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Systematic and structural analysis of forest mycobiota with the participation of *Abies alba* Mill. in the Pokutsko-Bukovyna Carpathians

Ivanna Kulbanska*

PhD in Biological Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
<https://orcid.org/0000-0002-3424-8106>

Abstract. The value and uniqueness of forest ecosystems are determined by their species diversity and biotic resistance to negative environmental impacts. The aim of the study is to determine the species composition, systematic position, trophic specialization, as well as the occurrence and abundance of forest mycobiota with *Abies alba* in the Pokutsko-Bukovyna Carpathians. The study was conducted in 2019-2023 within the forests of the branches “Kutske Forestry”, “Ivano-Frankivsk Forestry” and “Beregomet Forestry” of the State Specialized Enterprise “Forests of Ukraine”, as well as the forests of the National Nature Park “Vyzhnytskyi” and the National Nature Park “Hutsulshchyna”. Classical mycological identification methods were used in the study. Information from the interactive databases Index Fungorum, MycoBank, and World of Fungi of Ukraine was used to clarify the current systematic position and current names of taxa. It was found that the consortial relationships of the fungal biota of the Pokutsko-Bukovyna Carpathians forests are most closely related to the woody plants *Picea abies*, *Abies alba*, and *Fagus sylvatica*. During the mycological expedition, 54 species of representatives of the kingdom *Fungi* were identified, 81.5% of which belong to the order *Basidiomycota* and 18.5% to the order *Ascomycota*. It was found that the most numerous is the order *Polyporales*, and the least numerous are the orders *Corticiales*, *Gomphales*, *Phallales*, *Pucciniales* and *Tremellales*. It is shown that, according to trophic specialization, representatives of the studied mycobiota of the Pokutsko-Bukovyna Carpathians belong to the following groups: xylotrophic facultative saprotroph, xylotrophic facultative pathogen, xylotrophic obligate saprotroph, obligate pathogen and aboveground saprotroph. It is noted that the most widely represented are saproxyliotrophs, which generally develop on dead and fallen wood. Thus, the systemic and structural analysis of the fungal biota of the Pokutsko-Bukovyna Carpathians

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*Corresponding author



forests allows for assessing the biocenotic value of fungi as bioindicators of the current state of stands, as well as identifying reference and valuable areas characterized by high biodiversity

Keywords: white fir; mycocenosis; systematic position; species composition; trophic specialization

Introduction

One of the most important components of forest biocenosis is mycotic communities of different trophic affiliation, which, like other heterotrophs, determine its depth, systematically interact with woody plants at different stages of their ontogeny – from endophytism to biodegradation, and are valuable food and medicinal resources for humans. Fungi are directly involved in the functioning of the forest biocenosis as a biological system. The structure and relationships of species (communities) of mycocoenoses with other living organisms are of particular importance for the development of forest ecosystems. Most of them are xylobionts (from the Greek ξύλον – “felled tree” and βίωv (βιώντος) – “living”) and are present at all stages of wood xylolysis – from the moment of damage to living woody plants to complete utilization of the remains at the final stages of decomposition. A significant number of species grow on the soil and forest floor, some representatives of this group are mycorrhizal formers, while others are poorly lichenicolous. Being part of a consortium where the substrate or partner in life is higher, in this case, woody plant species, fungi can enter into indifferent, negative and antagonistic relations with the latter.

The fungal communities of the Ukrainian Carpathian forests have been studied to a certain extent (some literature sources have almost a century of history), which allows for a comparative analysis of previous results, despite some fragmentation of these studies. The taxonomic composition of the xylo-trophic ascomycobiota of forest ecosystems of protected areas of the Ukrainian Carpathians, which

were considered in the work of Y.Yu. Bublyk & O.S. Klymyshyn (2023), is represented by 406 taxa belonging to 190 genera, 66 families, 26 orders, 10 suborders, 6 classes of the subdivision *Pezizomycotina* of the division *Ascomycota*. It is noted that the distribution or specialization of wood-destroying ascomycetous fungi to woody substrates depends on the life forms and species diversity of trees.

Several works have been devoted to the study of the species diversity of mycorrhizal fungi of the Hutsulshchyna National Nature Park (including new rare species). The study by S.I. Fokshei (2022) involved a comprehensive study of the diversity and ecological role of *Ascomycota* fungi in the park's ecosystem. The study analysed the various *Ascomycota* species present in the region to reveal their distribution, ecological significance, and possible contribution to the overall biodiversity of the park. The results contributed to the formulation of conservation strategies and a deeper understanding of the ecological dynamics of Hutsulshchyna Park.

The results of the study by S.I. Fokshei & L.M. Derzypilskyi (2021) not only expand the understanding of the mycological component of the ecosystem of this park, but also identify new species of high rarity. This may have a significant impact on the conservation and management strategies of this unique natural area. In addition, the new species of mycetes discovered in the Hutsulshchyna National Park provide new information about biodiversity and ecological relationships in this unique natural environment (Bohoslavets & Prydiuk, 2023).

In total, as of 1 January 2022, more than 1000 species of fungi and fungi-like organisms were identified in the forest communities of the Hutsulshchyna NNP, 23 of which are listed in the Red Data Book of Ukraine (Pasayliuk, 2022).

Ectomycorrhizal fungi in the forest ecosystems of the Western Carpathians are discussed in the work by E. Luptáková & I. Mihál (2020). The authors identified 51 species of ectomycorrhizal mycorrhizal fungi, the dominant species being *Ramaria formosa*, *Hygrophorus pustulatus*, *Lactarius aurantiacus*, *Lactarius rufus*, *Paxillus involutus*, etc. It is noted that these species play an important role in the process of succession, in particular, in the reforestation of former agricultural lands. Also, M. Senila *et al.* (2024) presented the results of a study of toxic metals in some wild edible mushrooms (*Cantharellus cibarius*, *Boletus edulis*, and *Amanita rubescens*) growing in the mountainous region of the Western Carpathians. This study aims to investigate in detail the levels of toxic metals in these mushrooms, providing important information for determining the safety of their consumption and assessing the possible impacts of mining activities on their nutritional value. I. Sopushynskiy *et al.* (2021) focus on the peculiarities of biological damage to the stem wood of white fir *Phellinus Hartigii* in the Ukrainian Carpathians. The study aims to determine the mechanisms and features of the interaction between white spruce and Hartig's tinder fungus, taking into account the impact on the physiological and structural aspects of wood. Given the importance of white spruce as an important forest vegetation species in the Ukrainian Carpathians, understanding these features is important for developing strategies for managing and protecting forests from the parasitic impact of Hartig's tinder fungus.

Thus, even though the species composition of fungi and fungi-like organisms in the Carpathian region is to some extent outlined,

some issues, in particular, regarding phytopathogenic species, as well as their ecological and nutritional specialization, remain unresolved. Therefore, the present study is aimed at determining the species composition (with an assessment of biocenotic significance), systematic and structural analysis, and trophic groups of the mycobiota of forests with *Abies alba* Mill. in the Pokutsko-Bukovyna Carpathians.

Materials and Methods

Analysis of the system-structural analysis of representatives of the mycobiota of forest ecosystems with the participation of *Abies alba* Mill. in the Pokutsko-Bukovyna Carpathians is based on the processing of own herbarium collections of mycetes from the forests of the Kutske Forestry Branch, Ivano-Frankivsk Forestry Branch and Beregommet Forestry Branch of the State Specialized Economic Enterprise (SSE) "Forests of Ukraine", forests of the National Nature Park (NNP) "Vyzhnytskyi" and NNP "Hutsulshchyna", which fully represent the typical conditions of the study area, during 2019-2023. Some information was obtained from the data established during the processing of herbarium specimens stored in the collection of the Department of Forestry of the National University of Life and Environmental Sciences of Ukraine, the interactive database The world of mushrooms in Ukraine (n.d.).

The distribution of the trophic chain of the identified mycobiota representatives is based on the generally accepted trophic specialization (nutritional characteristics of heterotrophic organisms). Currently, they are divided into two large groups: parasites (using nutrients for their development from living cells throughout their lives) and saprotrophs (using nutrients for their development from dead cells). This is usually characteristic of the most extreme representatives of the trophic chain of the kingdom Fungi. Among the fungi found on the

experimental woody plants, we identified *obligate pathogens* – OPs (the ecological niche of this group of fungi is living plant tissue, and they are not capable of saprotrophic nutrition under natural conditions, the term “biotrophs” is synonymous with them); *optional (optional) pathogens* – OPs (spend most of their development on a dead substrate but are able to continue feeding on a living substrate, the term “necrotrophs” is synonymous with them). *Facultative (optional) saprotrophs* – FS (spend most of their development on a living substrate, but are able to continue feeding on a dead substrate); *obligate saprotrophs* – OS (live exclusively on a dead substrate); *Mycorrhizal fungi* – MF (symbiotrophic species that coexist with the roots of woody plants and are obligate exo-, endo- and exo-endogenous mycorrhizal fungi). Based on the fact that all the identified fungi are xylophages, i.e., they use wood (trunks, roots, shoots) for their nutrition, the authors added the word “xylophage” to this taxonomy to distinguish facultative saprotrophs and pathogens from other substrates on which they develop. In addition, the terms “obligate pathogen” and “facultative pathogen” were used to distinguish between the studied fungal species of different specializations (instead of the previously used “obligate parasite” and “facultative parasite”). This approach is based on a literal understanding of the term “pathogen” (from the Greek παθογένεια – “one that causes suffering”), i.e. organisms (usually myco- and microorganisms) that can cause infectious pathology. As for the term “parasite” (from the Greek Παράσιτο – “freeloader”), it is appropriate to refer to factors of living nature that cause damage that is not related to infection (pathological process). This approach allows for distinguishing between different types of impact on the plant (infectious and non-infectious). In any case, it is inappropriate to combine processes that are different in nature under one name.

Distribution by micro-horizons: 1 – root; 2 – above-ground (including dead wood, fallen trees, dead branches); 3 – coma; 4 – trunk; 5 – crown; “-” – not detected. The species occurrence was assessed on a conditional point scale: + – very rarely; 1 – rarely; 2 – not rarely; 3 – often; 4 – very often. The scale is based on the calculation of the average proportions of species (with fruiting bodies) in the community during the observation period (taking into account the long-term annual repetition of observations).

Species abundance (as the number of individuals per unit of inhabited space) was estimated on a point scale: + – very rare; 1 – rare and scattered; 2 – not abundant; 3 – abundant; 4 – very abundant. Latin names of higher plant species are given by: World Flora Online (n.d.), mycobiota – according to Index Fungorum (n.d.). The research was conducted in compliance with the standards specified in the Convention on Biological Diversity (1992) and the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973). Modern names of fungi and their systematic affiliation are consistent with the nomenclature database MycoBank (n.d.) and the International Code of Nomenclature for algae, fungi, and plants (2019).

Results and Discussion

The total number of recorded and identified species of forest mycobiota with *Abies alba* Mill. in the Pokutsko-Bukovyna Carpathians is 54 species, including 13 species of European spruce (*Picea abies* L.), 6 species of white fir (*Abies alba* L.), and 35 species of European beech (*Fagus sylvatica* L.).

The analysis of the taxonomic structure of the identified mycobiota showed that the species belong to 45 genera, 31 families, 4 suborders, 13 orders, 6 subclasses, 5 classes, 3 subdivisions and two divisions, in particular 18.5% of species are representatives of the division *Ascomycota* Caval.Sm., 1998, and 81.5%, respectively,

of *Basidiomycota* Whittaker ex Moore, 1980 of the subkingdom *Dikarya* Hibbett, 2007 of the kingdom *Fungi* Bartling, 1830. The systematic distribution of the detected and identified mycobiota is presented in Table 1.

All species of the order *Ascomycota* are represented by representatives of the suborder *Pezizomycotina* O.E. Erikss. & Winka, 1997 of the class *Sordariomycetes* O.E. Erikss. & Winka, 1997, within which 2 subclasses (*Hypocreomycetidae* and *Xylariomycetidae*), 2 orders (*Hypocreales* and *Xylariales*), 5 families (*Diatrypaceae*, *Hypocreaceae*, *Melanconidaceae*, *Nectriaceae*, *Xylariaceae*), 7 genera (*Diatrype*, *Kretzschmaria*, *Melogramma*, *Nectria*, *Neonectria*, *Trichoderma*, *Xylaria*) and 10 species of mycetes.

Basidiomycota is represented by 2 suborders (*Agaricomycotina* and *Pucciniomycotina*), 4 classes (*Agaricomycetes*, *Dacrymycetes*, *Pucciniomycetes* and *Tremellomycetes*), 4 subclasses (*Agaricomycetidae*, *Phallomycetidae*, *Phallomycetidae*, *Tremellomycetidae*), 11 orders (*Agaricales*, *Corticiales*, *Dacrymycetales*, *Gloeophyllales*, *Gomphales*, *Hymenochaetales*, *Phallales*,

Polyporales, *Pucciniales*, *Russulales*, *Tremellales*), 4 suborders (*Marasmiineae*, *Melampso-rineae*, *Phyllotopsidineae* and *Pleurotineae*), 26 families (*Amylocorticiaceae*, *Bondarzewiaceae*, *Clathraceae*, *Climacocystaceae*, *Corticaceae*, *Dacrymycetaceae*, *Fomitopsidaceae*, *Ganodermataceae*, *Gloeophyllaceae*, *Gomphaceae*, *Hericiaceae*, *Hymenochaetaceae*, *Incrustoporiaceae*, *Irpicaceae*, *Laetiporaceae*, *Mycenaceae*, *Phanerochaetaceae*, *Physalacriaceae*, *Polyporaceae*, *Pucciniastraceae*, *Pycnoporellaceae*, *Radulomycetaceae*, *Schizophyllaceae*, *Stereaceae*, *Tremellaceae* and *Trichaptaceae*), 38 genera (*Amylocorticium*, *Armillaria*, *Bjerkandera*, *Calocera*, *Cerioporus*, *Chondrostereum*, *Clathrus*, *Climacocystis*, *Dacrymyces*, *Daedalea*, *Daedaleopsis*, *Dentipellis*, *Fomes*, *Fomitopsis*, *Ganoderma*, *Gloeophyllum*, *Henningsomyces*, *Hericium*, *Heterobasidion*, *Inonotus*, *Irpex*, *Laetiporus*, *Melampsorella*, *Panellus*, *Phellinus*, *Plicaturopsis*, *Pycnoporellus*, *Radulomyces*, *Ramaria*, *Rhodofomes*, *Schizophyllum*, *Skeletocutis*, *Stereum*, *Trametes*, *Trametopsis*, *Tremella*, *Trichaptum* and *Vuilleminia*) and 44 species of mycetes (Table 1).

Table 1. Systematic position of macromycetes of the consortium *Abies alba* L., *Picea abies* L., and *Fagus sylvatica* L. in the forests of the Pokutsko-Bukovyna Carpathians

Department	Class.	Order.	Family.	Reid	View
<i>Ascomycota</i>	<i>Sordariomycetes</i>	<i>Xylariales</i>	<i>Melanconidaceae</i>	<i>Melogramma</i>	<i>Melampsorella cerastii</i> (Pers.) J. Schröt. 1887
			<i>Diatrypaceae</i>	<i>Diatrype</i>	<i>Melogramma spiniferum</i> (Wallr.) De Not., 1863
			<i>Xylariaceae</i>	<i>Kretzschmaria</i>	<i>Diatrype disciformis</i> (Hoffm.) Fr., 1849
		<i>Xylaria</i>		<i>Kretzschmaria deusta</i> (Hoffm.) P.M.D. Martin, 1970	
		<i>Hypocreales</i>	<i>Nectriaceae</i>	<i>Nectria</i>	<i>Xylaria polymorpha</i> (Pers.) Grev., 1824
				<i>Neonectria</i>	<i>Nectria ditissima</i> Tul. & C. Tul. 1865
					<i>Nectria cinnabarina</i> (Tode) Fr. 1849
<i>Nectria galligena</i> Bres. 1901					
		<i>Hypocreaceae</i>	<i>Trichoderma</i>	<i>Neonectria coccinea</i> (Pers.) Rossman & Samuels, 1999	

Table 1, Continued

Department	Class.	Order.	Family.	Reid	View	
Basidiomycota	Agaricomycetes	Russulales	Bondarzewiaceae	Heterobasidion	<i>Heterobasidion parviporum</i> Niemelä & Korhonen 1988 <i>Heterobasidion abietinum</i> Niemelä & Korhonen, 1998	
			Stereaceae	Stereum	<i>Stereum hirsutum</i> (Willd.) Pers. 1800	
			Hericiaceae	Dentipellis	<i>Dentipellis fragilis</i> (Pers.) Donk, 1962	
				Hericium	<i>Hericium cirrhatum</i> (Pers.) Nikol., 1950 <i>Hericium coralloides</i> (Scop.: Fr.) Pers 1974	
			Polyporales	Climacocystaceae	Climacocystis	<i>Climacocystis borealis</i> (Fr.) Kotl. & Pouzar., 1958
				Fomitopsidaceae	Fomitopsis	<i>Fomitopsis pinicola</i> (Sw.) P. Karst. 1881
					Rhodofomes	<i>Rhodofomes roseus</i> (Alb. & Schwein.) Vlasák, 1990
					Daedalea	<i>Daedalea quercina</i> (L.) Pers. 1801
				Pycnoporellaceae	Pycnoporellus	<i>Pycnoporellus alboluteus</i> (Ellis & Everh.) Kotl. & Pouzar 1963
				Polyporaceae	Cerioporus Cerioporus	<i>Cerioporus varius</i> (Pers.) Zmitr. & Kovalenko, 2016 <i>Cerioporus mollis</i> (Sommerf.) Zmitr. & Kovalenko, 2016
		Fomes				<i>Fomes fomentarius</i> (L.) Fr. 1849
		Daedaleopsis			<i>Daedaleopsis confragosa</i> (Bolton) J. Schröt, 1888	
		Trametes			<i>Trametes versicolor</i> (L.) Lloyd, 1920	
		Laetiporaceae		Laetiporus	<i>Laetiporus sulphureus</i> (Bull.: Fr.) Murrill 1920	
		Incrustoporiaceae	Skeletocutis	<i>Skeletocutis amorphia</i> (Fr.) Kotl. & Pouzar, 1958		
		Irpicaceae	Trametopsis	<i>Trametopsis cervina</i> (Schwein.) Tomsovský, 2008		
			Irpex	<i>Irpex lacteus</i> (Fr.: Fr.) Fr. 1828		
		Ganodermataceae	Ganoderma	<i>Ganoderma applanatum</i> (Pers.: Wallr.) Pat. 1887 <i>Ganoderma resinaceum</i> Boud. 1889		
		Phanerochaetaceae	Bjerkandera	<i>Bjerkandera adusta</i> (Willd.) P. Karst., 1879		
		Agaricales	Amylocorticiaceae	Amylocorticium	<i>Amylocorticium subsulphureum</i> (P. Karst.) Pouzar 1959	
				Plicaturopsis	<i>Plicaturopsis crispa</i> (Pers.) D.A. Reid, 1964	
			Physalacriaceae	Armillaria	<i>Armillaria mellea</i> (Vahl) P. Kumm.	
			Mycenaceae	Panellus	<i>Panellus stipticus</i> (Bull.) P. Karst., 1879	

Table 1, Continued

Department	Class.	Order.	Family.	Reid	View		
			<i>Schizophyllaceae</i>	<i>Henningsomyces</i>	<i>Henningsomyces candidus</i> (Pers.) Kuntze 1898		
				<i>Schizophyllum</i>	<i>Schizophyllum commune</i> Fr. 1815		
				<i>Chondrostereum</i>	<i>Chondrostereum purpureum</i> (Fr.) Pouzar 1959		
				<i>Radulomycetaceae</i>	<i>Radulomyces</i>	<i>Radulomyces molaris</i> (Chaillat ex Fr.) M.P. Christ., 1960	
			<i>Gloeophyllales</i>	<i>Gloeophyllaceae</i>	<i>Gloeophyllum</i>	<i>Gloeophyllum abietinum</i> (Fr.) P. Karst. 1882 <i>Gloeophyllum odoratum</i> (Wulfen) Imazeki, 1943	
			<i>Phallales</i>	<i>Clathraceae</i>	<i>Clathrus</i>	<i>Clathrus archeri</i> (Berk.) Dring, 1980	
			<i>Hymenochaetales</i>	<i>Trichaptaceae</i>	<i>Trichaptum</i>	<i>Trichaptum fuscoviolaceum</i> (Ehrenb.) Ryvar den 1972	
		<i>Trichaptum abietinum</i> (Pers. ex J.F. Gmel.) Ryvar den, 1972					
				<i>Hymenochaetaceae</i>	<i>Phellinus</i>	<i>Phellinus hartigii</i> (Allesch. & Schnabl) Pat., 1903 <i>Phellinus igniarius</i> (L.) Quél. 1886	
					<i>Inonotus</i>	<i>Inonotus obliquus</i> (Pers.) Pilát 1942	
			<i>Corticiales</i>	<i>Corticaceae</i>	<i>Vuilleminia</i>	<i>Vuilleminia comedens</i> (Nees.: Fr.) Maire 1902	
			<i>Gomphales</i>	<i>Gomphaceae</i>	<i>Ramaria</i>	<i>Ramaria aurea</i> (Fr.) Quél. 1888	
			<i>Dacrymycetes</i>	<i>Dacrymycetales</i>	<i>Dacrymycetaceae</i>	<i>Calocera</i>	<i>Calocera cornea</i> (Batsch) Fr., 1827
						<i>Dacrymyces</i>	<i>Dacrymyces stillatus</i> Nees, 1817
			<i>Tremellomycetes</i>	<i>Tremellales</i>	<i>Tremellaceae</i>	<i>Tremella</i>	<i>Tremella mesenterica</i> (Schaeff.) Retz., 1769
	<i>Pucciniomycetes</i>	<i>Pucciniales</i>	<i>Pucciniastraceae</i>	<i>Melampsorella</i>	<i>Melampsorella cerastii</i> (Pers.) J. Schröt. 1887		

Source: developed by the authors based on MycoBank (n.d.)

The maximum number of identified mycetes in the forests of the Pokutsko-Bukovyna Carpathians belongs to the order *Polyporales* – 31.4%. Typical representatives of this order are xylobionts, i.e. wood biodestructors, and therefore occupy an extremely important place in forest ecology. The species composition of the order *Polyporales* includes 17 species of mycetes belonging to 9 families: *Climacocystaceae*, *Fomitopsidaceae*, *Ganodermataceae*, *Incrustoporiaceae*, *Irpicaceae*, *Laetiporaceae*, *Phanerochaetaceae*, *Polyporaceae* and *Pycnoporellaceae*.

The share of the order *Agaricales* is 14.7% of the total. The representatives of this order include destructive fungi, mycorrhizal fungi and soil saprotrophs. A typical characteristic of the order is that the fruiting bodies of agaric fungi are predominantly stalked and capped with a lamellar hymenophore. The order *Agaricales* in the studied forests is represented by 8 species of fungi belonging to 5 families: *Amylocorticaceae*, *Mycenaceae*, *Physalacriaceae*, *Radulomycetaceae* and *Schizophyllaceae*. Also, relatively numerous is the order *Russulales* (11.1%),

which is represented mainly by mycorrhizal fungi, saprotrophs, and phytopathogenic species. We managed to identify 6 species of this order belonging to 3 families: *Bondarzewiaceae*, *Hericiaceae* and *Stereaceae*. Other orders are

less numerous, in particular *Hypocreales* and *Hymenochaetales* (9.3% each), *Xylariales* – 7.3%, *Gloeophyllales* and *Dacrymycetales* (3.7% each), *Corticiales*, *Gomphales*, *Phallales*, *Pucciniales* and *Tremellales* (1.9% each) (Fig. 1).

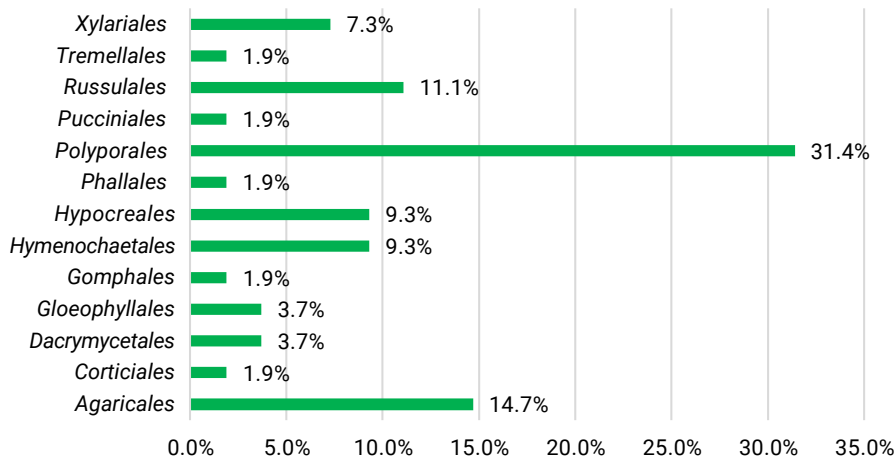


Figure 1. Taxonomic structure of the species composition of forest mycobiota with *Abies alba* in the Pokutsko-Bukovyna Carpathians at the level of orders

Source: developed by the authors

Analysing the distribution of mycobiota representatives of the forests of the study region by food specialization, it was found that most species are saprotrophs, whose vital activity is ensured by the decomposition of dead plant residues, carrying out ammonification (mineralization) of nitrogen, as well as releasing metabolic products (CO_2 , H_2O , urea, etc.), organic acids and siderophores, which affect the functionality of root cells and facilitate the release and supply of ferrous ions and other trace elements to the plant from insoluble compounds in the soil (Antonyak *et al.*, 2013). The most numerous is the group of obligate saprotrophs, their share is 49.1% of the total distribution. The share of obligate pathogens is 45.5%. Representatives of other trophic groups (xylotrophic facultative pathogen, obligate pathogen and aboveground saprotroph)

were not numerous, with their share in the total distribution reaching 1.8% (Fig. 2). The distribution of fungal taxa by nutritional regime may have elements of subjectivity, because, for some species of xylotrophic fungi, we have not found information on the presence of these fungi as normal mycobiota of healthy (or weakened) trees. If these fungi are present in such trees as endophytes, including vital obligates (i.e., fungi that are an integral component of living trees that use metabolites of living cells for their existence), they can be switched from obligate saprotrophs to facultative saprotrophs and vice versa. Thus, considering the consortial relations between fungi and consortium-edifying trees, we note that in indifferent consortial relations, representatives of mycobiota develop on no more than 10-20% of host plants, affecting (infecting) them to a relatively weak degree

and for a short period, without leading to noticeable deviations in growth and development compared to healthy specimens. A negative type of relationship should be considered when

fungi parasitize 50-80% of plants, causing severe damage to them, leading to general weakening, impaired assimilation capacity, and, often, loss of phytocoenosis.

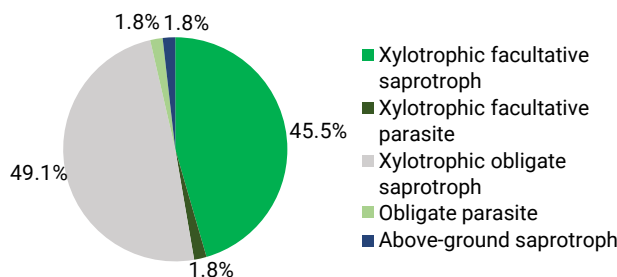


Figure 2. Distribution of mycobiota representatives of forests with *Abies alba* by food specialization

Source: developed by the authors

Analysing the trophic specialization of mycobiota in the context of tree species, we note that *Picea abies* consortia are represented mainly by xylotrophs-obligate saprotrophs, their share being 57.1%. Facultative saprotrophs, whose vital activity is confined mainly to living substrates, account for 35.7%. One fungal species is classified as a xylotrophic facultative pathogen, *Armillaria mellea*, whose basidiomycetes and rhizomorphs are found both in dead or dying wood and on the trunks of living trees.

The *Abies alba* consortium is also formed by three trophic groups of mycetes: xylotroph-obligate saprotroph (50.0%), xylotroph-facultative saprotroph (33.3%) and obligate pathogen (16.7%). In general, most of the identified fungal species are associated with symbiotic or mutualistic relationships with fir and, developing on dead wood, are active participants in bioconversion in the forest.

Representatives of the mycobiota associated with *Fagus sylvatica* wood were grouped into three trophic groups, with the most numerous being facultative (51.4%) and obligate (45.7%) saprotrophs. One species, *Clathrus archeri*, was

also recorded, which turned out to be a typical above-ground saprotroph. It should be noted that this fungus is a unique and valuable find, as it is listed in the Red Book of Ukraine and has the status of “endangered”.

The studied forest mesocosms of the Pokutsko-Bukovyna Carpathians are characterized by specialization in substrate-forming tree species (so-called consortium-unitising trees). The largest number of species was found within the *Fagus sylvatica microhabitat* (35 species, 64.8% of the total number of finds), with a much smaller number in *Picea abies* (13 species, 24.0%) and *Abies alba* (6 species, 11.1%). The species composition of the consortium and the nature of consortial relationships between its components are variable at different stages of ontogeny of higher woody plants and in different biogeocenoses, in particular, environmental conditions greatly influence them.

Analysing the overall distribution of the mycobiota of forests with *Abies alba* in the Pokutsko-Bukovyna Carpathians by microhierarchy, it was found that the largest number of species is confined to the subsoil horizon (Fig. 3).

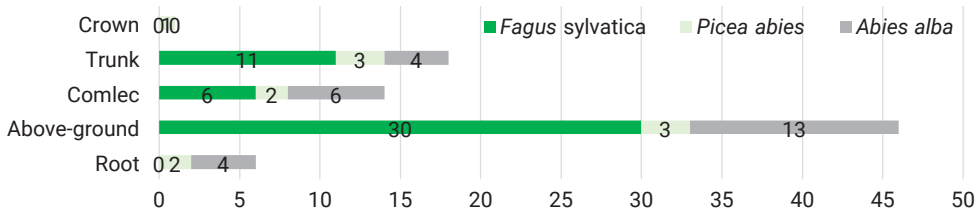


Figure 3. Distribution of forest mycobiota with *Abies alba* in the Pokutsko-Bukovyna Carpathians by microhierarchy

Source: developed by the authors

It is worth noting that some species (e.g. *Trichaptum abietinum* and *Fomitopsis pinicola*) were recorded simultaneously in microhabitats of different woody plant species. The following species were typical representatives of this group:

Amylocortium subsulphureum, *Vuilleminia comedens*, *Gloeophyllum abietinum*, *Irpex lacteus* (Fig. 4a), *Pycnoporellus alboluteus*, *Trichaptum fuscoviolaceum*, *Trichaptum abietinum*, *Chondrostereum purpureum*, *Cerioporus varius*, etc.

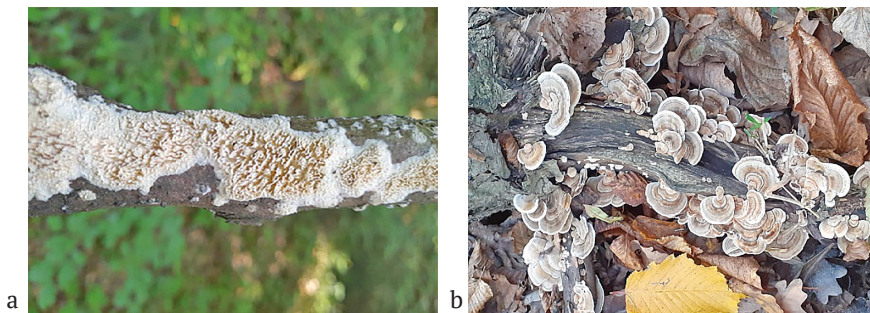


Figure 4. *Irpex lacteus* (a) and *Trametes versicolor* (b)

Source: photo by the authors

Representatives of pathogenic mycobiota of different levels of trophic nutrition are concentrated in the coma and root horizons, which, as a result of their vital activity, have a significant impact on the overall sanitary condition of the stand. For example, *Heterobasidion abietinum* basidiomata develop on the roots, lower parts of trunks, stumps, and trunks of living *Abies alba* trees (Fig. 5b), and *Heterobasidion parviporum* on *Picea abies*, which cause variegated core rot of wood and root system and are among the most dangerous pathogens of mycotic diseases that lead to massive drying of

coniferous forests. These macromycetes massively infect stands and lead to the loss of a significant amount of wood and a decrease in the protective properties of forests. They also lead to the gradual weakening and death of trees in plantations, which subsequently turn into sparse forests. In weakened trees, the pressure of the sapwood decreases, which mechanically and physiologically protects trees from damage by stem pests, whose breeding frequency occurs at irregular intervals, but is usually typical for weakened stands under physiological stress (Díaz-Yáñez *et al.*, 2019).



Figure 5. *Ramaria aurea* (a) and *Heterobasidion parviporum* (b)

Source: photo by the authors

A significant part of mycetes grows and develops within the stem microhabitat. These are mainly tinder fungi, which, settling on tree trunks, lead to the formation of various types of rot (core, sapwood or mixed), gradually weakening the plant. Among the most common species, we noted the following: *Gloeophyllum odoratum*, *Inonotus obliquus*, *Climacocystis borealis*, *Laetiporus sulphureus*, *Fomitopsis rosea*, *Phellinus hartigii*, *Phellinus igniarius*, *Fomitopsis pinicola*, *Fomes fomentarius*, etc. It was found that some species of macromycetes begin utilization of dead wood/substrate in xerophilic crown conditions and are grouped depending

on microclimatic and trophic preferences of individual species.

Basidiomata of *Ganoderma applanatum* and *Ganoderma resinaceum* were found in the basal part of the trunks of living trees, which cause light yellow root and basal rot of the corrosive-destructive type, making trees potentially dangerous to windbreaks. The fruiting bodies of an equally dangerous species of phytopathogenic fungus, *Armillaria mellea*, were also identified. It should be noted that the discovery of fruiting bodies of *Hericium coralloides*, which is a Red Data Book species for Ukraine and has a “vulnerable” status, was important (Fig. 6b).



Figure 6. *Clathrus archeri* (a) and *Hericium coralloides* (b)

Source: photo by the authors

The smallest number of species (1 species) were confined to the crown horizon. Thus, in the

crown of growing *Abies alba* trees, typical manifestations of infection with *Melampsorella*

caryophyllacearum, which is the causative agent of white fir ulcerative tumour disease and is currently spreading massively in the forests of the study region, were noted (Kulbanska *et al.*, 2024).

Table 2. Distribution of *Abies alba* forest mycobiota (by food specialization, microhabitats and other indicators)

Latin name	Trophic specialization	Micro-horizon	Encounter, point	Number, points
<i>Picea abies</i>				
<i>Heterobasidion parviporum</i> Niemelä & Korhonen 1988	K-FS	1,2,3	2	2
<i>Armillaria mellea</i> (Vahl) P. Kumm. 1871	K-FP	1,2,3	3	3
<i>Climacocystis borealis</i> (Fr.) Kotl. & Pouzar., 1958	K-OS	2,3,4	1	1
<i>Fomitopsis pinicola</i> (Sw.) P. Karst. 1881	K-FS	2,4	3	2
<i>Fomitopsis rosea</i> (Alb. & Schwein.) P. Karst. 1881	K-FS	2,3,4	1	1
<i>Trichaptum fuscoviolaceum</i> (Ehrenb.) Ryvarden 1972	K-OS	2	2	4
<i>Trichaptum abietinum</i> (Pers. ex J.F. Gmel.) Ryvarden, 1972	K-OS	2	2	3
<i>Amylocortium subsulphureum</i> (P. Karst.) Pouzar 1959	K-OS	2	1	3
<i>Henningsomyces candidus</i> (Pers.) Kuntze 1898	K-OS	3	+	2
<i>Pycnoporellus alboluteus</i> (Ellis & Everh.) Kotl. & Pouzar 1963	K-OS	2	+	3
<i>Gloeophyllum abietinum</i> (Fr.) P. Karst. 1882	K-OS	2	1	+
<i>Gloeophyllum odoratum</i> (Wulfen) Imazeki, 1943	K-FS	4	1	+
<i>Abies alba</i>				
<i>Heterobasidion abietinum</i> Niemelä & Korhonen 1988	K-FS	3	2	2
<i>Trichaptum abietinum</i> (Dicks.: Fr.) Ryvarden 1972	K-OS	2	2	3
<i>Hericium coralloides</i> (Scop.: Fr.) Pers 1974	K-OS	2	+	3
<i>Melampsorella cerastii</i> (Pers.) J. Schröt. 1887	OP	4,5	2	1
<i>Phellinus hartigii</i> (Allesch. & Schnabl) Pat., 1903	K-FS	2,3,4	2	1
<i>Gloeophyllum abietinum</i> (Fr.) P. Karst. 1882	K-OS	2	1	+
<i>Fagus sylvatica</i>				
<i>Nectria ditissima</i> Tul. & C. Tul. 1865	K-FS	4	2	2
<i>Neonectria coccinea</i> (Pers.) Rossman & Samuels, 1999	K-FS	2	2	2
<i>Nectria cinnabarina</i> (Tode) Fr. 1849	K-FS	2	2	1
<i>Nectria galligena</i> Bres. 1901	K-FS	2	3	2
<i>Stereum hirsutum</i> (Willd.) Pers. 1800	K-FS	2,5	3	3
<i>Irpex lacteus</i> (Fr.: Fr.) Fr. 1828	K-OS	2	1	2
<i>Chondrostereum purpureum</i> (Fr.) Pouzar 1959	K-OS	2	2	3
<i>Vuilleminia comedens</i> (Nees.: Fr.) Maire 1902	K-OS	2	1	1
<i>Schizophyllum commune</i> Fr. 1815	K-FS	2	3	2
<i>Cerioporus varius</i> (Pers.) Zmitr. & Kovalenko, 2016	K-OS	2	1	1
<i>Laetiporus sulphureus</i> (Bull.: Fr.) Murrill 1920	K-FS	4	3	1
<i>Ganoderma applanatum</i> (Pers.: Wallr.) Pat. 1887	K-FS	3,4	1	1
<i>Ganoderma resinaceum</i> Boud. 1889	K-FS	2,4	1	1
<i>Ramaria aurea</i> (Fr.) Quéf. 1888 (Fig. 5a)	K-OS	2	2	3
<i>Inonotus obliquus</i> (Pers.) Pilát 1942	K-FS	4	+	+
<i>Phellinus igniarius</i> (L.) Quéf. 1886	K-FS	2,4	2	2
<i>Daedalea quercina</i> (L.) Pers. 1801	K-FS	2	2	2

Table 2, Continued

Latin name	Trophic specialization	Micro-horizon	Encounter, point	Number, points
<i>Fomes fomentarius</i> (L.) Fr. 1849	K-FS	2,4	4	2
<i>Fomitopsis pinicola</i> (Sw.) P. Karst. 1881	K-FS	4	3	3
<i>Melogramma spiniferum</i> (Wallr.) De Not., 1863	K-OS	2,5	1	1
<i>Trichoderma sulphureum</i> (Schwein.) Jaklitsch & Voglmayr, 2014	K-OS	2	1	1
<i>Diatrype disciformis</i> (Hoffm.) Fr., 1849	K-OS	2	1	1
<i>Kretzschmaria deusta</i> (Hoffm.) P.M.D. Martin, 1970	K-OS	2	1	1
<i>Xylaria polymorpha</i> (Pers.) Grev., 1824	K-OS	2,3	1	2
<i>Plicaturopsis crispa</i> (Pers.) D.A. Reid, 1964	K-OS	2	1	1
<i>Panellus stipticus</i> (Bull.) P. Karst., 1879	K-OS	2	1	1
<i>Radulomyces molaris</i> (Chaillat ex Fr.) M.P. Christ., 1960	K-OS	2	2	2
<i>Calocera cornea</i> (Batsch) Fr., 1827 (Fig. 7a)	K-OS	2,3	2	2
<i>Dacrymyces stillatus</i> Nees, 1817	K-OS	2,3	1	1
<i>Trametopsis cervina</i> (Schwein.) Tomsovský, 2008	K-FS	4	1	2
<i>Bjerkandera adusta</i> (Willd.) P. Karst., 1879	K-FS	2	1	2
<i>Daedaleopsis confragosa</i> (Bolton) J. Schröt, 1888	K-FS	4	1	1
<i>Cerioporus mollis</i> (Sommerf.) Zmitr. & Kovalenko, 2016	K-OS	2,4	1	1
<i>Trametes versicolor</i> (L.) Lloyd, 1920 (Fig. 4b)	K-FS	2,3	3	3
<i>Clathrus archeri</i> (Berk.) Dring, 1980 (Fig. 6a)	EMERGENCY	2	+	+

Note: K-FS – xylotrophic facultative saprotroph, K-PP – xylotrophic facultative parasite, K-OS – xylotrophic obligate saprotroph, OP – obligate parasite, NS – aboveground saprotroph

Source: developed by the authors

The occurrence and abundance of species are partially correlated. For example, the species *Armillaria mellea*, *Fomes fomentarius*, *Fomitopsis pinicola*, *Nectria galligena*, *Schizophyllum commune*, *Stereum hirsutum* (Fig. 7b), *Trichaptum fuscoviolaceum* are characterized by almost equally high (3-4 points) occurrence and abundance within the study areas.

A similar dependence can be observed for very rare species (+) and is characterized by low numbers of individuals per unit of habitat. These are *Inonotus obliquus* and *Clathrus archeri*. It should be noted that these indicators are conditional and vary depending on the year, weather conditions, stand, microclimate, substrate, etc.



Figure 7. *Calocera viscosa* (a) and *Stereum hirsutum* (b)

Source: photo by the authors

I. Dudka *et al.* (2019) noted that the problems of studying the species diversity of fungi of the Ukrainian Carpathians and protecting their gene pool are currently inseparable. Establishing the boundaries of the species' range and the degree of its endemism is essential not only for assessing the actual rarity of the species but also for determining the level of sensitivity of the phytocoenosis to anthropogenic changes in the landscape. Every year, reports of discoveries of rare fungal species in the forests of the Carpathian region become available. S. Fokshei & L. Derzypilskyi (2021) indicate the discovery and identification of 9 species of mycetes included in the Red Data Book of Ukraine (*Anthurus archeri* (Berk.) E. Fischer, *Boletus regius* Krombh, *Clavariadelphus pistillaris* (L.) Donk, *Hericium coralloides* (Scop.) Pers., *Leucagaricus nympharum* (Kalchbr.) Bon., *Mutinus caninus* (Huds.) Fr, *Polyporus umbellatus* (Pers.) Fr, *Russula turci* Bres., *Strobilomyces strobilaceus* (Scop.) Berk.), 6 species rare for Ukraine (*Ganoderma lucidum* (Curtis) P. Karst, *Gyromitra infula* (Schaeff.) Quél., *Hericium alpestre* Pers, *Hericium cirrhatum* (Pers.) Nikol., *Sarcosphaera coronaria* (Jacq.) J. Schröt., *Sparassis nemecii* Pilát & Veselý) and 2 species of macromycetes that are candidates for inclusion in the Red List of Fungi of the International Union for Conservation of Nature (*Asterophora lycoperdoides* (Bull.) Ditmar, *Craterellus cornucopioides* (L.) Pers.) Their studies emphasize the value and uniqueness of the Kamystychnyi tract of the Hutsulshchyna National Park as a place of concentration of rare representatives of fungal biota. M.O. Zghonnyk (2022) described the lichenicolous species *Multiclavula mucida* (Pers. ex Fr.) R.H. Petersen, which parasitizes green algae of the genus *Coccomyxa*. The species was found on the semi-decomposed wood of an unidentified woody plant in the Skole Beskydy mountain range. It is noted that *M. mucida* is an indicator of the biological value of old-growth forests.

During a mycological excursion by V.O. Grebenshchikov & U.V. Pakhar (2022), a population (60 individuals) of *Porpolomopsis calyptriformis* (Berk.) Bresinsky was found for the first time in the Ukrainian Carpathians on the edge of the Prochert pasture in Putyla village, Chernivtsi region. This finding confirmed that the forests of the Putyla region are promising for the expansion of existing and the formation of new objects of the nature reserve fund due to the significant diversity of mycobiota. O. Klymyshyn (2020), studying the representatives of xylophilic ascomycobiota in the forests of the Skole Beskydy, emphasizes its role and importance in the processes of dead wood destruction. Attention is focused on their key role and importance in the processes of dead wood degradation. This study contributes to our better understanding of the internal mechanisms of wood decomposition in montane forest ecosystems, which can have practical applications in the context of optimizing forest management and conservation of natural bioresources.

It should be remembered that in addition to valuable and useful species, the mycobiota of the Ukrainian Carpathian forests are also represented by species that act as dangerous phytopathogens, infesting living growing trees, slowly weakening them, and causing the formation of various types of rot. A thorough study of the species composition of beech destructors in the forests of the Hutsulshchyna NNP was conducted by M. Pasaylyuk (2018). In the process of beech wood destruction, 50 species of fungi and fungi-like organisms were found on beech wood. This study indicates a high level of biological activity in forest ecosystems. These results contribute to a deeper understanding of wood decay processes and their impact on the ecological functions of the forest environment. I. Sopushynskyi *et al.* (2021) investigated the wood science aspects of the quality of fir stem wood affected by *Phellinus Hartigii*

(Allesch et Schnadl) Bond. This study is of great forestry importance in the context of the dying of fir stands in the Carpathians and the rational use of forest wood resources. The study by I. Sopushynskiy *et al.* (2021) on the formation of the quality of fir stem wood affected by *Phellinus Hartigii* is an important contribution to the study of the impact of fungal infection on wood characteristics, which is important for the rational use of forest resources and planning of forestry activities in the Carpathian region. O. Bogoslavets (2022), studying wood-destroying fungi of the Gorgany Nature Reserve, identified 25 species of fungi inhabiting the wood substrate. Among the valuable finds were the following species: *Athelia decipiens* (Höhn. & Litsch.) J. Erikss., *Antrodia sinuosa* (Fr.) P. Karst, *Coniophora puteana* (Schumach.) P. Karst, *Ceriopora excelsa* (S. Lundell) Parmasto, *Dacrymyces chrysospermus* Berk. & M.A. Curtis, *Mucronella calva* (Alb. & Schwein.) Fr., *Hericium coralloides* (Scop.) Pers, *Pholiota limonella* (Peck) Sacc., *Piloderma byssinum* (P. Karst.) Jülich, *Pholiotina brunnea* (Watling) Singer, *Postia caesia* (Schrad.) P. Karst, *Pluteus leoninus* (Schaeff.: Fr.) P. Kumm., *Rigidoporus sanguinolentus* (Alb. & Schwein.) Donk, *Skeletocutis amorpha* (Fr.) Kotl. & Pouzar.

The fungal biota of the Earth is one of its most important components, which performs biodegradation, ensures and supports the functioning of higher plants, and is a valuable resource of food and medicinal raw materials. At the same time, the fungal biota, its participation in the functioning of the biosphere, the role of fungi in global energy processes in biomass utilization, the importance of fungi of different groups for the development of forest ecosystems, the structure, and relationships of species within mycocoenoses with other organisms, the properties of fungi and their use in human life, as well as many other aspects have been insufficiently studied and evaluated. Therefore, knowledge about species diversity,

population size, habitat conditions, ecological and trophic specialization makes it possible to assess the current state of the biocenosis, of which representatives of the kingdom Fungi are an integral part.

Conclusions

Based on the systematic and structural analysis of the mycobiota of forests with *Abies alba* in the Pokutsko-Bukovyna Carpathians, 54 species of fungi were recorded and identified. Of these, 13 species form consortial relationships with *Picea abies*, 6 species with *Abies alba*, and 35 species with *Fagus sylvatica*.

The current state and peculiarities of the taxonomic structure of the identified species showed that during the mycological expedition, 18.5% of representatives of the *Ascomycota* and 81.5% of representatives of the *Basidiomycota* of the kingdom of Fungi were identified. The identified fungal biota belongs to 5 classes, 6 subclasses, 13 orders, 4 suborders, 31 families, 45 genera. The most numerous was the order *Polyporales*, which includes 31.4% of mycobiota species. The least numerous are the orders *Corticiales*, *Gomphales*, *Phallales*, *Pucciniales* and *Tremellales*, which include 1.9% of species for each order, respectively.

Among the representatives of the studied mycobiota of forests with *Abies alba* in the Pokutsko-Bukovyna Carpathians, the following ecological groups were identified: xylotrophic facultative saprotroph, xylotrophic pathogen, xylotrophic obligate saprotroph, obligate pathogen and aboveground saprotroph. According to the data obtained, saproxytrophs are most widely represented in the studied mycoflora, which generally develop on dead and fallen wood. Obligate and facultative pathogens, as well as humus saprotrophs, are represented by a much smaller number of species.

In particular, a group of micromycetes as pathogens of infectious diseases of various

organs of forest woody plants and macromycetes – wood-destroying fungi (xylobiotrophs) that cause root and stem rot – were identified. These pathogens can have a significant impact on the formation and viability of forest stands at different stages of their ontogeny. By analysing the nature of the relationship in the system “plant-host-phytopathogen-environment”, it is possible to assess the role of phytopathogenic fungi in the forest consortium of a particular region and, accordingly, to predict measures aimed at reducing the harmful effects they cause.

It has been established that the occurrence and abundance of forest mycobiota species with *Abies alba* in the Pokutsko-Bukovyna Carpathians are mostly directly related. For example, some species (*Schizophyllum commune*, *Armillaria mellea*, *Stereum hirsutum*, *Fomes fomentarius*, *Nectria galligena*, *Fomitopsis pinicola*, *Trichaptum fuscoviolaceum*, etc.) within the study areas are characterized by relatively high rates of both occurrence and number of individuals per unit of inhabited space. A similar dependence was observed for species characterized by low occurrence and abundance (e.g. *Inonotus obliquus* and *Clathrus archeri*). It is important to understand that these indicators are rather conditional and correlate depending on the season, microclimate, meteorological conditions, state of the forest ecosystem,

substrate environment, etc. Thus, the accumulation of knowledge about the species diversity and functional purpose of mycobiota, the study of factors influencing the distribution and biology of fungi, the analysis of the systematic position, and the determination of trophic relationships with higher plants within the forest biocenosis makes it possible to establish certain systemic relationships in the secondary succession processes of the forests of the study region, as well as to form knowledge about the fungal biota as a significant bioindicator of forest condition.

A promising area for further research is to assess the degree of transformation of forest ecosystems, in addition to the known silvicultural and sanitary changes in the stand, signs of forest floor and soil degradation, based on qualitative and quantitative changes in xylomycorrhizal indicators (species composition, distribution along microhumidifiers, the stage of wood destruction by xylotrophs, an increase in the proportion of stenotrophs and biotrophic facultative species, etc.)

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None.

Conflict of Interest

None.

References

- [1] Antonyak, H.L., Kalynets'-Mamchur, Z.I., Dudka, I.O., Babych, N.O., & Panas, N.Ye. (2013). *Ecology of fungi*. Lviv: Ivan Franko National University.
- [2] Bogoslavets, O.M. (2022). [Wood-destroying mushrooms of the nature reserve “Gorgany”](#). In *Proceedings of the first winter readings in Sinohora (scientific-practical conference) “Nature protection in the context of energy and ecological security of Ukraine”* (pp. 38-40). Stara Huta: Synihora National Nature Park Institute of Carpathian Ecology.
- [3] Bohoslavets, O.M., & Prydiuk, M.P. (2023). New records of rare wood-inhabiting fungi from the Ukrainian Carpathians. *Czech Mycology*, 75(1), 61-83. doi: 10.33585/cmy.75105.
- [4] Bublyk, Y.Yu., & Klymyshyn, O.S. (2023). [Xylotrophic ascomycetes of protected ecosystems of the Ukrainian Carpathians](#). In *XXXVI International Scientific and Practical Conference “Modern problems and the latest theories of development”* (pp. 21-27). Munich, Germany.
- [5] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.

- [6] Convention on the Trade in Endangered Species of Wild Fauna and Flora. (1973, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_129#Text.
- [7] Díaz-Yáñez , O., Pukkala, T., Packalen, P., & Peltola, H. (2019). [Optimal forest management in multi-purpose forestry under changing climate](#). *Geophysical Research Abstracts*, 21, article number EGU2019-13079.
- [8] Dudka, I.O., Geluta, V.P., Andrianova, T.V., Gayova, V.P., Tikhonenko, Y.Y., Prydiuk, M.P., Holubtsova, Y.I., Kryvomaz, T.I., Dzhagan, V.V., Leontiev, D.V., Akulov, O.Y., & Syvokon, O.V. (2019). [Mushrooms of reserves and national natural parks of the Ukrainian Carpathians](#). Kyiv: Naukova dumka.
- [9] Fokshei, S.I. (2022). Research of *Ascomycota* species in the Hutsulshchyna National Nature Park. *Ukrainian Botanical Journal*, 79(4), 246-253. doi: 10.15407/ukrbotj79.04.246.
- [10] Fokshei, S.I., & Derzypilskyi, L.M. (2021). [New mycological findings on the territory of the National Park “Hutsulshchyna”](#). *Scientific Bulletin of Chernivtsi University. Biology (Biological systems)*, 13(2), 172-190.
- [11] Grebenshchikov, V.O., & Pakhar, U.V. (2022). [A new discovery of *Porpolomopsis calyptriformis* \(Berk.\) Bresinsky, listed in the red book of Ukraine](#). In *Natural sciences: Projects, research, perspectives: Materials of the 3rd International Scientific and Practical Conference* (pp. 34-36). Poltava: Luhansk Taras Shevchenko National University.
- [12] Index Fungorum. (n.d.). Retrieved from <http://www.indexfungorum.org>.
- [13] International Code of Nomenclature for algae, fungi, and plants. (2019). Retrieved from <https://www.iapt-taxon.org/nomen/main.php>.
- [14] Klymyshyn, O. (2020). [Participation of xylotrophic ascomycobiota in the processes of destruction of dead wood in the forests of Skolivskyi Beskids](#). In *Constructive geography and cartography: State, problems, prospects: Materials of the International scientific conference* (pp. 221-225). Lviv: Prostir-M.
- [15] Luptáková, E., & Mihál, I. (2020). Dynamics of ectomycorrhizal mycobiota (Basidiomycota) communities on a former agricultural land (West Carpathians). *Mycological Progress*, 19, 845-857. doi: 10.1007/s11557-020-01597-1.
- [16] MycoBank. (n.d.). Retrieved from <http://www.mycobank.org/quicksearch.aspx>.
- [17] Pasayliuk, M.V. (2022). [History of studies of fungi and mushroom-like organisms on the territory of Hutsulshchyna National Park and the role of in situ, ex situ, re situ methods in preserving their diversity](#). *Scientific Notes of the State Natural History Museum*, 38, 63-72.
- [18] Pasaylyuk, M.V. (2018). [Destructive fungi of *Fagus sylvatica* \(Fagaceae\) dead wood in the forests of Hutsulshchyna National Nature Park](#). *Ukrainian Botanical Journal*, 75(4), 348-355.
- [19] Senila, M., Resz, M.A., Torok, I., & Senila, L. (2024). Nutritional composition and health risk of toxic metals of some edible wild mushrooms growing in a mining area of Apuseni Mountains, Western Carpathians. *Journal of Food Composition and Analysis*, 128, article number 106061. doi: 10.1016/j.jfca.2024.106061.
- [20] Sopushynskyi, I., Kopolovets, Ya., & Polyak, V. (2021). [Peculiarities of biological damage to white fir trunk wood by Hartig's tinder in the Ukrainian Carpathians](#). In *Actual problems, ways and prospects of the development of landscape architecture, horticulture, urban ecology and phytoremediation: Materials of the International scientific conference* (pp. 100-102). Bila Tserkva: Bila Tserkva National Agrarian University.
- [21] The world of mushrooms in Ukraine. (n.d.). Retrieved from: <http://gribi.net.ua/>.
- [22] World Flora Online. (n.d.). Retrieved from <https://www.worldfloraonline.org>.

- [23] Zghonnyk, M.O. (2022). [New findings of the rare lichenised fungus *Multiclavula mucida* \(Pers. ex Fr.\) R.H. Petersen from the Ukrainian Carpathians](#). In *Proceedings of the VII International Scientific Conference of students, postgraduates and young scientists "Topical issues of biology and ecology development"* (pp. 71-72). Vinnytsia: Publishing House "Tvory".

Системно-структурний аналіз мікобіоти лісів за участю *Abies alba* Mill. у Покутсько-Буковинських Карпатах

Іванна Кульбанська

Кандидат біологічних наук, доцент

Національний університет біоресурсів і природокористування України

03041, вул. Героїв Оборони, 15, м. Київ, Україна

<https://orcid.org/0000-0002-3424-8106>

Анотація. Цінність та унікальність лісових екосистем визначаються їх видовим різноманіттям та біотичною стійкістю до негативного впливу навколишнього середовища. Метою дослідження є визначення видового складу, систематичного положення, трофічної спеціалізації, а також показників зустрічності та чисельності представників мікобіоти лісів за участю *Abies alba* у Покутсько-Буковинських Карпатах. Дослідження проводили впродовж 2019-2023 років у межах лісових масивів філій «Кутське лісове господарство», «Івано-Франківське лісове господарство» та «Берегометське лісомисливське господарство» Державного спеціалізованого господарського підприємства «Ліси України», а також лісів Національного природного парку «Вижницький» та Національного природного парку «Гуцульщина». У роботі використано класичні мікологічні методи ідентифікації. Для уточнення сучасного систематичного положення та актуальної назви таксонів використано інформацію із інтерактивних баз даних «Index Fungorum», «Mycobank» та «Світ грибів України». Досліджено, що консортивні зв'язки грибної біоти лісів Покутсько-Буковинських Карпат найбільш тісно пов'язані із деревними рослинами *Picea abies*, *Abies alba* та *Fagus sylvatica*. У ході мікологічної експедиції ідентифіковано 54 види представників царства *Fungi*, які на 81,5 % належать до відділу *Basidiomycota* та на 18,5 % – до відділу *Ascomycota*. Встановлено, що найбільш чисельним є порядок *Polyporales*, а найменш чисельно представлені порядки *Corticiales*, *Gomphales*, *Phallales*, *Pucciniales* та *Tremellales*. Показано, що згідно трофічної спеціалізації представники досліджуваної мікобіоти лісів Покутсько-Буковинських Карпат належать до наступних груп: ксилотроф-факультативний сапротроф, ксилотроф-факультативний патоген, ксилотроф-облігатний сапротроф, облігатний патоген та надгрунтовий сапротроф. Зазначається, що найширше представлені сапроксилотрофи, що загалом розвиваються на сухостійній та опалій деревині. Таким чином, системно-структурний аналіз грибної біоти лісів Покутсько-Буковинських Карпат дозволяє провести оцінку біоценотичного значення грибів як біоіндикаторів сучасного стану деревостанів, а також виокремити еталонні та цінні території, які характеризуються високими показниками біорізноманіття

Ключові слова: ялиця біла; мікоценоз; систематичне положення; видовий склад; трофічна спеціалізація