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Protection of pine plantations in Ukrainian Polissia

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Abstract. The protection of pine plantations in Ukrainian Polissia is one of the most significant environmental problems that have a significant impact on biodiversity, ecological balance and climatic conditions. The aim of the study was to investigate the effect of the bioorganic composition "Meganit Nirbator" on the growth and development of Scots pine (*Pinus sylvestris* L.) planting material. The methods used in the study were: field method and laboratory method. According to the results of the study, it was found that for the period 2022-2024, a positive impact on the growth of seedlings and young pine trees was recorded on the territory of the Volodymyr-Volyn Forestry branch of the State Enterprise "Forests of Ukraine". It was found that the bioorganic composition based on biochemical fractions of basidiomycetes stimulated the growth and development of seedlings and young trees of Scots pine. According to the results of laboratory and field studies, it was noted that an increase in the solution concentration contributed to a significant improvement in plant growth parameters: height, boot diameter, number of new shoots and chlorophyll content. The most effective were solution concentrations of 2% and 5%, which indicated increased resistance to diseases and a decrease in the number of pests. A decrease in the level of disease infections and the number of pests was noted, which indicated the high efficiency of the composition as a biofungicide and insecticide. It was demonstrated that a 5% solution of the biopreparation contributed to a 90% increase in disease resistance 12 months after the field studies, while after 24 months the resistance rate was 80%. The results of the study can be used to develop and implement environmental measures and programmes aimed at restoring Scots pine trees in the Volyn Region

Keywords: *pinus sylvestris*; entomopathogenic fungi; biological preparation; biological method; apical bark beetle; luboid

INTRODUCTION

One of the key environmental challenges facing Ukraine is the destruction of pine forests in Volyn Region due to diseases and pests. The loss of pine plantations can lead to ecosystem degradation and the loss of numerous species of flora and fauna. The problem of the study is that the impact of human activity, climate change and water supply disruptions contribute to an increase in the area of forests affected by disease and pest epidemics. In conformity with the Polissia branch of the Ukrainian Order of the Badge of Honour of the H.M. Vysotskyi Research Institute of Forestry and Agroforestry in Volyn Oblast, more than 7,300 hectares of pine forests have been affected by pests, including the pine beetle (Volyn foresters sound..., 2017).

L. Romanchuk & P. Didenko (2019) found that Scots pine (*Pinus sylvestris* L.) was highly susceptible to the disease under conditions of high

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humidity and warm temperatures, which created favourable conditions for the development and spread of fungi that cause the disease. According to the results of this study, it was noted that the most affected by the Shute disease were forest areas in the Zhytomyr Region. V.F. Drozda & M.S. Karpovich (2020) noted the need for systematic monitoring of temperature conditions in the natural places of diapause of phytophages for the effective use of Boverin in the control of pest populations. In conformity with the findings, it was found that at elevated temperatures (above 17°C), the time of caterpillar death was significantly reduced.

P.V. Didenko *et al*. (2019) noted the need for further research to better understand the mechanisms of action of "Bioecofungus-1" and cerium dioxide nanoparticles on loblolly pine plants. According to the results of their work, it was found that the use of biopreparation and a complex with cerium dioxide nanoparticles contributed to a significant acceleration of the growth and development of Scots pine seedlings. The authors O. Furdychko *et al.* (2020) identified the problem of viral diseases in agricultural and forest crops. The authors recommend the use of basidiomycete fungal compositions for the prevention of viral infections in plants, as well as the use of simulated microgravity processes to heal plants from viral diseases.

Scientists V. Levchenko *et al*. (2023) pointed out the problem of the spread of necrotic and cancerous diseases of boots and branches of forest plantations and putrefactive diseases. They noted that the proposed phytopathological methodology proved to be effective in carrying out forestry preventive measures to localise fungal, bacterial, vascular, necrotic and cancerous pathology. Researchers A.D. Vorobei *et al*. (2023) studied the problem of determining the effectiveness of different pheromone trap designs and their ability to capture pine beetles in the natural conditions of Ukraine. As a result of the scientific work performed by the researchers, it was noted that type A (Funnel) traps with funnels demonstrated the highest efficiency in catching two species of bark beetles, while type B (Theyson) and C (Crosstrap® mini) traps caught a smaller number of pests.

O.A. Boyko *et al*. (2020) noted that the development of methodological approaches is important for the production of growth stimulants and plantation development using components from basidiomycetes. In biotopes with high levels of radiocesium in the soil, populations of fungi such as *Agaricus bisporus* and *Armillariella mellea* have been found to have reduced resistance to pathogens, which has led to a decrease in their density. O.E. Sakici *et al.* (2023) addressed the need to study the unexplored long-term effects of mistletoe infestation on pine tree growth. It is noted that it is relevant to develop strategies aimed at reducing the level of infection, such as timely removal of infected trees and implementation of preventive measures to reduce the spread of mistletoe in the future.

The problem raised in the study by O. Maaß & H. Kehlenbeck (2024) was that the economic feasibility of insect pest monitoring and aerial insecticide spraying is not yet well understood, especially in the context of massive outbreaks of insect pests such as the pine beetle (*Dendrolimus pini* L.). It is noted that the effectiveness and cost-effectiveness of these measures was confirmed by high net cost and cost values, which made them attractive to forest owners in the context of massive outbreaks of insect pests. J. Lee *et al.* (2023) outlined the problem that indicated the need for research to improve the composition of abamectin formulations for more effective control of the pine stem nematode (*Bursaphelenchus xylophilus*), a species of nematode from the family *Aphelenchidae* or *Parasitaphelenchidae*. It was proved that pest paralysis occurred at a dose of 0.06 μg/mL or higher.

The technological parameters of the use of preparations based on biochemical fractions of the basidiomycetes "Meganit Narrator" for forest plantations are insufficiently studied. The need to conduct research on the use of biological products can be justified by several key aspects: reducing the use of chemical pesticides; maintaining biodiversity; and reducing the cost of forestry treatment. The aim of the study was to verify the feasibility of using an organic composition based on biochemical fractions of basidiomycetes to protect pine seedlings and young trees from pests and diseases. Objectives were analysing long-term observation of the growth and physiological state of trees; studying the effect of the organic composition on the growth and resistance of Scots pine plants.

MATERIALS AND METHODS

When studying the feasibility of using the entomopathogenic fungal biological product "Meganit

Nirbator" to protect pine plantations from diseases and pests, the methodology was applied, which is regulated by the Law of Ukraine No. 180-XIV "On Plant Protection" (1998), FSC national forest management system standard for Ukraine (2018). The study used a field method to collect samples of plant litter on the soil surface from the near-stem circles of model trees and to collect caterpillars from tree crowns. The laboratory method was used for species identification and physiological monitoring of caterpillars. The study used an entomopathogenic fungal biological product with a titer of 6 billion spores/g and in concentrations of 1, 2 and 5%.

The collected materials were placed in gauze cages with branches of Scots pine. The caterpillars of three pest species were selected: the larvae of the larvae beetle (165 caterpillars, 55 individuals for each age, in three replications), the apical bark beetle, and the pine chermes (the total number of their caterpillars was 120 individuals, 40 individuals for each species), which were diapaused on tree boles and in the soil. In the experiments with the bark beetle, the experiments were carried out using caterpillars of the third, fourth and fifth instars. The field research was conducted in the period 2022-2024 on plots located in the Volodymyr-Volyn Forestry branch of the state enterprise "Forests of Ukraine", which is located in the southern part of Volyn Region.

During the laboratory stage, preliminary testing of the composition's effectiveness was carried out on seedlings grown under controlled conditions. The field stage included the application of the composition on seedlings and young trees in natural conditions to combat diseases such as pine rust, fusarium and pine bark cancer. A total of 100 seedlings were selected for the study. The chlorophyll content was measured using the gasometrical method. The laboratory stage included: the preparation of seedlings for treatment; treatment of seedlings with different concentrations of the organic composition; and assessment of the growth and physiological condition of seedlings for three months. The field stage involved: selecting a site for planting the seedlings; treating the seedlings with the organic composition before planting; monitoring the growth and physiological condition of the trees for three months, one and two years.

The following parameters were used to evaluate the treatment effectiveness: seedling height (cm); boot diameter (mm); number of new shoots; photosynthetic activity (determined by chlorophyll content); and resistance to diseases and pests. For effective protection of Scots pine plantations from third instar caterpillars, the consumption of *B. bassiana* spores should be at least 8.05 billion/m^2 with the titre of "Meganit Nirbator" 6 billion/g. To determine the amount of "Meganit Nirbator" per hectare, it is necessary to calculate the required number of grams per square metre, and then convert this value to hectares. When calculating the number of grams of the biopreparation per square metre, the following data were obtained (1):

$$\frac{8.05 \text{ billion spores}}{6 \text{ billion spores/g}} = 1.34167 \text{ g/m}^2. \tag{1}$$

Converting this value to a hectare yields the corresponding values (2):

$$\mathrm{W}1.34167\,\frac{\mathrm{g}}{\mathrm{m}^2} \times \frac{10000 \text{ m}^2}{\mathrm{ha}} = 13.4167 \text{ g/ha}. \tag{2}$$

The laboratory study was carried out in the laboratory of "Monitoring of carbon-absorbing capacity of phytocoenoses" of the Western Ukrainian National University, located at the following address: 3 Peremohy Square, Ternopil, Ukraine, building No. 3. Saplings and young trees of Scots pine (*Pinus sylvestris*), aged from one to three years, were used for the study. The organic composition was created on the basis of biochemical fractions of the basidiomycetes "Meganit Nirbator". The composition included 4 bacterial strains: *Azotobacter chroococcum* (nitrogen-fixing aerobic bacteria, pH optimum – 7-7.5; *Azospirillum Lipoferum* (rhizosphere nitrogen-fixing bacteria with a pH optimum of 7-7.5, and temperature 20-30°C); *Bacillus subtillis* or "blue bacillus" (spore-forming bacterium with amylolytic properties, capable of hydrolysing polysaccharides to simple carbohydrates, effective against Fusarium, Aspergillosis, Rhizoctonia, phytopathogenic pseudomonas; *Bacillus megatherium* – rod-shaped bacterium, optimum pH – 6.5-7.5 and a temperature of 28-35°C, has amylolytic activity, immobilises phosphorus from complex compounds in the form of P_2O_5, and has antifungal properties. The manufacturer is Raktarbazisz-Transit Limited Liability Company (Hungary, Nirbator).

To control the number of pests in the samples, the following equipment and products were used:

Gruntek HS-1.5 hand-held sprayers (manufactured in China), pheromone traps for *Scolytidae* pests (manufactured in China) and biological pathogenic agents *Beauveria bassiana* (manufactured in the USA). The chlorophyll content was measured using a portable fluorometer "Floratest" developed by the Glushkov Institute of Cybernetics of the National Academy of Sciences of Ukraine.

RESULTS

Forest protection is a major part of the environmental policy of many countries. One of the areas of this policy was to ensure the healthy growth of seedlings and young trees, in particular pine. In this context, organic compositions based on biochemical fractions of basidiomycetes can play a pivotal role. *Basidiomycota* is a class of fungi with significant potential in the natural environment, as they are able to produce various biologically active compounds such as antibiotics, enzymes, antioxidants and other metabolites. They can be used to control pathogens and pests in various agronomic and ecological systems due to their natural properties, such as: antagonistic properties – certain species of basidiomycetes can inhibit the growth of pathogens by releasing antimicrobial compounds or by competing for resources. This can reduce plant diseases and improve soil health; pathogenic infestation: several species of basidiomycetes can parasitise other fungi or pathogens, which helps control their populations; bioinsecticide production – basidiomycetes can produce compounds that act as bioinsecticides, killing pests or reducing their numbers.

In forests, Scots pine is often affected by pine rust disease and pine fusarium. Damage to pine plantations is caused by the pine beetle, as well as by the pine top borer and pine chermes. Pine rust (*Peridermium pini*) is a fungal disease that affects pine trees. The pathogen is a fungus from the genus *Cronartium*. It causes the formation of rusty spots and growths on the trunks and branches of trees, which leads to a decrease in their viability and death. *Fusarium* pine blight is a fungal disease that caused browning of needles, wilting and drying of shoots, discolouration of the bark in the areas of infection and damage to the root system of pine trees. The bark beetle can damage trees by making passages under the bark, leading to nutritional disorders and tree death.

According to previous studies, it became known that the treatment of seedlings and young pine trees with the bioorganic composition "Meganit Nirbator", created on the basis of biochemical fractions of basidiomycetes and recommended for use by the Department of Physiology, Plant Biochemistry and Bioenergy of the National University of Life and Environmental Sciences of Ukraine, can be a preventive measure against the pathogen of pine rust, fusarium and pine bark cancer, as well as pests (Sus *et al.*, 2020). The results of the laboratory stage showed a positive effect of the organic composition on the growth and physiological state of pine seedlings (Table 1).

Table 1. Effect of bioorganic composition on the growth of pine seedlings (after 3 months)

Group	Height (cm)	Barrel diameter (mm)	Number of new shoots	Chlorophyll content (mg/g)
Control	25.3 ± 1.2	4.1 ± 0.3	3.2 ± 0.4	1.4 ± 0.1
Composition of 1% solution of the biological product	27.8 ± 1.5	4.5 ±0.3	3.7 ± 0.5	1.7 ± 0.2
Composition of a 2% solution of the biological product	30.2 ± 1.4	4.8 ± 0.2	4.1 ± 0.4	1.9 ± 0.2
Composition of a 5% solution of the biological product	33.1 ± 1.3	5.2 ± 0.3	4.6 ± 0.5	2.1 ± 0.2

Source: compiled by the author

The bioorganic composition stimulated the growth and development of Scots pine plants. With increasing solution concentration (from 1% to 5%), a gradual increase in height, boot diameter, number of new shoots and chlorophyll content was observed. The greatest positive effect was achieved when using a 5% solution of the biological product. After the field research, the results of laboratory studies were confirmed and a long-term positive effect of the organic composition on the growth and stability of young pine trees was demonstrated (Table 2).

Table 2. Effect of bioorganic composition on the growth of young pine trees (after 12 months)

Group	Height (cm)	Barrel diameter (mm)	Number of new shoots	Chlorophyll content (mg/g)	Disease resistance (%)
Control	38.5 ± 2.1	5.4 ± 0.4	4.2 ± 0.5	1.5 ± 0.2	60
Composition of 1% solution of the biological product	42.3 ± 2.2	5.9 ± 0.4	4.8 ± 0.4	1.8 ± 0.2	70
Composition of a 2% solution of the biological product	46.7 ± 2.4	6.3 ± 0.3	5.4 ± 0.5	2 ± 0.2	80
Composition of a 5% solution of the biological product	52.1 ± 2.5	6.8 ± 0.4	6.1 ± 0.5	2.3 ± 0.2	90

Source: compiled by the author

According to the results of the study, a positive effect of the bioorganic composition of the solution on seedlings and young pine trees was noted. Higher concentrations of the solution (2% and 5%) were especially effective, as they stimulated an increase in height, boot diameter and number of new shoots compared to the control group. The high chlorophyll content of the treated plants indicated increased photosynthetic activity, which contributed to their better growth. Disease resistance also increased significantly in the treated plants. This could be due to the biologically active substances contained in the biochemical fractions of basidiomycetes, which were capable of acting as natural fungicides and insecticides.

The study was continued to confirm the long-term effect of the biopreparation on pine trees and the possibility of its widespread use in forestry. An additional observation was conducted for two years to assess the stability and effectiveness of the formulation on mature pine trees. The following parameters were measured: height, boot diameter, number of new shoots, chlorophyll content, disease resistance, and number of pests (Table 3).

Table 3. Effect of bioorganic composition on the growth of adult pine trees (after 24 months)

Group	Height (cm)	Barrel diameter (mm)	Number of new shoots	Chlorophyll content (mg/g)	Disease resistance (%)	Number of pests (individuals/tree)
Control	65.4 ± 3.2	8.3 ± 0.5	5.2 ± 0.6	1.6 ± 0.3	50	70
Composition of 1% solution of the biological product	70.3 ± 3.4	8.7 ± 0.5	5.8 ± 0.6	1.9 ± 0.2	60	50
Composition of a 2% solution of the biological product	75.8 ± 3.5	9.2 ± 0.4	6.4 ± 0.6	2.1 ± 0.2	70	35
Composition of a 5% solution of the biological product	81.5 ± 3.6	9.7 ± 0.5	7.1 ± 0.6	2.4 ± 0.2	80	20

Source: compiled by the author

According to the data obtained, the positive effect of the bioorganic composition continued for two years. The best results were observed in the groups with a concentration of 2% and 5%, which confirmed the effectiveness of these concentrations in stimulating the growth and resistance of pines. Increases in boot height and diameter were greatest in the 5% solution group. The difference between control and treated trees remained significant. The number of new shoots and chlorophyll content were significantly higher in the treated plants, indicating increased photosynthetic activity. A high level of disease resistance was found in the treated plants, especially in the group with 5% solution, which reduced the risk of infections. The number of pests was significantly reduced, which confirmed the effectiveness of the bio-organic solution as a natural insecticide. The pine trees were treated by applying the composition created by mixing the extracted fractions with organic solvents to the surface of the tree bark (Table 4).

Table 4. Results of pine treatment against pests

Pest	Control group (no treatment)	Processed group	Reduction in the number of pests
The mushroom (*Tomicus piniperda* L.)	50 individuals per tree	10 individuals per tree	80%
The treetop bark beetle (*Scolytus mali*)	30 individuals per tree	5 individuals per tree	83.3%
Pine Hermes (*Pineus pini Hermes*)	20 individuals per tree	3 individuals per tree	85%

Source: compiled by the author

It was found that the treatment with the composition against all three types of pests: the larvae of the pine tree, the pine apex beetle and the pine tree chermes, provided a significant reduction in their number (from 80% to 85%). According to the results of the study, it was found that the organic composition based on biochemical fractions of basidiomycetes reduced the level of disease infections among pine trees (Table 5).

Table 5. Results of pine treatment against diseases

Disease	Control group (no treatment)	Processed group	Reduction of infection
Rusty pine (*Peridermium pini*)	40% of infected trees	10% of infected trees	75%
Fusarium	35% of infected trees	8% of infected trees	77.1%
Pine bark cancer (*Cronartium ribicola*)	25% of infected trees	5% of infected trees	80%

Source: compiled by the author

Pine rust infection decreased from 40% in the control group to 10% in the treated group, representing a 75% reduction in infection. Fusarium infection rates decreased from 35% in the control group to 8% in the treated group, representing a 77.1% reduction in infection. The infection rate of pine bark cancer decreased from 25% in the control group to 5% in the treated group, resulting in an 80% reduction in infection. Due to its environmental safety, this formulation can be used as an alternative method of plant protection compared to chemical pesticides and fungicides. Table 6 shows the mortality rates of caterpillars of herbivorous phytophages of the *Luboid phytophagous* beetle infected with the biopreparation solution, depending on age and temperature.

Table 6. Indicators of mortality dynamics of caterpillars infected with the biological product depending on age and temperature

Types of herbivorous phytophages	Time required to kill 50% of the LT_{50} caterpillar population (days) at temperature					
	Phase of development of the phytophage	13°C	18°C	23°C	28°C	33°C
The mushroom (*Tomicus piniperda* L.)	L_3	10.5	8.4	5.2	2.5	1.2
	L_4	17.2	11.3	7.5	5.5	2.5
	L_5	20.5	19.3	14.5	9.6	7.4
The treetop bark beetle (*Scolytus mali*)	L_3	31.7	30.2	25.3	19.2	5.2
NIR_{05}		N/A	N/A	N/A	N/A	N/A
Pine Hermes (*Pineus pini Hermes*)	L_5	19.1	15.6	11.3	4.5	4.9
NIR_{05}	N/A	N/A	N/A	N/A	N/A	N/A

Notes: L_3, $L_{4,}$ L_5 – phytophagous caterpillars of different ages
Source: compiled by the author

According to the results of the study, it was found that the population of third instar caterpillars collected from leaf litter and soil surface is particularly vulnerable to the action of *B. bassiana*, the biological basis of the biological product. With increasing temperature, the value of LT_{50} (days) (the time required for the death of 50% of the population) decreased. This indicated that the effectiveness of the bioorganic composition increased at higher temperatures. The air temperature in the range of 13-18°C for a period of 8.4-10.5 days contributed to the death of 50% of the population of caterpillars of the broomrape. With increasing temperature, the period of caterpillar death was reduced. *Luboid caterpillars* in later stages of phytophagous development (L_4, L_5) require more time to die under the influence of the biological product. In conformity with the data on the dynamics of mortality of third instar caterpillars, it is advisable to take measures to apply the solution to the places of diagnosis of the phytophagous phage. The diagnosing caterpillars of the fifth instar pine chermes, as well as the caterpillars of the third instar of the apex bark beetle, were much more resistant to the action of the biological product, and, accordingly, the period of their death was longer. Thus, it can be concluded that the effectiveness of the bioorganic composition depended on the temperature of the environment, the developmental stage of the caterpillars and the type of herbivorous phytophages. Higher temperatures resulted in faster caterpillar death, and caterpillars at later stages of development were more resistant to infection. In comparison with the top bark beetle and pine chermes, it was found that the caterpillars of the larvae of the larvae were more favourable to the effect of the preparation. Table 7 shows the toxicological parameters of the biological product activity against caterpillars of different age groups of phytophages.

Table 7. Toxicological parameters of the biological product activity against caterpillars of different ages of phytophages

Types of herbivorous phytophages	Phase of development of the phytophage	Physiological state of the caterpillars	Concentration of a bio-organic agent that causes the death of 50% of the LK_{50} caterpillar population (days)	
			% by drug	The term of the decisive days
The mushroom (*Tomicus piniperda* L.)	L_3	Active, healthy	0.025%	14
	L_4	Development of organs	0.04%	18
	L_5	Big, ready to fly	0.05%	22
The treetop bark beetle (*Scolytus mali*)	L_3	Active, newly hatched	0.03%	12
Pine Hermes (*Pineus pini Hermes*)	L_5	Mature, with a large supply of nutrition	0.045%	20

Notes: L_3, L_4 L_5 – phytophagous caterpillars of different ages
Source: compiled by the author

The biopreparation demonstrated different toxicological parameters (LK_{50}) for different stages of caterpillar development of different phytophagous species. For example, for caterpillars of the bark beetle in the phases L_3, L_4 and L_5, the concentration of the bioorganic agent that causes the death of 50% of the caterpillar population LK_{50} (days) percentage by the preparation increased from 0.025% to 0.05% due to the increase in the physiological state of caterpillars from active to ready to fly. As for the pine top bark beetle and pine chermes, the LK_{50} value also varied depending on the stage of caterpillar development, indicating a variation in the effectiveness of the preparation depending on the stage of the phytophage life cycle. Table 8 shows the consumption rates of the biological product.

Table 8. Indicators of consumption rates of a biological product for the protection of pine plantations depending on the age of the bark beetle caterpillars

Age of the caterpillars of the bowhead beetle	Concentration of a bio-organic agent that causes the death of 90% of the population of LK_{50} caterpillars$_{90}$ (billion spores/mL) as a function of phytophage mortality		Parameters of *B. bassiana* spore consumption, billion/m^2	
	Crop residues – soil surface	Total mortality rate	For plant protection needs	To destabilise the effective part of the phytophage
The second	0.025	0.005	1.5	0.41
The third	0.04	0.003	8.05	0.35
The fourth	0.55	0.07	12.55	1.2

Source: compiled by the author

The number of grams of the biological product per m^2 was 13.4167 g/ha. Thus, for effective protection of Scots pine plantations from third instar caterpillars, 13.42 g/ha of the biological product with a titre of 6 billion/g should be used. The bioorganic composition stimulated the growth and development of Scots pine plants. With increasing concentration of the solution, a gradual increase in height, boot diameter, number of new shoots and chlorophyll content was observed. The use of the bio-organic composition has reduced the use of chemical pesticides and fungicides, which has had a positive impact on the region's environment. The high effectiveness of the biological product in controlling pests and diseases, as well as stimulating plant growth, makes it an attractive solution for forestry enterprises seeking to ensure sustainable use of forest resources. Protecting pine plantations from pests and diseases is critical to maintaining the ecological balance in the region. Pine trees affected by diseases and pests can cause significant environmental problems, including reduced biodiversity, poor air and water quality, and increased risk of forest fires.

The use of a bio-organic composition based on biochemical fractions of basidiomycetes helped to solve a number of local environmental problems: the replacement of chemical plant protection products with biological ones reduced the negative impact on the environment, in particular soil and water pollution; the composition contributed to increasing the resistance of pine trees to diseases and pests, which helped to maintain healthy forests and reduce tree mortality; treatment with the composition increased the chlorophyll content and photosynthetic activity of trees, which had a positive impact on the environment. Thus, the application of the biopreparation contributed to solving local environmental problems, ensuring healthy growth and sustainability of pine plantations, which, in turn, improved the overall environmental condition of the region and the state of forest ecosystems.

DISCUSSION

Analysing the results of the study, it can be concluded that it is possible to apply the technology of coniferous trees treatment with a bioorganic composition based on biochemical fractions of basidiomycetes, since the treatment of seedlings and young trees has shown high efficiency.

It was found that for the effective protection of Scots pine trees from third instar caterpillars, the required dose was 13.42 g/ha of a biological product with a titer of 6 billion g. A similar issue was raised by C.J. Fettig *et al*. (2020). They found that lower doses of SPLAT® Verb verbenone (7 grams per tree) can be effectively used to protect pine trees from the mountain pine beetle (*Dendroctonus ponderosae Hopkins*). This statement can be agreed with, as really low doses of verbenone can be effective for a long time, providing long-term protection of trees from pests.

It was noted that the infection with pine rust decreased from 40% in the control group to 10% in the treated group. A similar problem was studied by J. Kuang *et al.* (2024). They found that the use of multi-temporal satellite data significantly improved the accuracy of monitoring forest stands affected by pine wilt disease compared to the use of single satellite images. The results of the current study did not coincide with the conclusions of the researchers as they conducted a detailed study at the local level using additional ground monitoring methods and laboratory analysis, which allowed them to identify different stages of the disease and apply effective control measures in a timely manner.

It was found that *Fusarium* infection decreased from 35% in the control group to 8% in the treated group. A similar issue was studied by K. Youssef (2023). In the course of the study, the researcher found that latent root infections of loblolly pine trees in areas with a low risk of infection with the root sponge disease *Heterobasidion annosum* L. were quite common. In addition, these infections were more common in plots with a higher site index, indicating a higher probability of infection of trees on more fertile soils. This statement should be accepted, as a higher site index may indicate a higher tree density and greater competition for resources, which can weaken trees and make them more vulnerable to infections.

According to the results of the study, it was shown that the treatment of pines with an organic composition based on biochemical fractions of basidiomycetes effectively reduced the number of pests of the apex bark beetle. A similar issue was studied by O. Golan *et al*. (2022). According to the results of their work, it was found that the use of trap trees and their treatment with bifenthrin reduced the number of dead trees in the plantations, which indicated the effectiveness of such measures to prevent the spread of bark beetles. The study came to similar conclusions, which revealed that after the application of the bio-organic composition, the number of apex bark beetle pests decreased by 83.3%.

The caterpillars of the third age of the apex bark beetle were much more resistant to the biological product, so the time of their death was longer. The results of these indicators were reviewed by N. Erbilgin *et al.* (2021), who noted that pine trees exposed to bark beetle attacks and drought showed a significant decrease in carbohydrate reserves, which limited their ability to synthesise protective diterpenes and increased the likelihood of tree death due to physiological exhaustion and mechanical damage to vascular tissue by beetles. Thus, both studies present different aspects of the study of pine forest mortality: determination of resistance to the drug of the caterpillar of the apex bark beetle in this study and analysis of the impact of environmental factors on the phytosanitary state of forests in the scientific work of the researchers.

It was demonstrated that air temperature in the range of 28-33°C for a period of 5.2-19.2 days contributed to a reduction in the death of caterpillars of the top bark beetle. A similar study was conducted by M. Haseeb (2023). According to the results of this scientist's work, it became known that the invasions of the southern pine beetle and black terpentine beetle were limited to trees that were damaged by fire, lightning or other pests, but pines that were stressed due to drought or shading were rarely attacked. This statement can be agreed with, as beetle infestations are often observed in conditions where trees are vulnerable due to physical or biological damage.

It was recorded that the treatment with the bio-organic composition demonstrated effectiveness in the fight against the apex bark beetle, reducing their number to 5 individuals per tree, compared to the control group, where their number was 30 individuals per tree. A similar study was conducted by E.M. Hansen *et al*. (2023). It was noted that climatic water scarcity significantly affected the probability of infestation, showing that periods of high-water stress could contribute to the spread of beetles and further damage to the pine forest. The results obtained in the present study differed from the conclusions drawn by the researchers, which could be due to differences in their research methods, such as the method of assessing abiotic conditions (temperature, precipitation) using *Daymet* interpolation in the analysed study and the field method in the present study. The fifth instar caterpillars of the pine hermes (*Pineus pini Hermes*) were much more resistant to the biological product, and, accordingly, the time of their death was longer. The issue under discussion was studied by L. Heiðarsson *et al*. (2020). According to the results of their work, it was noted that lodgepole pines of Icelandic origin were less susceptible to woolly aphid (*Pineus pini*) invasion compared to pine plantations of non-Icelandic origin, which can be explained by natural selection, which contributed to the adaptation of lodgepole pine in Icelandic conditions. The results of my study did not coincide with the findings of the researchers as they analysed the resistance to the effects of a bio-organic composition.

The effectiveness of treating pine trees with a bioorganic composition against pine rust disease showed a 75% reduction in infection. A similar issue was studied by K. Zhang & J. Stenlid (2023). Their study found that the protocols for monitoring and managing the lodgepole pine rust epidemic, developed to detect the rust fungus (*Cronartium pini*), were effective and specific for identifying this fungus in lodgepole pine samples. These protocols were used not only to detect the presence of this pathogen in asymptomatic and symptomatic trees, but also to track the occurrence of Scots pine rust in Northern Europe. The conclusions presented in this study differed from those of the researchers, as this study focuses on the use of a bio-organic composition based on biochemical fractions of basidiomycetes to control pine rust disease, while the researchers' investigated protocols for monitoring and managing the epidemic of this disease. An organic composition based on biochemical fractions of basidiomycetes effectively reduced the level of disease infections among pine trees by 77.1%. A similar issue was studied by L. de Vos *et al*. (2024). The results of this work revealed that one of the pine *fusarium* strains (*Fusarium circinatum*) showed significant differences in the length of this chromosome, with large parts of its distal and proximal regions missing. These regions were characterised by a lower gene density and an increased prevalence of repetitive elements, which can be contrasted with syntenic segments and core chromosomes. It is worth agreeing with the results of this study, as the detection of significant differences in chromosome length and the absence of large parts of the distal and proximal regions indicates genetic instability or specific adaptive mechanisms of this strain.

The infection of pine bark cancer decreased from 25% in the control group to 5%. A similar issue was studied by D. Martin *et al*. (2022). According to the results of their work, it can be stated that Raman spectroscopy has become an effective tool for the early detection of biochemical changes associated with pine bark cancer caused by the fungus *Fusarium circinatum*. The study showed that this method can be used to select trees resistant to pine resin canker, in particular due to lignin as a key component of resistance. The results of this study should be accepted, as Raman spectroscopy can detect changes in the molecular composition of tissues at very early stages, making it extremely valuable for detecting pathogenic changes before visible symptoms appear. Lignin, as one of the main components of wood, plays an important role in fungal resistance, as its structure and chemical properties affect the ability of the fungus to penetrate and grow in wood. The use of a bioorganic composition based on biochemical fractions of basidiomycetes helped to effectively reduce the level of Fusarium infections in pine trees. A similar problem was investigated by T. Wendhausen *et al.* (2019). The results of this scientific study showed that the use of an antagonistic biological product *Trichoderma* sp. for the treatment of pine seeds effectively reduced the incidence of Fusarium root rot and also contributed to an increase in the number of seedlings and plant growth. Agreeing with the statement, it should be noted that the opinion of the researchers and colleagues is correct, as the use of the biological product *Trichoderma* sp. had several confirmed advantages. Firstly, this fungus is able to inhibit the growth of pathogenic fungi, such as *Fusarium*, due to its antagonistic properties. The biological product *Trichoderma* sp., together with other microorganisms, releases enzymes and antibiotics that inhibit pathogenic microflora. Secondly, *Trichoderma* sp. helps to improve plant growth, as it stimulates the development of the root system, improves the availability of nutrients and increases plant resistance to stressful conditions.

As a result of using the bio-organic composition, the infection of pine bark cancer decreased from 25% in the control group to 5% in the treated group, thus reducing the infection rate by 80%. A similar issue was investigated by F. Ratsoma *et al*. (2024). They presented results that showed that the pine resin cancer pathogen Fusarium circinatum formed biofilms with increased extracellular matrix (ECM) production in response to abiotic factors such as temperature and pH, which highlighted the adaptability of this phytopathogen to environmental changes. The findings of the researchers should be accepted, as the extracellular matrix of biofilms can indeed provide protection for pathogen cells from adverse environmental conditions such as high or low temperatures and extreme pH levels. In the presented study, it was noted that the created organic composition demonstrated effectiveness due to the content of phenolic compounds (bioactive substances capable of exhibiting antioxidant and antibacterial properties). A similar issue was studied by I. Amri *et al*. (2022). In the course of the study, they found that pine essential oils were characterised by significant phytotoxic and antifungal activity due to the high content of monoterpene hydrocarbons, among which limonene, α-pinene and β-pinene were the dominant components. The highest herbicidal activity was demonstrated by the essential oil of *Pinus pinea*, while the highest antifungal activity was demonstrated by the essential oils of *Pinus pinea* and *Pinus nigra*. It is worth agreeing with this formulation of the researchers' conclusions, as the researchers' findings are based on specific experimental data indicating a significant content of monoterpene hydrocarbons in pine essential oils, which may indeed have pronounced phytotoxic and antifungal properties.

After the treatment with the bioorganic composition, an increase in disease resistance of Scots pine plants was observed. The present topic was studied by A.H. Wani *et al*. (2010). According to the results of the study, it was noted that the application of rhizobacteria of the genus *Bacillus* to the seeds of blue pine (*Pinus wallichiana*) led to an improvement in the growth and health of seedlings. It is possible to agree with the opinion of the researchers, as *Bacillus* rhizobacteria have an antagonistic effect on plant pathogens, producing antibiotics or other antimicrobial compounds, which reduces the risk of disease. A high level of disease resistance was found in the treated Scots pine plants in the group with a 5% solution of the composition. This topic was studied by E. Karlsen-Ayala *et al*. (2022). The results of their work showed that pine seedlings grown in soil with natural mycorrhizal communities showed better growth and health indicators compared to those grown using commercial inoculants. The conclusion of the researchers, as natural mycorrhizal communities consist of many species of fungi that interact with plants on a deeper level, providing better water and nutrient absorption and increasing resistance to stress and disease.

In 12 months after the field research, a high level of disease resistance was found in the treated loblolly pine plants, which amounted to 90%. A similar topic was studied by R.A. Sniezko *et al*. (2023). According to the results of their study, it was noted that after inoculation with the fungal pathogen *Cronartium ribicola*, a high level of genetic resistance to blister rust was found in certain populations of whitebark pine. The results of my research coincided with the findings of the researchers, as they also conducted a detailed analysis of the genetic resistance of loblolly pine to various pathogens. The composition of the composition for the treatment of pine seedlings included fungal extracts enriched with proteins from basidiomycetes. A similar topic was studied by H. Patel *et al*. (2023). The results of this study showed that fungi of the *Basidiomycetes* group were collected and stored for further use, in particular in important areas such as medicine, education and agriculture, which highlighted their importance for local development and the ecosystem. It is worth agreeing with the conclusion of the researchers as these fungi do have significant potential as a source of medicinal substances and for biodegradation of organic matter in soils. In 24 months after the field trials, high disease resistance of the treated Scots pine plants was observed, which amounted to 80%. The same topic was studied by T. Persson *et al*. (2024). According to the results of the study presented by the authors, it was shown that the selection of loblolly pine to increase resistance to blister rust can be successful without the risk of adversely affecting other critical breeding traits, such as vitality, which was 0.17, and height, which reached a value of 0.25. The conclusions of the researchers should be accepted, as they confirm the feasibility of such selection in terms of preserving valuable genetic resources of Scots pine, which is critical for the further development of pine variety improvement programmes.

CONCLUSIONS

According to the results of studies of the effect of bioorganic composition on the growth and development of Scots pine planting material, it was shown that the treatment of seedlings and young pine trees with an organic composition based on biochemical fractions of basidiomycetes had a positive effect on their growth and development. The composition concentration of 2% and 5% showed the best results. The use of such an organic composition can be recommended to increase the efficiency of pine cultivation in forest nurseries and forest plots. The effectiveness of the product depended significantly on the temperature. At higher temperatures, the death of caterpillars occurred in a shorter period of time. For the caterpillars of the broomrape (*Tomicus piniperda* L.) in the L_3 phase, the LT_{50} (time to death of 50% of the population) decreased from 10.5 days at 13°C to 1.2 days at 33°C. It was found that caterpillars at later stages of development (L_4, L_5) require more time to die under the influence of the biological product. For example, for caterpillars in the L_5 phase, the LT_{50} value at 13°C was 20.5 days, which is significantly higher compared to the L_3 phase (10.5 days). It was determined that the caterpillars of the larvae of the larvae were more favourable to the effect of the drug compared to the apical bark beetle and pine chermes. For pine chermes, even at the highest temperature (33°C), LT_{50} is higher than for the larvae of the bark beetle.

In the review of studies of forest areas of the Volodymyr-Volyn Forestry Enterprise destroyed by pests and diseases, it should be noted that some data on the condition of pine plantations are not available for analysis. The study did not take into account the impact of environmental factors, such as climatic conditions, soil characteristics, pollution levels and other external factors that can also affect the health of forest stands. Further research may include the introduction of additional field observations to develop methods for the mass production of biochemical fractions of basidiomycetes. The research may include improving the composition of the composition and studying its effect on other woody plant species.

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CONFLICT OF INTEREST

None.

REFERENCES

[1] Amri, I., Khammassi, M., Gargouri, S., Hanana, M., Jamoussi, B., Hamrouni, L., & Mabrouk, Y. (2022). Tunisian pine essential oils: Chemical composition, herbicidal and antifungal properties. *Journal of Essential Oil Bearing Plants*, 25(3), 430-443. doi: 10.1080/0972060X.2022.2084347.

[2] de Vos, L., van der Nest, M.A., Santana, Q.C., van Wyk, S., Leeuwendaal, K.S., Wingfield, B.D., & Steenkamp, E.T. (2024). Chromosome-level assemblies for the pine pitch canker pathogen *Fusarium circinatum*. *Pathogens*, 13(1), article number 70. doi: 10.3390/pathogens13010070.

[3] Didenko, P.V., Romanchuk, L.D., Boyko, O.A., Sus, N.P., Demchenko, O.A., Orlovskiy, A.V., & Boyko, A.L. (2019). Growth and development of planting material of Scots pine (*Pinus sylvestris* L.) under the influence of bioorganic compositions from basidiomycetes and cerium dioxide nanoparticles. *Agriciltural Microbiology*, 30, 61-68. doi: 10.35868/1997-3004.30.61-68.

[4] Drozda, V.F., & Karpovich, M.S. (2020). Experimental justification of prospects of using the entomopathogenic preparation boveryn for the protection of pinetum. *Agriciltural Microbiology*, 31, 83-91. doi: 10.35868/1997-3004.30.61-68.

[5] Erbilgin, N., Zanganeh, L., Klutsch, J., Chen, S.H., Zhao, S., Ishangulyyeva, G., Burr, S.J., Gaylord, M., Hofstetter, R., Keefover-Ring, K., Raffa, K., & Kolb, T. (2021). Combined drought and bark beetle attacks deplete non-structural carbohydrates and promote death of mature pine trees. *Plant Cell and Environment*, 44(12), 3866-3881. doi: 10.1111/pce.14197.

[6] Fettig, C.J., Steed, B., Munson, S., & Progar, R. (2020). Evaluating doses of SPLAT® verb to protect lodgepole pine trees and stands from mountain pine beetle. *Crop Protection*, 136, article number 105228. doi: 10.1016/j.cropro.2020.105228.

[7] FSC national forest management system standard for Ukraine. (2018). Retrieved from https://ua.fsc.org/sites/default/files/2021-12/FSC-STD-UKR-01-2019_B8_0.pdf.

[8] Furdychko, O., Boiko, A., Demianiuk, O., & Tsvihun, V. (2020). Virus diseases of plants in agrocenosis and forest ecosystems: Diagnostics and prevention. *Bulletin of Agricultural Science*, 98(2), 5-11. doi: 10.31073/agrovisnyk202002-01.

[9] Golan, O., Attias, R., & Elron, M. (2022). Bark beetle-related pine mortality in Israeli planted forests and the effect of trap trees. *Forest*, 22(7), 71-81.

[10] Hansen, E.M., Bentz, B., Vandygriff, J., & Garza, C. (2023). Factors associated with bark beetle infestations of Colorado Plateau ponderosa pine using repeatedly-measured field plots. *Forest Ecology and Management*, 545, article number 121307. doi: 10.1016/j.foreco.2023.121307.

[11] Haseeb, M. (2023). *Beetle mania. How to detect and manage pine tree pests*. Retrieved from https://www.researchgate.net/publication/375160902_TLHLIFE_BEETLE_MANIA_How_to_detect_and_manage_pine_tree_pests.
[12] Heiðarsson, L., Sigurdsson, B.D., Davíðsson, B.Ö., Hrafnkelsdóttir, B., Sigurgeirsson, A., Skúlason, B., Vest, M.D., & Halldorsson, G. (2020). The effect of the pine woolly aphid (*Pineus pini*) on survival, growth and natural selection in Scots pine (*Pinus sylvestris*) in Iceland. *Agricultural and Forest Entomology*, 22(2), 146-156. doi: 10.1111/afe.12369.
[13] Karlsen-Ayala, E., Smith, M.E., Askey, B., & Gazis, R. (2022). Native ectomycorrhizal fungi from the endangered pine rocklands are superior symbionts to commercial inoculum for slash pine seedlings. *Mycorrhiza*, 32(5-6), 465-480. doi: 10.1007/s00572-022-01092-3.
[14] Kuang, J., Yu, L., Zhou, Q., Wu, D., Ren, L., & Luo, Y. (2024). Identification of pine wilt disease-infested stands based on single- and multi-temporal medium-resolution satellite data. *Forests*, 15(4), article number 596. doi: 10.3390/f15040596.
[15] Law of Ukraine No. 180-XIV "On Plant Protection". (1998, October). Retrieved from https://zakon.rada.gov.ua/laws/show/180-14#Text.
[16] Lee, J., Mwamula, A.O., Choi, J., Lee, H., Kim, Y.S., Kim, J.H., & Lee, D.W. (2023). The potency of abamectin formulations against the pine wood nematode, *Bursaphelenchus xylophilus*. *The Plant Pathology Journal*, 39(3), 290-302. doi: 10.5423/PPJ.OA.02.2023.0023.
[17] Levchenko, V., Shulga, I., Fuchylo, Y., Karpovych, M., Romanyuk, A., & Hornovska, S. (2023). Phytopathological monitoring of dangerous outbreaks disease of forest trees with use method of changing radial increments in the conditions of the Polisky nature reserve. *Paradigm of Knowledge*, 55(1). doi: 10.26886/2520-7474.1(55)2023.1.
[18] Maaß, O., & Kehlenbeck, H. (2024). Cost-benefit analysis of monitoring insect pests and aerial spraying of insecticides: The case of protecting pine forests against *Dendrolimus pini* in Brandenburg (Germany). *Forests*, 15(1), article number 104. doi: 10.3390/f15010104.
[19] Martin, D., Santos, I.P., Monteiro, P., Amaral, J., da Costa, R., Martín-Garcia, J., Batista de Carvalho, L., Marques, M., & Pinto, G. (2022). Unravelling pine response to *Fusarium circinatum* through Raman spectroscopy. *Journal of Raman Spectroscopy*, 53(12), 2086-2099. doi: 10.1002/jrs.6446.
[20] Patel, H., Solanki, H.A., & Patel, D. (2023). Basidiomycetes fungi of nandigram service centre. *International Association of Biologicals*, 2(2), 7-13. doi: 10.56588/iabcd.v2i2.180.
[21] Persson, T., Hall, D., Barklund, P., Samils, B., & Gull, B.A. (2024). The inheritance of resistance to Scots pine blister rust in *Pinus sylvestris*. *Forest Ecology and Management*, 568, article number 122135. doi: 10.1016/j.foreco.2024.122135.
[22] Ratsoma, F., Mokoena, N.Z., Santana, Q.C., Wingfield, B.D., Steenkamp, E.T., & Motaung, T.E. (2024). Characterization of the *Fusarium circinatum* biofilm environmental response role. *Journal of Basic Microbiology*, 64(4), article number 2300536. doi: 10.1002/jobm.202300536.
[23] Romanchuk, L., & Didenko, P. (2019). Ecological and biological properties of the causative agent of pine-leaf cast of Scotch pine (*Pinus sylvestris* L.) under conditions of Zhytomyr Polissia forests. *Scientific Horizons*, 22(7), 3-7. doi: 10.33249/2663-2144-2019-80-7-3-7.
[24] Sakici, O.E., Özcan, G.E., Seki, M., & Sağlam, F. (2023). The effects of pine mistletoe (*Viscum album* subsp. *austriacum*) on the growth of Scots pine and Crimean pine in Turkey. *Forest Pathology*, 53(2), article number e12802. doi: 10.1111/efp.12802.
[25] Sniezko, R.A., Johnson, J.S., Kegley, A., & Danchok, R. (2023). Disease resistance in whitebark pine and potential for restoration of a threatened species. *Plants, People, Planet*, 6(2), 341-361. doi: 10.1002/ppp3.10443.
[26] Sus, N.P., Boyko, O.A., Protsenko, L.V., Demchenko, O.A., Tymoshok, N.O., Biletskyi, A.V., & Boyko, A.L. (2020). Carlaviral load distribution in hop plants (*Humulus lupulus* L.). *Agroecological Journal*, 2, 40-44. doi: 10.33730/2077-4893.2.2020.207679.

[27] Volyn foresters sound the alarm: Pine forests are dying due to a pest. (2017). Retrieved from https://www.volynpost.com/articles/1218-volynski-lisnyky-byut-na-spoloh-cherez-shkidnyka-vidmyraie-sosnovyj-lis#google_vignette.
[28] Vorobei, A.D., Baturkin, D.O., Davydenko, K.V., & Meshkova, V.L. (2023). Evaluation of pheromone traps for bark beetles and their predators in pine forests in the Kharkiv Region. *Forestry and Forest Melioration*, 143, 94-101. doi: 10.33220/1026-3365.143.2023.94.
[29] Wani, A.H., Wani, M.A., & Peer, L.A. (2010). Effect of plant growth promoting Bacillus species on the growth of blue pine seedlings. *Journal of Mycology and Plant Pathology*, 40(4), 564-566.
[30] Wendhausen, T., Santos, Á.F., Auer, C.G., & Tessmann, D.J. (2019). Pine seeds treatment with trichoderma for fusarium control. *Floresta e Ambiente*, 26(2), article number e20170875. doi: 10.1590/2179-8087.087517.
[31] Youssef, K. (2023). *Heterobasidion root rot infections on Scots pine: A cryptic threat to sustainable forest management in Sweden*. (Doctoral thesis, Swedish University of Agricultural Sciences, Alnarp, Sweden).
[32] Zhang, K., & Stenlid, J. (2023). Detection and quantification of *Cronartium pini* from Scots pine bark and wood with *Cronartium* spp.-specific quantitative PCR. *Forest Pathology*, 53(6), article number e12833. doi: 10.1111/efp.12833.

Захист соснових насаджень Українського Полісся

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Анотація. Захист соснових насаджень Українського Полісся є однією з найбільш значущих екологічних проблем, які мають суттєвий вплив на біорізноманіття екологічну рівновагу та кліматичні умови. Метою дослідження було вивчення впливу біоорганічної композиції «Меганіт Нірбатор» на ріст і розвиток посадкового матеріалу сосни звичайної (*Pinus sylvestris* L.). В ході дослідження застосовувались методи: польовий метод, лабораторний метод. По результатам дослідження виявлено, що за період 2022-2024 років на території філії «Володимир-Волинське лісове господарство» державного підприємства «Ліси України» зафіксовано позитивний вплив на ріст саджанців та молодих дерев сосни. Виявлено, що біоорганічна композиція на основі біохімічних фракцій базидіоміцетів стимулювала ріст і розвиток саджанців та молодих дерев сосни звичайної. За результатами лабораторних і польових досліджень відзначено, що збільшення концентрації розчину сприяло значному покращенню параметрів росту рослин: висоти, діаметру стовбура, кількості нових пагонів та вмісту хлорофілу. Найбільш ефективними були концентрації розчину 2 % та 5 %, що свідчило про підвищену стійкість до хвороб та зниження кількості шкідників. Відмічено зниження рівня інфекцій хворобами та кількості шкідників, що свідчило про високу ефективність композиції як біофунгіциду та інсектициду. Продемонстровано, що 5 % розчин біопрепарату сприяв збільшенню стійкості до хвороб через 12 місяців після проведення польових досліджень на 90 %, тоді як через 24 місяці показник стійкості становив 80 %. Результати дослідження можуть бути використані з метою розробки та впровадження екологічних заходів та програм, спрямованих на відновлення дерев сосни звичайної в Волинській області

Ключові слова: *pinus sylvestris*; ентомопатогенні гриби; біопрепарат; біологічний метод; верхівковий короїд; лубоїд