophages under the influence of the complex microbial preparation in 2021-2023**

| Year | Option | Consumption rate, $ha^{-1}$ | Indicator | | | |
|---|---|---|---|---|---|---|
| | | | Black plum sawfly, ovaries damaged, % | Plum pollinated aphid, moving forms, specimen/ shoot | Plum moth, fruits damaged, | Gray bud weevil, adult/tree |
| 2021 | Control | – | 25.3c | 190.0d | 23.3c | 5.7b |
| | BI-58 new, 40% k.e. | 2.0 | 13.0ab | 3.5a | 6.7a | 2.5a |
| | CMP | 5.0 | 17.1b | 50.2c | 13.3b | 4.1ab |
| | CMP | 6.5 | 11.7a | 45.9c | 16.7b | 3.5a |
| | CMP | 8.0 | 14.2ab | 20.2b | 10.0ab | 3.2a |
| 2022 | Control | – | 8.0c | 240.8d | 9.5c | 4.3b |
| | BI-58 new, 40% k.e. | 2.0 | 1.8a | 4.7a | 2.5a | 1.4a |
| | CMP | 5.0 | 5.9bc | 110.7c | 5.8b | 2.6ab |
| | CMP | 6.5 | 3.8ab | 58.9bc | 4.4ab | 1.8a |
| | CMP | 8.0 | 4.5abc | 27.8b | 3.9ab | 2.0a |
| 2023 | Control | – | 2.0b | 1047.3d | 14.9b | 11.0b |
| | BI-58 new, 40% k.e. | 2.0 | 0.1a | 3.0a | 5.1a | 3.0a |
| | CMP | 5.0 | 1.0ab | 542.3c | 5.7a | 3.5a |
| | CMP | 6.5 | 0.6a | 334.3b | 6.6a | 4.7a |
| | CMP | 8.0 | 1.3a | 343.0b | 8.8a | 4.3a |

Note: abcd – values, denoted by different letters, are essentially different at $p < 0.05$

Table 3

**Technical efficiency of the complex microbial preparation against the dominant phytophages of the plum variety Stanley in 2021-2023**

| Year | Option | Consumption rate, $ha^{-1}$ | Technical efficiency, % | | | |
|---|---|---|---|---|---|---|
| | | | Black plum sawfly | Plum pollinated aphid | Plum moth | Gray bud weevil |
| 2021 | BI-58 new, 40% k.e. | 2.0 | 48.6 | 98.2 | 71.2 | 56.1 |
| | CMP | 5.0 | 24.5 | 73.6 | 42.9 | 28.1 |
| | CMP | 6.5 | 34.0 | 75.8 | 28.3 | 38.6 |
| | CMP | 8.0 | 27.7 | 89.4 | 57.1 | 43.9 |
| 2022 | BI-58 new, 40% k.e. | 2.0 | 77.5 | 98.0 | 73.7 | 67.1 |
| | CMP | 5.0 | 38.7 | 54.0 | 40.0 | 40.0 |
| | CMP | 6.5 | 52.5 | 75.5 | 29.5 | 58.5 |
| | CMP | 8.0 | 43.7 | 88.5 | 58.9 | 46.9 |
| 2023 | BI-58 new, 40% k.e. | 2.0 | 13.0 | 3.5 | 6.7 | 2.5 |
| | CMP | 5.0 | 50.0 | 48.2 | 61.7 | 68.2 |
| | CMP | 6.5 | 66.5 | 68.1 | 55.7 | 37.3 |
| | CMP | 8,0 | 33.5 | 67.2 | 27.5 | 60.9 |

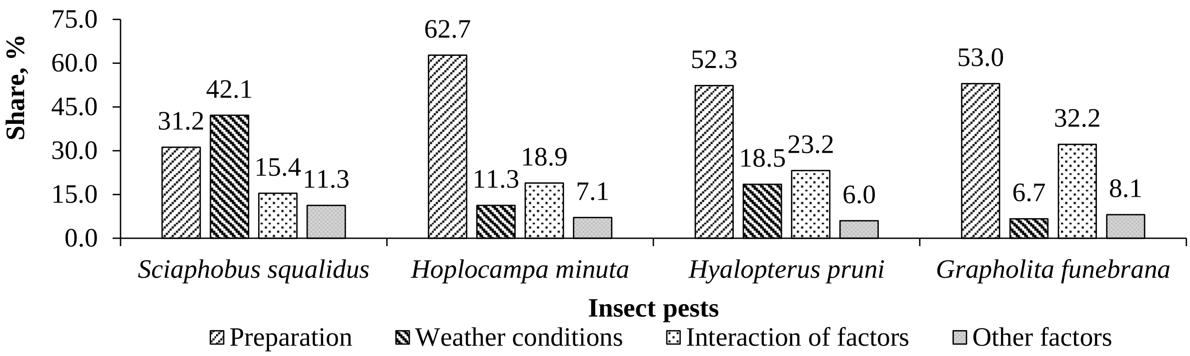


Fig. 1. **Influence of the factors to be studied upon the population density and harmfulness of the main pests of the *Stanley* plum variety in 2021-2023**

Testing of the new preparaion showed good efficiency against the plum codling moth. Considering that caterpillars lead a hidden lifestyle, they are vulnerable to the action of the preparaion only for a short time that passes from the moment when they hatch from eggs until they are implanted into the fruit. For high-quality protection of plums from *G. funebrana*, 4 (2021 and 2022) to 6 (2023) sprayings are required. During the research period the average efficiency against the phytophage was 42.9-57.1% (Table 3), with the fruit damage of 13.3 and 10.0% (Table 2). High efficiency against the codling moth was observed in 2023 at a level of 61.7% (5.1% of damaged fruits were found) at the 5.0 $l \cdot ha^{-1}$application rate of the preparation. A low protective effect of 27.5% (the fruit damage 8.8%) was observed in 2023 with a product consumption of 8.0 $l \cdot ha^{-1}$. By the factor analysis it was found that the population density and harmfulness of phytophages depend on the preparation by 53.0% (Fig. 1). The interaction of the factors "preparation" and "weather conditions" is essential, their share is 32.2%. The preparation at application rates of 5.0 and 6.5 $l \cdot ha^{-1}$, when used against *G. funebrana*, is very sensitive to weather conditions when the efficiency varied widely between 40.0-61.7 and 28.3-55.7%.

The grey bud weevil is a polyphagous insect; starting from the BBCH 53 phenophase, the beetles gnaw out large holes in the buds. In the absence of protective measures and with the onset of warm weather, their harmfulness increases. After a single spraying of the plums the highest technical efficiency of the biopreparation was 68.2, and the lowest was 28.1% at a consumption rate of 5.0 $l \cdot ha^{-1}$ in 2021 and 2023, respectively (Table 3). The increase in the protective effect against *S. squalidus* is explained by the fact that during the phenophase of the plum BBCH 57 a precipitation deficit of 2.6 mm (5.5%) was detected, and the air temperature was within the climatic norm of 7.9°C (2021). The reduction in the protective effect of the biopreparation was obtained due to the excess of precipitation and the air temperature by 124 and 126%, respectively, in the BBCN 56 phase (2023). It has been established that the population density of the phytophage is controlled by the biopreparation by 31.2%, and by the weather conditions by 42.1%. It depends on the interaction of the investigaed factors by 15.4% (Fig. 1).

## Conclusions

1. Excess precipitation and the air temperature in the spring period have a beneficial effect on the development of black plum sawfly and gray bud weevil, increasing the density of the imago population. An increase in air temperature and a decrease in the amount of precipitation in the summer period have a positive effect on the increase in the number of plum moth adults and aphid larvae.
2. The use of the complex microbial preparation against the main plum pests ensured 57.1-89.4% technical efficiency. Optimal consumption of the biological product, taking into account the population density of the imago against *H. minuta* and *S. squalidus*, is 5.0-6.5 against *H. pruni* and *G. funebrana* 6.5-8.0 $l \cdot ha^{-1}$.

## Author contributions

Conceptualization, V.B.; methodology, I.G. and N.P.; software, I.S.; validation, I.G. and V.B; formal analysis, V.B and J.O.; investigation, V.B., S.I., V.N. and J.O.; data curation, A.A., V.B. an A.D.;

writing – original draft preparation, A.R.; writing – review and editing, A.A. and V.B.; visualization, A.D., A.R.; project administration, V.B.; funding acquisition, A.R. All authors have read and agreed to the published version of the manuscript.

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