Efficiency of using Bioorganic Preparations to Protect Pine Stands from Pests and Diseases: Lessons from the Application of Basidiomycetes

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Efficiency of using Bioorganic Preparations to Protect Pine Stands from Pests and Diseases: Lessons from the Application of Basidiomycetes

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Abstract: The purpose of this study was to investigate the effectiveness of a bioorganic composition for the protection of pine plantations, to assess its effects on the growth, development, and resistance of trees to pests and diseases. The methodology included field and laboratory studies, during which various concentrations of the bioorganic composition were used to treat seedlings and young pine trees. The findings revealed that the use of the bioorganic composition increased the height, trunk diameter, and number of new shoots of pine trees. It also reduced the infection with diseases such as pine blister rust, fusariosis, and white pine blister rust, while the number of pests decreased by 80-85%.

Keywords: Biological Products; Environmental Rehabilitation; Forest Stands; Fusariosis; Pine Blister Rust; Plant Protection

1. Introduction

Considering the global transition to environmentally friendly plant protection products and the restoration of degraded ecosystems, the development and use of bioorganic products has become both relevant and necessary. This shift is vital to ensure environmental safety and conserve forest resources, particularly in Ukraine. The increased focus on sustainable, bio-based alternatives is part of broader efforts to reduce the harmful impacts of chemical pesticides, which often pose risks to ecosystems and human health. The adoption of bioorganic products can help mitigate these environmental challenges, offering a sustainable way to protect forests without compromising ecological integrity.

The spread of pests and diseases such as pine blister rust, fusariosis, and white pine rust, however, poses a great threat to forest ecosystems. These issues are exacerbated by the rapid reproduction of pests, which negatively affects biodiversity, degrades forest resources, and disrupts the ecological balance. This, in turn, increases the risk of forest fires and other environmental disasters. Addressing these challenges requires effective, environmentally friendly methods to protect pine forests and prevent the further spread of these harmful pathogens and pests.

The current state of research on forest protection from diseases and pests highlights an increasing focus on environmentally friendly and sustainable methods, particularly bioorganic products. As the harmful effects of chemical pesticides on ecosystems and human health are well-documented, these alternatives are becoming increasingly necessary. With increasing concerns over ecosystem degradation and restoration, developing bio-based solutions for pest and disease management is crucial for forest conservation. This study is important because it addresses the urgent need for effective, eco-friendly strategies to combat the spread of pests and diseases such as pine blister rust, fusariosis, and white pine rust, which threaten forest health. By focusing on bioorganic products,

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particularly those based on basidiomycetes, this research contributes to the ongoing efforts to reduce reliance on harmful chemicals and promote sustainable forest management practices.

Aioub et al.[1] considered the transition to organic products to mitigate environmental pollution and combat climate change according to the United Nations Sustainable Development Goals. Particular attention was paid to the use of biopesticides derived from plants and algae, such as *Anethum sowa, Thymus vulgaris*, and numerous algae species, which serve as a safe and effective alternative to synthetic pesticides. These natural biopesticides effectively control pests without affecting beneficial microorganisms or polluting the environment. The study emphasised the significance of biopesticides in integrated pest management, noting their benefits in increasing sustainability, maintaining environmental safety, and contributing to global initiatives aimed at achieving a clean environment, food security, poverty alleviation, and sustainable development by 2050.

Lalík et al.[2] investigated the effective strategies for protecting young coniferous seedlings from the large pine weevil (*H. abietis*), a major pest of European forests. In 2016 and 2017, the researchers conducted two semi-natural trials to evaluate the effectiveness of an insecticide (alpha-cypermethrin), wax and glue coatings on Douglas fir and Norway spruce seedlings. Over a 16-week period, all treatments noticeably reduced damage to Norway spruce by the Norway spruce weevil, but the reduction in damage to Douglas fir was not statistically significant. Importantly, the wax and adhesive coatings demonstrated comparable effectiveness to pesticides in reducing damage. The study indicated that wax coatings can serve as a viable alternative to chemical insecticides for seedling protection, providing a more environmentally friendly approach to pest management.

Willoughby et al.[3] investigated alternative methods of controlling the large pine weevil (*H. abietis*) in UK forests, replacing synthetic pyrethroid insecticides (alpha-cypermethrin and cypermethrin). Between 2009 and 2015, more than 50 chemical and non-chemical treatments were tested at 16 sites. The findings revealed that acetamiprid (0.037 g a.i. / trunk) effectively protects young Sitka spruce with less impact on aquatic ecosystems and bees, analogous to pyrethroids. Chlorantraniliprol (0.0129 g a.i. / stem) also showed potential as a safer option, while imidacloprid and thiacloprid were effective but limited due to environmental risks. Natural compounds such as spinosad and the fungal agent *Metarhizium anisopliae* provided limited protection but may have potential under better conditions. The study concluded that neonicotinoid insecticides, especially acetamiprid, are viable and less harmful alternatives to pyrethroids for controlling *H. abietis*, and that physical barriers are only appropriate in low-pest areas as part of an integrated approach.

Dai et al.[4] examined the use of *Bacillus pumilus* HR10 as a sustainable biocontrol agent against *Sphaeropsis* shoot blight disease caused by the pathogen *Sphaeropsis sapinea*, which causes severe damage to pine forests around the world. The study revealed that HR10 inhibits the pathogen by forming secondary compounds that change the structure of the mycelium, delay spore germination, and disrupt the integrity of the cell membrane. Furthermore, HR10 prevents pathogen penetration by colonising pine branches and aggregating around the mycelium. In greenhouse trials, preventive application of HR10 on *Pinus massoniana* resulted in 90% disease control. The study demonstrated the effectiveness of *B. pumilus* HR10 in controlling *S. sapinea*, which highlights its potential as a reliable and sustainable approach to controlling shoot blight disease in pines. Liu et al.[5] emphasised the effectiveness of biopesticides in the control of diseases and pests of crops and their advantages over synthetic pesticides. Biopesticides, which are derived from natural substances and microorganisms, are environmentally sustainable, pose little danger to non-target creatures and humans, rapidly degrade in the environment and are suitable for organic agriculture. They also benefit from accelerated regulatory approval, shorter development times, and lower costs compared to chemical pesticides. In China, biopesticides, including *Bacillus thuringiensis, Jinggangmycin*, pyrethrins, and brassinolide, are being promoted as viable substitutes for conventional chemical pesticides.

Previous research has largely focused on ecological alternatives to chemical pesticides and their effects on forest stands, but most studies have focused on particular aspects such as the effectiveness of insecticides or specific methods of controlling individual pests and diseases. The current study can fill the gap in the comprehensive analysis of the application of a bioorganic composition based on biochemical fractions of basidiomycetes to protect pine stands from several types of pests and diseases simultaneously. The present study also examined the long-term effects of such preparations on the growth and development of pine trees, making it a valuable contribution to the field of sustainable forestry.

The purpose of this study was to investigate the effectiveness of using a bioorganic composition based on biochemical fractions of basidiomycetes to protect forest plantations, specifically pine trees, from diseases and pests, as well as to assess its effects on tree growth and development under various environmental conditions. To fulfil this purpose, the following objectives were set:

- To investigate the effects of various concentrations of bioorganic composition on the growth and development of seedlings and young trees of Scots pine.
- To evaluate the effectiveness of the biopreparation in reducing the number of pests

such as the common pine shoot beetle, the larger shothole borer, and the pine hermes.
- To investigate the effects of the bioorganic composition on the resistance of trees to diseases, specifically pine blister rust, fusariosis, and white pine blister rust.
- To compare the effectiveness of the biopreparation with conventional chemical means of protecting forest stands.
- To assess the long-term effect of the bio-organic composition on the state of forest ecosystems and the possibility of its widespread use in the forestry of Ukraine.

A significant element of the study was that the proposed bio-organic preparation derived from biochemical fractions of basidiomycetes represented a new alternative to chemical pesticides and fungicides. The use of biological products not only protects plants from pests, but also enhances their growth, increases photosynthetic activity, and improves disease resistance, making these strategies very relevant in sustainable forestry.

2. Materials and Methods

In the study of the feasibility of using the entomopathogenic fungal biological product Meganit Nirbator to protect pine stands from diseases and pests, the methodology was applied, which is regulated by the Law of Ukraine No. 180-XIV "On Plant Protection"[6] and the FSC National Forest Stewardship Standard of Ukraine[7].

The study employed a field method to collect samples of plant litter on the soil surface from the 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 employed an entomopathogenic fungal biological product with a titre of 6 bn spores/g and a concentration 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 common pine shoot beetle (165 caterpillars, 55 individuals for each age, in three replications), the larger shothole borer, and the pine hermes (the total number of their caterpillars was 120 individuals, 40 individuals for each species), which were diapaused on tree boles and in the soil. The experiments with the common pine shoot beetle larvae were conducted using caterpillars of the third, fourth, and fifth instars. A method for research comparing control plots and plots affected by fires involved using the Sørensen-Chekanovsky species similarity index to assess the degree of change in vegetation cover in different types of forest vegetation conditions.

Field studies were conducted at sites located in the forest ecosystems of Sumy region, namely in the forests of the State Enterprise SE "Forests of Ukraine", Konotop Forestry Branch, SE "Forests of Ukraine", Lebedynske Forestry Branch, and in the Mykhailivska Tsilyna Nature Reserve. During the laboratory stage, the composition was pre-tested 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 blister rust, fusariosis, and white pine blister rust. A total of 100 seedlings were selected for the study. The chlorophyll content was measured using the gasometric method.

At the field stage, the following was carried out: selection of a site for planting seedlings; treatment of seedlings with an organic composition before planting; monitoring of the growth and physiological condition of trees for 3 months, one and 2 years. To determine the amount of Meganit Nirbator per hectare, the required number of grams per square metre should be calculated, and then this value should be converted to hectares. When calculating the number of grams of the biopreparation per square metre, the following data were obtained:

$$\frac{8.05\ bn\ spores}{6\ bn\ spores/g} = 1.34167\ g/m^2.$$

When converting the value per hectare, the corresponding values were obtained:

$$1.34167\,\frac{g}{m^2} \times \frac{10{,}000\ m^2}{ha} = 13.4167\ g/ha.$$

Seedlings and young trees of Scots pine (*Pinus sylvestris*), aged from one to three years, were used for the study. The organic composition was created based on biochemical fractions of the basidiomycetes Meganit Nirbator. The following equipment and products were used to control the number of pests in the samples: Gruntek HS-1.5 hand sprayers (manufactured in China), pheromone traps for *Scolytidae* pests (manufactured in China), and *Beauveria bassiana* biological pathogenic agents (manufactured in the USA). The chlorophyll content was measured using a Floratest portable fluorometer.

3. Results

In this study, it was decided to investigate a bioorganic composition intended for the rehabilitation of forest ecosystems. The bio-organic composition Meganit Nirbator is an innovative product based on biochemical fractions of basidiomycetes, designed to restore forest resources after fires. Basidiomycetes, or cap fungi, have unique properties that can help restore soil and improve its fertility, making them a promising tool for environmental rehabilitation.

According to previous studies, it became known that the treatment of seedlings and young pine trees with the bioorganic composition Meganit Nirbator, created based on 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 blister rust, fusariosis, and white pine blister rust, as well as pests[8)-10)]. The findings of the laboratory stage revealed a positive effect of the organic composition on the growth and physiological state of pine seedlings (Table 1).

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, trunk 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 findings 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). The study found that the bioorganic composition, based on biochemical fractions of basidiomycetes, positively affected the growth and development of pine trees, particularly at higher concentrations (2% and 5%). These concentrations stimulated increases in height, trunk diameter, and the number of new shoots compared to the control group. The high chlorophyll content in the treated plants indicated enhanced photosynthetic activity, contributing to improved growth and better nutrient absorption. Additionally, the bioorganic composition enhanced the trees' protective properties, increasing their resistance to diseases such as needle blight and white pine rust, as well as reducing damage from pests like bark beetles and pine midges. This was likely due to the biologically active substances in the composition, which function as natural fungicides and insecticides. As a result, the preparation not only improved the growth and health of the trees but also helped reduce disease incidence and pest populations, ultimately benefiting the overall condition of the forest stands.

The study was continued to confirm the long-term effect of the biological product on pine trees and the possibility of its widespread use in forestry. An additional observation was conducted for 2 years to assess the stability and effectiveness of the formulation on mature pine trees. The following parameters were measured: height, trunk diameter, number of new shoots, chlorophyll content,

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

Group	Height (cm)	Trunk 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
1% solution of the biological preparation	27.8±1.5	4.5±0.3	3.7±0.5	1.7±0.2
2% solution of the biological preparation	30.2±1.4	4.8±0.2	4.1±0.4	1.9±0.2
5% solution of the biological preparation	33.1±1.3	5.2±0.3	4.6±0.5	2.1±0.2

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

Group	Height (cm)	Trunk 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
1% solution of the biological preparation	42.3±2.2	5.9±0.4	4.8±0.4	1.8±0.2	70
2% solution of the biological preparation	46.7±2.4	6.3±0.3	5.4±0.5	2.0±0.2	80
5% solution of the biological preparation	52.1±2.5	6.8±0.4	6.1±0.5	2.3±0.2	90

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

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

disease resistance, and number of pests (Table 3). According to the data obtained, the positive effect of the bioorganic composition continued for 2 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. The increase in trunk height and diameter was greatest in the 5% solution group. The difference between control and treated trees stayed significant. The number of new shoots and chlorophyll content were significantly higher in the treated plants, indicating increased photosynthetic activity. A prominent 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 isolated fractions with organic solvents to the surface of the tree bark (Table 4).

It was found that the treatment with the composition against all three types of pests: the common pine shoot beetle, the larger shothole borer, and the pine hermes, provided a significant reduction in their number (from 80% to 85%). According to the findings 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).

Pine blister rust infection decreased from 40% in the control group to 10% in the treated group, representing a 75% reduction in infection. Fusariosis 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 white pine blister rust 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.

The Law of Ukraine No. 180-XIV "On Plant Protection" (1998) governs plant protection practices within Ukraine, establishing the legal framework for managing plant diseases, pests, and the use of protective products. This law provides guidance on what substances and biological agents are permitted for plant protection, ensuring that only approved chemicals and biological agents, like the entomopathogenic fungal biological product Meganit Nirbator, are used in ways that minimize environmental impact and public health risks. In your study, referencing this law is essential to underline the legal validity of using such a product, confirming that the methodology adheres to Ukrainian agricultural and environmental standards. By citing this law, the research indicates that the study followed national regulations concerning plant protection and pesticide use, ensuring compliance with local laws and sustainable practices.

The Forest Stewardship Council (FSC) National Forest Stewardship Standard of Ukraine sets the criteria for forest management practices, including the management of pests and diseases, aimed at maintaining ecological integrity and sustainable forestry practices. The standard is designed to prevent overexploitation, protect biodiversity, and ensure that forest management activities do not degrade the environment. By referencing this standard, the study aligns itself with globally recognized principles for sustainable forest management, as the FSC is known for promoting responsible forest management worldwide. The methodology applied in your study, particularly in the context of pest and disease management, must adhere to these sustainability criteria, ensuring that forest management is not only effective in protecting against pests but also in maintaining the long-term health and biodiversity of the forest ecosystems.

Table 6 showed the mortality rates of caterpillars of herbivorous phytophages of the common pine shoot beetle infected with the biopreparation solution depending on age and temperature.

According to the findings of this 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 LT_{50} (days) value (time required for 50% of the population to perish) decreased. This indicated that the effectiveness of the bioorganic composition increased at hotter temperatures. The air temperature within 13-18°C for 8.4-10.5 days contributed to the death of 50% of the population of common pine shoot beetle caterpillars. With increasing temperature, the period of caterpillar death was reduced. Common pine shoot beetle caterpillars at later stages of phytophage development (L_4, L_5) require more time to perish under the influence of the biological product.

According to the data on the dynamics of mortality of caterpillars of the third instar, it is advisable to take

Table 4: Results of pine treatment against pests

Pests	**Control group (no treatment)**	**Treated group**	**Pest reduction**
Common pine shoot beetle (*Tomicus piniperda L.*)	50 specimens / tree	10 specimens / tree	80%
Larger shothole borer (*Scolytus mali*)	30 specimens / tree	5 specimens / tree	83.3%
Pine hermes (Pineus pini Hermes)	20 specimens / tree	3 specimens / tree	85%

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Table 5: Results of treatment of pine trees against diseases

Disease	Control group (no treatment)	Treated group	Infection reduction
Pine blister rust (*Peridermium pini*)	40% infected trees	10% infected trees	75%
Fusariosis (*Fusarium*)	35% infected trees	8% infected trees	77.1%
White pine blister rust (*Cronartium ribicola*)	25% infected trees	5% infected trees	80%

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 phytophage development	13°C	18°C	23°C	28°C	33°C
Common pine shoot beetle (*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
Larger shothole borer (*Scolytus mali*)	L_3	31.7	30.2	25.3	19.2	5.2
LSD_{05}						
Pine hermes (Pineus pini Hermes)	L_5	19.1	15.6	11.3	4.5	4.9
LSD_{05}						

Note: L_3, L_4, L_5 – caterpillars of phytophages of different ages.

measures to apply the solution to the places of diagnosis of the phytophage. The diagnosing caterpillars of the fifth instar pine hermes, as well as the caterpillars of the third instar of the larger shothole borer 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. Hotter temperatures resulted in faster caterpillar mortality, and caterpillars at later stages of development were more resistant to infection.

When compared with the larger shothole borer and pine hermes, it was found that the caterpillars of the common pine shoot beetle were more favourable to the effect of the preparation. Table 7 presents the toxicological parameters of the biological product activity against caterpillars of different age groups of phytophages. The biopreparation demonstrated different toxicological parameters (LC_{50}) for distinct stages of caterpillar development of different phytophagous species. For example, for caterpillars of the common pine shoot 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 LC_{50} (days) percentage of the preparation increased from 0.025% to 0.050% due to the increase in the physiological state of caterpillars from active to ready to fly. As for the top bark beetle and pine hermes, the LC_{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 presents the consumption rates of the biological product. The number of grams of biological product per square metre was 13.4167 g/ha. Thus, for effective protection of Scots pine stands from third instar caterpillars, 13.42 g/ha of the biological product with a titer of 6 bn g/ha should be used. The bioorganic composition

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

Types of herbivorous phytophages	Phase of phytophage development	Physiological state of caterpillars	Concentration of the bio-organic agent that causes the death of 50% of the caterpillar population LC_{50} (days)	
			% by preparation	Term of determining days, days
Common pine shoot beetle (*Tomicus piniperda L.*)	L_3	Active, healthy	0.025%	14
	L_4	Development of organs	0.040%	18
	L_5	Large, ready to fly	0.050%	22
Larger shothole borer (*Scolytus mali*)	L_3	Active, newly hatched	0.030%	12
Pine hermes (Pineus pini Hermes)	L_5	Mature, with a large nutrition supply	0.045%	20

Note: L_3, L_4, L_5 – caterpillars of phytophages of different ages.

Table 8: Indicators of consumption rates of a biological product for the protection of pine stands depending on the age of the common pine shoot beetle caterpillars

Instar of pine shoot beetle caterpillars	Concentration of a bio-organic agent that causes the death of 90% of the caterpillar population LC90 (bn spores/ml) as a function of phytophage mortality		Parameters of *B. bassiana* spore vitrates, bn/m^2	
	Plant residues – soil surface	Total mortality rate	For plant protection needs	To destabilise the effective part of the phytophage
Second	0.025	0.005	1.5	0.41
Third	0.040	0.003	8.05	0.35
Fourth	0.55	0.070	12.55	1.20

stimulated the growth and development of Scots pine plants. With increasing solution concentration, a gradual increase in height, trunk diameter, number of new shoots and chlorophyll content was observed. The use of the bio-organic composition reduced the use of chemical pesticides and fungicides, which positively affected the ecological state of the region. 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.

Forestry managers should consider adopting bioorganic products like Meganit Nirbator for pest and disease management as a sustainable alternative to chemical pesticides. These products can be integrated into broader pest management strategies and applied to various tree species, promoting sustainability across forest ecosystems[11),12)]. Establishing a monitoring system to track the long-term effectiveness of bioorganic treatments is essential, with key indicators like tree growth and disease resistance measured over time. Bioorganic products should be incorporated into forest management plans focused on biodiversity protection, particularly in forest rehabilitation efforts.

Optimizing application rates and timing based on environmental conditions and pest life cycles will maximize effectiveness. Training forestry personnel in the safe use of these products is vital for successful application. Collaboration with research institutions will ensure that forest management practices stay aligned with the latest scientific advancements in bioorganic pest control. Public awareness and policy support are also crucial for encouraging broader adoption of eco-friendly pest management methods.

Protecting pine stands from pests and diseases is critical to maintaining the ecological balance in the region. Pine trees, as dominant species in many forest ecosystems, play a pivotal role in regulating the environment[13)]. When affected by diseases and pests, they can cause significant environmental problems, including reduced biodiversity, as many species depend on pine forests for habitat, food, and shelter. The loss of healthy pine trees disrupts this delicate balance, leading to the decline of dependent species and the loss of ecosystem services.

The degradation of pine forests due to pests and diseases can lead to poorer air and water quality. Healthy forests act as carbon sinks, absorbing carbon dioxide from the atmosphere and reducing the impact of climate change[14),15)]. When these forests are weakened or destroyed, their ability to capture carbon diminishes, exacerbating global warming. Furthermore, pine trees play an important role in regulating water quality by preventing soil erosion, filtering pollutants, and maintaining water retention in forest ecosystems. When forests are affected by diseases or pests, this role is compromised, leading to soil erosion, increased sedimentation in waterways, and reduced water quality[16)-18)].

The experiment demonstrated that the bioorganic composition Meganit Nirbator significantly improved the growth, development, and disease resistance of pine trees. Higher concentrations (2% and 5%) were particularly effective in increasing tree height, trunk diameter, the number of new shoots, and chlorophyll content, while also enhancing resistance to diseases like pine blister rust and fusariosis. The product also reduced pest populations, showing its effectiveness in controlling common pests such as the pine shoot beetle. Long-term effects observed over two years confirmed its potential as a sustainable alternative to chemical pesticides, supporting both tree health and forest ecosystem management. The findings suggest that bioorganic products can be integrated into forestry practices for more environmentally friendly pest control and forest rehabilitation.

4. Discussion

The findings revealed that the application of the bioorganic composition significantly improved the growth and development of pine stands, as evidenced by increased tree height, trunk diameter, and the number of new shoots. This positive effect can be attributed to the bioactive components in the bioorganic composition, which stimulate the physiological processes of the trees. The higher concentrations of the bioorganic solution (2% and 5%) were particularly effective, resulting in enhanced chlorophyll content, indicating improved photosynthetic activity. This increase in growth and health also correlates with the observed improvement in disease resistance, as trees treated with the bioorganic product showed a notable reduction in infection rates from pine blister rust, fusariosis, and white pine blister rust. These results suggest that the bioorganic composition not only supports the physical growth of pine trees but also boosts their ability to withstand environmental stresses, further reinforcing the potential of bioorganic products as an environmentally friendly alternative to chemical pesticides in forest management.

The application of bioorganic products like Meganit Nirbator presents significant economic advantages in forest management, particularly in pest and disease control. This product, derived from biochemical fractions of basidiomycetes, provides an effective and sustainable alternative to chemical pesticides and fungicides, reducing the need for costly chemical treatments. Its long-term efficacy, as demonstrated in the study, not only supports the growth and health of pine trees but also minimizes the environmental impact by reducing the use of harmful chemicals, which can contaminate soil and water resources. By promoting the natural resilience of pine forests against pests and diseases, the bioorganic composition contributes to the overall stability and productivity of the forest ecosystem, ensuring that it remains a valuable resource for timber, biodiversity, and carbon sequestration.

The cost-effectiveness of using bioorganic products in pest and disease management can be observed through the reduction in pest populations, lower disease incidence, and improved tree health, which directly translates to higher productivity in forest stands[19)]. Over time, this reduces the need for costly interventions, such as extensive pest control or the restoration of heavily damaged forest areas. Additionally, integrating bioorganic products into forest management strategies helps maintain biodiversity and supports forest regeneration efforts, which are essential for long-term ecological balance[20)-22)]. This approach enhances the economic sustainability of forestry enterprises, contributing to both environmental protection and forest resource conservation, crucial for the future of sustainable forestry in Ukraine and beyond.

The environmental safety of using the Meganit Nirbator bioproduct is an important aspect in terms of its impact on biodiversity, soil microflora, and long-term benefits for the ecosystem. Since bioorganic products use natural components, such as biochemical fractions of basidiomycetes, they have a lower negative impact on the environment compared to traditional chemical pesticides[23)]. They not only control pests and diseases but also maintain the natural balance of the ecosystem, contributing to the restoration and maintenance of forest ecosystem health.

The impact on biodiversity is manifested through improved conditions for the development of various species, including beneficial insects, soil organisms, and plants. The use of biological products helps to reduce pest populations while preserving the integrity and health of other organisms that depend on these ecosystems[24),25)]. Biological products, free from toxic chemicals, do not harm non-target species, helping maintain ecological balance in forests.

Soil microflora is also an important target for biological products. Basidiomycetes have the ability to restore soil and improve its fertility, which helps maintain healthy microflora and improve soil structure. This reduces the risk of erosion and promotes stable growth of forest crops. Long-term benefits for the ecosystem include improved water retention properties of soils, reduced water pollution, and preservation of forest health, which contributes to their resilience to climate change[26),27)]

There was a significant increase in the height, trunk diameter, number of new shoots, and chlorophyll content of the treated trees, indicating increased photosynthetic activity. Furthermore, the use of the biopreparation led to a significant reduction in the number of pests (by 80-85%) and a decrease in the level of infection with diseases such as pine blister rust, fusariosis, and white pine blister rust[28)-30)].

It was found that for effective protection of Scots pine trees from third instar caterpillars, the required dose was 13.42 g/ha of the biological product with a titre of 6 bn g/ha. Fettig et al.[31)] raised an analogous question in their study. The researchers found that lower doses of verbenone SPLAT® verb (7 g/tree) can be effectively used to protect pine trees from the mountain pine beetle (*Dendroctonus ponderosae Hopkins*). The statement can be agreed with, as really low doses of verbenone can act for a long time, providing long-term protection of trees from pests. It was noted that infection with pine blister rust decreased from 40% in the control group to 10% in the treated group. Kuang et al.[32)] investigated an analogous problem. The researchers 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 simultaneous satellite images. The findings of the present study did not coincide with the conclusions of Kuang et al., as the researchers conducted a detailed study at the local level using additional ground-based monitoring methods and laboratory analysis, which enabled them to identify different stages of the disease and apply prompt and effective control measures.

It was found that fusariosis infection decreased from 35% in the control group to 8% in the treated group. Youssef[33)] investigated an analogous issue. The researcher found that latent root infections of Scots pine trees in areas with a low risk of infection with the root sponge disease *Heterobasidion annosum s. l.* were quite common. Furthermore, these infections were more common in plots with a greater site index, indicating a greater probability of infection in trees on more fertile soils. This statement should be accepted, as a greater site index may indicate a greater stand density and greater competition for resources, which can weaken trees and make them more vulnerable to infections. This study aligns with and extends existing research on forest pest and disease management. Youssef's findings highlighted the link between site conditions and tree vulnerability to infections. In contrast, this study demonstrated that bioorganic treatments based on basidiomycetes can effectively reduce pest populations like the larger shothole borer. While Youssef's[33] study suggests that fertile soils may increase disease susceptibility, this research shows that bio-based products can mitigate pest infestations, offering a sustainable solution for managing tree vulnerability in such conditions. This approach contributes to the broader knowledge of sustainable forest health management.

Golan et al.[34] investigated an analogous issue. According to the findings of these scientists, the use of trap trees and their treatment with bifenthrin reduced the number of dead trees in stands, which indicated the effectiveness of such measures to prevent the spread of bark beetles. Analogous findings were obtained in the study, according to which it was found that after the application of the bio-organic composition, the number of larger shothole borer pests decreased by 83.3%. The caterpillars of the third instar of the larger shothole borer were much more resistant to the biological preparation, and therefore the time of their death was longer. Erbilgin et al.[35] considered the results of these indicators, noting 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 probability of tree death due to physiological exhaustion and mechanical damage to vascular tissue by beetles.

For the caterpillars of the larger shothole borer in the L_3 phase, the LC_{50} (days) percentage value of the preparation was 0.030%, while the caterpillars were in an active physiological state and had recently hatched. Eroglu and Harman[36] studied an analogous issue. According to their findings, the effectiveness of pheromone traps was extremely low during the epidemic, and therefore the most effective method of controlling bark beetles during epidemic periods was the method of ‘trap trees’. The findings of Eroglu and Harman should be agreed with, as the method of “trap trees” allows attracting and destroying a considerable number of bark beetles without the use of chemicals, which is a more environmentally friendly approach. It was demonstrated that air temperature within 28-33°C for 5.2-19.2 days contributed to a reduction in the death of caterpillars of the larger shothole borer beetle. Haseeb[37] conducted an analogous study. According to the findings of this researcher, 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 under stress 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. The findings of this study align with Haseeb’s[37] research, which emphasized that pests, such as the southern pine beetle and black terpentine beetle, tend to infest trees weakened by physical or biological stress. Similarly, this study showed that bioorganic treatments significantly reduced pest populations, including the larger shothole borer, supporting the notion that pest control can be most effective when trees are in a healthy, non-stressed state. This research contributes to the broader understanding of forest pest dynamics and the role of environmental factors in pest vulnerability.

It was recorded that the treatment with the bio-organic composition demonstrated effectiveness in the fight against the larger shothole borer, reducing their count to 5 specimens per tree, compared to the control group, where their count was 30 specimens per tree. Hansen et al.[38] investigated an analogous issue. It was noted that climatic water deficit significantly affected the probability of infestation, showing that periods of pronounced water stress could contribute to the spread of beetles and further damage to the pine forest. The findings obtained in the present study differed from the conclusions drawn in Hansen et al., which could be conditioned by differences in the research methods used, such as the method of estimating abiotic conditions (temperature, precipitation) using *Daymet* interpolation in the analysed study and the field method in the present study. The caterpillars of the fifth instar of the *pine hermes (Pineus pini Hermes)* were significantly more resistant to the biological product, and, accordingly, the time of their death was longer. Heiðarsson et al.[39] explored the issue under study. According to their study, lodgepole pines of Icelandic origin were less susceptible to woolly aphid (*Pineus pini*) invasion compared to pine stands of non-Icelandic origin, which can be explained by natural selection, which contributed to the adaptation of lodgepole pine in Icelandic conditions. The findings of the present study did not coincide with the findings of Heiðarsson et al. [39] as the researchers analysed the resistance to the effects of a bioorganic composition.

The effectiveness of treating pine trees with a bioorganic composition against pine blister rust disease showed a 75% reduction in infection. Zhang and Stenlid[40] also explored this issue. The researchers found that the protocols for monitoring and managing the pine blister rust epidemic, developed to detect the rust fungus (*Cronartium pini*), were effective and specific for identifying this fungus in 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 the current study differed from those of Zhang and Stenlid,

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as the study focused on the use of a bioorganic composition based on biochemical fractions of basidiomycetes to control pine blister rust disease, while Zhang and Stenlid investigated the protocols for monitoring and managing the epidemic of this disease.

In this study, the use of bioorganic preparations based on basidiomycetes to protect pine forests from pests and diseases demonstrated promising results. Similar approaches have been explored in other studies, highlighting the potential of biofungicides for managing forest health. For instance, Liu et al.[41] examined the resistance of limber pine to white pine blister rust, which, like fusariosis in this study, shows the importance of disease resistance in forest management. The results of this study are consistent with this research on disease resistance, particularly regarding white pine blister rust. Just as Liu et al. highlighted the importance of resistance in managing forest diseases, this study demonstrates that the bioorganic composition enhances pine tree resistance to diseases like fusariosis and white pine blister rust. This supports the growing body of literature emphasizing the role of biological treatments in improving disease resistance and overall forest health management.

The cost-effectiveness of using natural treatments, such as bioorganic compositions, aligns with Maaß and Kehlenbeck’s[42] cost-benefit analysis of aerial spraying for pest control in Germany, which indicates the growing interest in sustainable pest management strategies. The findings of this study regarding the effectiveness and cost-efficiency of bioorganic compositions for pest and disease control align with Maaß and Kehlenbeck's cost-benefit analysis of sustainable pest management strategies. Their work highlights the increasing preference for environmentally friendly treatments over traditional methods like aerial spraying, reinforcing the broader trend in forestry toward integrating natural and bio-based solutions to enhance both ecological sustainability and cost-effectiveness in pest control.

Cardinal et al.[43] also explored the role of volatile compounds in reducing mortality in whitebark pines, further supporting the efficacy of bioactive compounds in forest health management. The integration of fungal treatments for pest control, such as those derived from *Suillus bovinus* and *Gomphidius roseus*, also parallels the use of basidiomycetes in this study to enhance pine resilience[44].

Similarly, the findings of Figueroa-Corona et al.[45] on the defense responses in whitebark pine to blister rust infections highlight the potential of bioorganic agents to activate defense mechanisms in trees. This study’s emphasis on reducing the use of chemical pesticides and fungicides aligns with current trends in sustainable forestry practices, as demonstrated by Martos and Domínguez-Núñez[46], who noted the importance of soil microbial health in forest ecosystems. The long-term benefits observed in this study are consistent with research indicating that biofungicides can enhance forest ecosystem resilience, as seen in other studies focused on pine species, such as the work by Assyov and Slavova[47] on the role of macrofungi in forest stands. Overall, the findings of this study contribute to the growing body of research supporting bioorganic approaches as an effective and sustainable method for protecting pine forests from pests and diseases, with potential applications in global forestry management strategies.

The study of bioorganic compositions for the protection of pine stands aligns with recent research on forest health, particularly in relation to disease resistance and microbial interactions. For example, Stein Åslund et al.[48] identified distinct metabolic profiles in Scots pines tolerant to Melampsora pinitorqua and Diplodia sapinea, offering insights into the complex biochemical mechanisms that contribute to pine resilience against pathogens. Similarly, Liu et al.[49] documented the virulence of a Cronartium ribicola race affecting limber pine restoration in Alberta, underscoring the importance of identifying genetic resistance and managing pathogens effectively to maintain forest health. The findings of this study, which show increased resistance to diseases like fusariosis and pine blister rust in treated pine seedlings, complement these studies by demonstrating that biological treatments, such as those based on basidiomycetes, can enhance tree defense mechanisms. This aligns with previous research, such as Li et al.[50], who examined the impact of pine wilt disease on the endophytic microbial communities of Pinus koraiensis, highlighting the significance of soil microbiomes and the role of fungi in plant health. The use of bioorganic treatments in this study also suggests potential applications for managing microbial interactions within pine ecosystems, similar to those observed in other pine species facing diverse pathogen pressures.

As a result of the conducted studies, it was found that a bioorganic composition based on biochemical fractions of basidiomycetes is an effective and environmentally friendly means of protecting pine stands. It helps to improve tree growth, increases their resistance to pests and diseases, providing a long-term positive influence on forest ecosystems. The findings confirmed the prospects of using biological products as an alternative to chemical pesticides for sustainable forestry.

5. Conclusions

The findings of the present study demonstrated the great efficiency of a bioorganic composition based on biochemical fractions of basidiomycetes in protecting pine stands from pests and diseases. The use of this biological preparation significantly improved the growth and development of trees, increasing the height, trunk diameter, and number of new shoots compared to the control group.

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There was also an increase in the photosynthetic activity of the trees, as evidenced by an increase in the chlorophyll content of the leaves of the treated plants. A vital advantage of the bio-organic composition lies in its ability to effectively reduce the count of pests, such as the common pine shoot beetle, larger shothole borer, and pine hermes, which resulted in a reduction of pest populations by 80-85%.

Furthermore, the biopreparation proved to be effective in combating the main diseases affecting pine trees, including pine blister rust, fusariosis, and white pine blister rust. The use of the composition reduced the level of infection by 75-80%, which indicates its great fungicidal activity. Importantly, the positive effect of the biological product was maintained for 2 years, which confirms its long-term effectiveness. Comparison of the findings with conventional chemical protection products revealed that the bio-organic composition is no less effective, but more environmentally friendly. It does not cause pollution of soil and water resources, preserving biodiversity and ecosystem stability.

Thus, the use of bio-organic products, specifically compositions based on basidiomycetes, is a promising solution for sustainable forestry. They can provide effective protection of forest stands without harming the environment, which is especially significant in the context of the global transition to environmentally friendly management practices. Future research could be aimed at further investigating the mechanisms of action of bioorganic products, specifically their effects on various types of pests and diseases in diverse climatic conditions. It is especially promising to investigate the effects of biological products on ecosystem sustainability and interaction with other components of forest ecosystems, such as soil microorganisms and beneficial insects. It is also vital to explore the possibilities of combining bio-organic products with other environmentally friendly plant protection methods to increase their effectiveness. In addition, methods for large-scale application of biological products in forestry should be developed to ensure their availability and practicality in real-world production.

Further research may be directed toward studying the mechanisms of action of biofractions contained in bioorganic compounds in order to better understand their effectiveness in combating diseases and pests. Assessing the effectiveness of biological products in different climatic zones will help to determine how climatic conditions affect their effectiveness in forestry. In addition, an important area of research is a comprehensive analysis of the impact of bioorganic preparations on soil microorganisms, which will make it possible to assess the long-term ecological consequences for soil health and the biodiversity of forest ecosystems.

References

1) A.A.A. Aioub, S. Ghosh, A. Al-Farga, A.N. Khan, R. Bibi, A.M. Elwakeel, A. Nawaz, N.T. Sherif, S.A. Elmasry, and E.E. Ammar, "Back to the origins: Biopesticides as promising alternatives to conventional agrochemicals," Eur. J. Plant Pathol., 169 (4), 697-713 (2024). doi: 10.1007/s10658-024-02865-6.
2) M. Lalík, J. Galko, C. Nikolov, S. Rell, A. Kunca, R. Modlinger, and J. Holuša, "Non-pesticide alternatives for reducing feeding damage caused by the large pine weevil (Hylobius abietis L.)," Ann. Appl. Biol., 177 (1), 132-142 (2020). doi: 10.1111/aab.12594.
3) I.H. Willoughby, R. Moore, A.J. Moffat, J. Forster, I. Sayyed, and K. Leslie, "Are there viable chemical and non-chemical alternatives to the use of conventional insecticides for the protection of young trees from damage by the large pine weevil Hylobius abietis L. in UK forestry?" Forestry, 93 (5), 694-712 (2020). doi: 10.1093/forestry/cpaa013.
4) Y. Dai, X.-Q. Wu, Y.-H. Wang, and M.-L. Zhu, "Biocontrol potential of Bacillus pumilus HR10 against Sphaeropsis shoot blight disease of pine," Biol. Control, 152, 104458 (2020). doi: 10.1016/j.biocontrol.2020.104458.
5) X. Liu, A. Cao, D. Yan, C. Ouyang, Q. Wang, and Y. Li, "Overview of mechanisms and uses of biopesticides," Int. J. Pest Manag., 67 (1), 65-72 (2021). doi: 10.1080/09670874.2019.1664789.
6) Verkhovna Rada of Ukraine, Law of Ukraine No. 180-XIV “On Plant Protection” (2023). https://zakon.rada.gov.ua/laws/show/180-14#Text.
7) Forest Stewardship Council, The FSC national forest stewardship standard of Ukraine, Bonn: FSC International Center (2018). https://open.fsc.org/server/api/core/bitstreams/f623201b-6389-40dc-b315-79c25fc124dd/content.
8) N.P. Sus, O.A. Boyko, L.V. Protsenko, O.A. Demchenko, N.O. Tymoshok, A.V. Biletskyi, and A.L. Boyko, "Distribution of carlavirus load in hop plants (Humulus lupulus L.)," Agroecol. J., 2, 40-44 (2020). doi: 10.33730/2077-4893.2.2020.207679.
9) B. Yelkenova, R. Beisenova, R. Tazitdinova, Z. Rakhymzhan, and N. Karipbaeva, “Accumulation of heavy metals in the needles of Scots pine of the Semipalatinsk Pre-Irtysh region and Burabay National Park,” Evergreen, 10(3), 1231–1241 (2023). doi: 10.5109/7148444.
10) K.T. Abayeva, G.M. Rakhimzhanova, G. Myrzabayeva, E. Zhilkibayeva, and A. Beisekeyeva, “The Relevance of Sustainable Development of Forest Resource Reproduction in Kazakhstan,” Evergreen, 11(1), 46–55 (2024). doi:

10.5109/7172209.

11) V.V. Tkach, M.V. Kushnir, L.V. Romaniv, S.C. de Oliveira, Y.G. Ivanushko, Y.V. Nazymok, O.V. Ahafonova, P.I. Yagodynets, A.O. da Silva, N.P. Derevianko, M.P. Zavhorodnii, V.M. Odyntsova, M.P. Krasko, O.O. Vasylieva, O.V. Hrabovska, D.M. Musayeva, R. Sharipova, B. Samadov, L.N. Niyazov, T.V. Morozova, J.R. Garcia, J.I.F. da Paiva Martins, Zh.O. Kormosh, A.V. Grekova, I.F. Burdina, I.M. Khmeliar, and L.O. Kushnir, "The theoretical description for ibotenic acid and muscimol electrochemical determination in mushroom pulp and mushroom-based alcoholic beverages on nano-CuS composite with conducting polymer," Lett. Appl. NanoBioSci., 13 (1), 37 (2024). doi: 10.33263/LIANBS131.037.

12) V.V. Tkach, N.M. Storoshchuk, B.D. Storoshchuk, S.C. de Oliviera, Y.G. Ivanushko, V.V. Kryvetskyi, I.I. Kryvetska, I.V. Kryvetskyi, N.R. Yemelianenko, V.I. Narsiia, P.I. Yagodynets, A.O. da Silva, Z.Z. Masna, I.M. Shevchenko, V.A. Gnitsevych, A.O. Medvedeva, O.O. Vasylieva, D.M. Musayeva, X. Kosimov, O. Jabbarova, B. Samadov, G. Sagdullayeva, G. Hamdanova, M.V. Karputina, D.D. Khargella, J.R. Garcia, V.M. Odyntsova, and J.I.F. da Paiva Martins, "The theoretical description of sucralose cathodic electrochemical determination over a poly(safranin) modified electrode in acidic media," Biointerf. Res. Appl. Chem., 13 (6), 520 (2023). doi: 10.33263/BRIAC136.520.

13) Ya. Fuchylo, Yu. Hayda, I. Ivanyuk, O. Mazhula, and T. Ivaniuk, "Provenance tests of Pinus sylvestris L.: Estimation at the age of the half-rotation period," Sci. Hor., 26(7), 34-44 (2023). doi: 10.48077/scihor7.2023.34.

14) N. Yaroshenko, V. Skliar, and G. Rosenthal, "Evaluation of ontogenetic and vital structures of Stelliaria Holostea L. in beech forests in the South of Low Saxony, Germany," Int. Multidisc. Sci. GeoConf. Surv. Geol. Min. Ecol. Manag., SGEM, 23(3.2), 325–332 (2023). doi: 10.5593/sgem2023V/3.2/s14.40.

15) I. Skliar, V. Skliar, M. Sherstiuk, and I. Zubtsova, "Dimensional characteristics of Nymphoides Peltata (S.G. Gmel.) Kuntze in different ecological and cenotic conditions of the basin's water bodies Desna River (Ukraine)," Int. Multidisc. Sci. GeoConf. Surv. Geol. Min. Ecol. Manag., SGEM, 23(3.2), 103–110 (2023). doi: 10.5593/sgem2023V/3.2/s12.13.

16) B.R. Rexhepi, F.G. Rexhepi, M.K. Sadiku, and B. Dauti, "Ecosystem services of forests and their economic valuation: Prospects for sustainable development," Ukrain. J. Forest Wood Sci., 15(1), 109–125 (2024). doi: 10.31548/forest/1.2024.109.

17) M. Filss, W. Botsch, J. Handl, R. Michel, V.P. Slavov, and V.V. Borschtschenko, "A Fast Method for the Determination of Strontium-89 and Strontium-90 in Environmental Samples and its Application to the Analysis of Strontium-90 in Ukrainian Soils," Radiochim. Acta, 83(2), 81–92 (1998). doi: 10.1524/ract.1998.83.2.81.

18) L.D. Romanchuck, T.P. Fedonyuk, and R.G. Fedonyuk, "Model of influence of landscape vegetation on mass transfer processes," Biosyst. Divers., 25(3), 203–209 (2017). doi: 10.15421/011731.

19) S. Shahini, E. Skura, A. Huqi, E. Shahini, A. Ramadhi, and F. Sallaku, "Integrated Management of the Mediterranean Fruit Fly (Ceratitis capitata) on Citrus in the Konispol, Albania," Grassr. J. Natur. Resourc., 7(2), 324–346 (2024). doi: 10.33002/nr2581.6853.070217.

20) O. Skydan, M. Shvets, I. Kulbanska, A. Vyshnevsky, and O. Andreieva, "Monitoring of the phytosanitary condition of Larix decidua Mill. plants in the Modryna tract of the Zviahel Forestry branch of the State Enterprise Forests of Ukraine," Sci. Hor., 27(3), 23-33 (2024). doi: 10.48077/scihor3.2024.23.

21) S. Kerimkhulle, Z. Kerimkulov, Z. Aitkozha, A. Saliyeva, R. Taberkhan, and A. Adalbek, "The estimate one-two-sided confidence intervals for mean of spectral reflectance of the vegetation," J. Phys.: Conf. Ser., 2388(1), 012160 (2022). doi: 10.1088/1742-6596/2388/1/012160.

22) I. Zubtsova, and V. Skliar, "Population analysis of medicinal plants of the floodplain of the Seim River (Sumy Region, Ukraine)," Int. Multidisc. Sci. GeoConf. Surv. Geol. Min. Ecol. Manag., SGEM, 23(3.2), 187–194 (2023). doi: 10.5593/sgem2023V/3.2/s12.24.

23) A. Shuvar, N. Rudavska, I. Shuvar, and H. Korpita, "Realization of genetic potential of fiber flax varieties under the influence of growth stimulators of organic origin," E3S Web Conf., 254, 03004 (2021). doi: 10.1051/e3sconf/202125403004.

24) Zh.M. Yeraliyeva, M. Kunelbayev, Zh.O. Ospanbayev, M.S. Kurmanbayeva, T.P. Kolev, S.M. Kenesbayev, and A.S. Newsome, "The study of agricultural techniques of cultivation of new varieties of winter wheat under drip irrigation," Asian J. Microbiol., Biotech. Environ. Sci., 18(3), 779–785 (2016).

25) I. Ivanova, M. Serdiuk, V. Malkina, I. Bandura, I. Kovalenko, T. Tymoshchuk, O. Tonkha, O. Tsyz, M. Mushtruk, and A. Omelian, "The Study Of Soluble Solids Content Accumulation Dynamics Under The Influence Of Weather Factors In The Fruits Of Cherries," Potrav. Slovak J. Food Sci., 15, 350–359 (2021). doi: 10.5219/1554.

26) O. Horbachova, S. Mazurchuk, N. Buiskykh, V.

Lomaha, and A. Matviichuk, “Effect of the operating environment conditions of wood composites on the adhesive joint strength,” Ukrain. J. Forest Wood Sci., 15(4), 56–71 (2024). doi: 10.31548/forest/4.2024.56.

27) O. Horbachova, N. Buiskykh, S. Mazurchuk, and V. Lomaha, “Acetylation of Aspen and Alder Wood. Preliminary Tests,” Key Engin. Mater., 986, 45–52 (2024). doi: 10.4028/p-d9fYLX.

28) S. Sae-ngow, N. Kulpanich, M. Worachairungreung, P. Ngansakul, K. Thanakunwutthirot, and P. Hemwan, “Comparison of carbon sequestration in family forest using tree height measurement by UAV and field surveys,” Evergreen, 11(3), 1593–1601 (2024). doi: 10.5109/7236814.

29) B. Mulyana, A. Polgár, and A. Vityi, “Three decades of forest carbon dynamics modeling using CO2FIX: A bibliometric analysis,” Evergreen, 10(4), 2105–2119 (2023). doi: 10.5109/7160871.

30) J.F. Fatriansyah, S.R. Kurnianto, S.N. Surip, A.F. Pradana, and A.G. Boanerges, “Molecular docking and molecular dynamics of herbal plants Phylantus niruri Linn (green meniran) towards SARS-CoV-2 main protease,” Evergreen, 10(2), 731–741 (2023). doi: 10.5109/6792822.

31) C.J. Fettig, B.E. Steed, A.S. Munson, R.A. Progar, and A. Mafra-Neto, "Evaluating doses of SPLAT® verb to protect lodgepole pine trees and stands from mountain pine beetle," Crop Prot., 136, 105228 (2020). doi: 10.1016/j.cropro.2020.105228

32) J. Kuang, L. Yu, Q. Zhou, D. Wu, L. Ren, and Y. Luo, "Identification of pine wilt disease-infested stands based on single- and multi-temporal medium-resolution satellite data," Forests, 15 (4), 596 (2024). doi: 10.3390/f15040596.

33) K. Youssef, ,"Heterobasidion root rot infections on Scots pine: A cryptic threat to sustainable forest management in Sweden,", Acta Univ. Agric. Suec., 2023, 101 (2023). doi: 10.54612/a.2pbp3kii82.

34) O. Golan, R. Attias, M. Elron, A. Protasov, Z. Mendel, and R. Schwartz-David, "Bark beetle-related pine mortality in Israeli planted forests and the effect of trap trees," Forest, 22, 71-82 (2022).

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

36) M. Eroglu, İ. Harman, "Bark beetles – Trap trees," in: M. Eroğlu et al. (Eds.), Proc. 4th Int. Forest Entomol. Pathol. Symp., Trabzon: Karadeniz Tech. Univ., 48–49 (2022).

37) M. Haseeb, "Beetle mania: How to detect and manage pine tree pests", Tallahassee Democrat (2023). https://www.researchgate.net/publication/375160902_TLHLIFE_BEETLE_MANIA_How_to_detect_and_manage_pine_tree_pests.

38) E.M. Hansen, B.J. Bentz, J.C. Vandygriff, and C. Garza, "Factors associated with bark beetle infestations of Colorado Plateau ponderosa pine using repeatedly-measured field plots," For. Ecol. Manag., 545, 121307 (2023). doi: 10.1016/j.foreco.2023.121307.

39) L. Heiðarsson, B.D. Sigurdsson, B.Ö. Davíðsson, B. Hrafnkelsdóttir, A. Sigurgeirsson, B. Skúlason, and M.D. Vest, "The effect of the pine woolly aphid (Pineus pini) on survival, growth and natural selection in Scots pine (Pinus sylvestris) in Iceland," Agric. For. Entomol., 22 (2), 146-156 (2020). doi: 10.1111/afe.12369.

40) K. Zhang, and J. Stenlid, "Detection and quantification of Cronartium pini from Scots pine bark and wood with Cronartium spp.-specific quantitative PCR," For. Pathol., 53 (6), e12833 (2023). doi: 10.1111/efp.12833.

41) J.-J. Liu, R.A. Sniezko, S. Houston, A. Kegley, B. Rancourt, “Genome-Wide Association Study Reveals Polygenic Architecture for Limber Pine Quantitative Disease Resistance to White Pine Blister Rust,” Phytopathology, 114(7), 1626–1636 (2024). doi: 10.1094/phyto-09-23-0338-r.

42) O. Maaß, H. Kehlenbeck, “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), 104 (2024). doi: 10.3390/f15010104.

43) E. Cardinal, B. Shepherd, J. Krakowski, C.J. Schwarz, J. Stirrett-Wood, “Verbenone and green-leaf volatiles reduce whitebark pine mortality in a northern range-expanding mountain pine beetle outbreak,” Can. J. For. Res., 52(2), 158–168 (2022). doi: 10.1139/cjfr-2021-0120.

44) D. Li, G. Yuan, X. Sun, “Unravelling the complex relationship between Suillus bovinus and Gomphidius roseus through investigation of their sporocarps in Pinus massoniana forests,” BMC Microbiol., 25(1), 170 (2025). doi: 10.1186/s12866-025-03881-0.

45) L. Figueroa-Corona, K. Baesen, A. Bhattarai, J. Wegrzyn, A.R. De La Torre, “Transcriptional Profiling of Early Defense Response to White Pine Blister Rust Infection in Pinus albicaulis (Whitebark Pine),” Genes, 15(5), 602 (2024). doi: 10.3390/genes15050602.

46) Martos, J.A. Domínguez-Núñez, “Soil Fungal Pathogens in Pinus pinaster Mature Reforestation: Silvicultural Treatments Effects,” Pathogens, 13(8),

637 (2024). doi: 10.3390/pathogens13080637.
47) B. Assyov, M. Slavova, “Macrofungi in stands of the endemic pine Pinus Peuce as inferred from morphological and molecular data,” C. R. Acad. Bulg. Sci., 76(5), 707–715 (2023). http://dx.doi.org/10.7546/CRABS.2023.05.06.
48) M. Stein Åslund, M. Reichelt, K. Zhang, J. Gershenzon, M. Elfstrand, “Scots Pines With Tolerance to Melampsora pinitorqua and Diplodia sapinea Show Distinct Metabolic Profiles,” Plant Cell Environ., 48(2), 1479–1493 (2025). doi: 10.1111/pce.15218.
49) J.-J. Liu, R.A. Sniezko, S. Houston, B. Rancourt, A. Kegley, “A New Threat to Limber Pine (Pinus flexilis) Restoration in Alberta and Beyond: First Documentation of a Cronartium ribicola Race (vcr4) Virulent to Cr4-Controlled Major Gene Resistance,” Phytopathology, 115(1), 44–53 (2025). doi: 10.1094/phyto-04-24-0129-r.
50) D. Li, Y. Yu, C. Tian, S. Lu, S. Jiang, “The impact of pine wilt disease on the endophytic microbial communities structure of Pinus koraiensis,” Front. Microbiol., 15, 1493808 (2024). doi: 10.3389/fmicb.2024.1493808.