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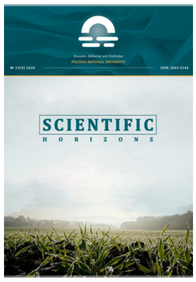

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The role of aphyllophoroid macromycetes as indicators of forest ecosystem disruption and reducers of biomass accumulation

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Abstract. Aphyllophoroid macromycetes are a key link in natural and artificial biocenoses, in particular, forest ecosystems. Their peculiarity is due to the variety of morphological forms and the ability to colonise various substrates. The establishment of fundamental issues of the biotic organisation of this group of fungi, which considers both their specific features and integration into general ecological patterns, forms the necessary basis for their further research, protection, and practical use (in particular, when indicating and monitoring the state of forest biocenoses). The purpose of the study was to establish the species composition, taxonomic structure, and distribution (by mycohorizons) of aphyllophoroid macromycetes of forest stands in Zhytomyr Polissia. In the course of the study, classical phytopathological and forestry-inventory (biometric)

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analysis methods were used. Special methods of mycology, in particular, mycoindication, were also used in terms of identifying and examining aphyllophoroid macromycetes. Mycoflora of aphyllophoroid macromycetes of forest stands of Zhytomyr Polissia has 27 species belonging to 17 families, 8 orders of the *Agaricomycetes* class of the *Basidiomycota* division and is typical for the European temperate zone. The systematic component of the group under study is represented by the following orders: *Polyporales* (40.7% of their total number), *Hymenochaetales* (18.5%), *Agaricales* (14.8%), *Russulales* (11.2%), *Cantharellales*, *Thelephorales*, *Auriculariales*, and *Gomphales* (3.7% each). Analysis of the food structure of aphyllophoroid macromycetes shows that most of the mycoflora is represented by a complex of saproxilotrophic species, to a lesser extent parasite fungus (for example, *Inonotus hispidus, Phellinus robustus, Heterobasidion annosum*) and humus saprotrophs (*Thelephora terrestris*) are noted. The distribution of macromycetes by mycohorizons identifies that more than 70% of all finds were located in the subsurface mycohorizon, and the root mycohorizon is characterised by the smallest number of finds and species of macromycetes. There is a gradual decrease in the species diversity of aphyllophoroid macromycetes in the forest edge areas, which demonstrates fundamentally different stages of forest ecosystem degradation processes. The investigation of historical relationships between woody plant species and aphyllophoroid macromycetes, which act as biological indicators of the state of forest ecosystems, will further allow forming the of "maps of disruption of the integrity of forest biocenoses" for the analysis of sanitary risks, which should be implemented in the practice of forest protection

Keywords: wood-destroying fungi; mycohorizons; mycoflora; fruit bodies; edifying trees; Zhytomyr Polissia

INTRODUCTION

Forest biocenoses, as components of forest ecosystems, are a set of organisms consisting of various components – phytocenoses, zoocenoses, mycocenoses, and microbocenoses, which are closely interrelated in metabolism, energy, and information, which are manifested in competition for life resources, symbiosis, allelopathy, and consort relations. The use of these links as an indicator of anthropogenic disturbance of forest ecosystems is a relevant research area since the system "woody plant species – aphyllophoroid macromycetes" combines the processes of weakening and damage to trees, the accumulation of wood fall, and the rate of its decomposition by mycetes into a holistic process that clearly reflects the corresponding characteristics of the forest ecosystem.

One of the most numerous and insufficiently examined paraphyletic groups of fungi is aphyllophoroid macromycetes, from the standpoint of modern systematic structures, they are positioned as a set of life forms that unites representatives of the Basidiomycota division of multiple lines of phylogenetic order (Blinkova & Ivanenko, 2016; Holec *et al.,* 2020; Kunttu *et al.,* 2021). This group is a component of the heterotrophic complex of forest ecological systems. In particular, it is aphyllophoroid macromycetes that are the main reducers of dead trees. A large group of species is used in forestry practice as biological indicators of the condition, some species can destroy xenobiotics, while others – produce biologically active substances (Lavrov *et al.,* 2019; Kunca *et al.,* 2022; Rudawska *et al.*, 2022).

The fraction of aphyllophoroid macromycetes, in particular, xylotrophic species, in terms of qualitative and quantitative representation is the most numerous in the composition of mycobiota of forest cenoses (Shevchenko *et al.,* 2021). Therewith, the importance of xylotrophic fungi is absolutely ambiguous, since, on the one hand, they are pathogens of root and trunk wood rot, which negatively affects the overall phytosanitary state of the forest (Mihál *et al.,* 2021; Goychuk *et al.,* 2022). In contrast, saprotrophic species of xylotrophic fungi can destroy wood waste (i.e., dead organic matter, mortmass) (Ruszkiewicz-Michalska *et al.,* 2022); basidiomas and mycelium of aphyllophoroid fungi are the leading elements in the food chains of many species of stem pests, and some species of these macromycetes can also be used as biological indicators of untransformed anthropic forest coenoses (Rudolph *et al.,* 2018; Lavrov *et al.,* 2019; Alshammari *et al.,* 2021).

A targeted study of this group of aphyllophoroid macromycetes of forest stands has not yet been conducted. Currently, it is known about individual studies that describe the species composition and distribution of this group of fungi on the territory of a particular region (Christofides *et al.,* 2019; Kunttu *et al.,* 2020; Krynytska *et al.,* 2021). The authors also investigate the role and importance of aphyllophoroid macromycetes in the mycoindication of anthropogenic transformation of forest ecosystems (Lavrov *et al.,* 2019; Purahong *et al.,* 2022; Zou *et al.,* 2022). Thus, inventory and analysis of the species composition of mycoflora of aphyllophoroid macromycetes is a relevant research area and is of value for practitioners and researchers of the forest industry. The investigation and use of knowledge about aphyllophoroid macromycetes as biological indicators of anthropic forest disturbance is now a new and little-researched area.

In forest biocenoses, connections of higher woody plant species with fungi and fungi-like organisms are particularly common and developed (Yakhyaev *et al.,* 2019; Embacher *et al.,* 2023). Among the representatives of the group of wood-destroying, fungi or tinder plants (xylomycobionts) are substantial in terms of the qualitative and quantitative composition of the mycological biota of forests. Therewith, parasitic aphyllophoroid and agaricoid fungi can have a negative impact on the overall sanitary condition of forest stands, in particular, as pathogens of root and stem rot processes (Kunttu *et al.,* 2018; Li *et al.,* 2022). In turn, saprotrophic fungi, conducting organic decomposition of plant raw materials, provide a cycle of energy and matter in the biogeocenosis (Krynytska *et al.,* 2019).

During the mycological diagnostics of the transformation of forest biocenoses, considering the species composition and distribution of aphyllophoroid macromycetes as bioindicators, it is necessary to consider the differences inherent in forest objects growing in different types of forest (Lavrov *et al.,* 2019). It is also known that the systematic, trophic, and species structures of aphyllophoroid macromycetes, the features of their functioning, and distribution may vary depending on changes occurring in the structure of the forest stand, the level of its anthropic load, the volume of forest litter, and tree fall (Blinkova & Ivanenko, 2016). There are separate studies concerning the species composition of the mycological complex in forests of natural and artificial origin that grow in various natural zones: Forest-Steppe – in field-protecting plantings and operational forests, Kyiv Polissia (Blinkova & Ivanenko, 2016), Transcarpathia (Krynytska *et al.,* 2021) etc. In particular, V.V. Lavrov *et al.* (2019) examined the features of the mycological diversity of forests located within the green zones of urbanised environments of Ukraine.

Identification of the species composition and features of the distribution of xylomycobionts in various natural zones of Ukrainian phytocenoses remain poorly examined today, despite the experience gained by researchers regarding the use of wood-destroying fungi and higher woody plants in the form of biological indicators of the sanitary state of forests (Haas *et al.,* 2019; Holec & Kučera, 2020).

The purpose of the study is a comprehensive examination of aphyllophoroid macromycetes of forest stands of Zhytomyr Polissia, in particular, identification, distribution, and taxonomic distribution, for the use of these indicators as mycoindication signs of disruption of the state of forest ecosystems.

MATERIALS AND METHODS

The research materials of the study were samples of aphyllophoroid macromycetes collected during the growing season of 2020-2022 within the forest stands of Zhytomyr Polissia. The collection of prototypes was conducted by the route-expedition method, and on temporary test areas in forest stands of the region under study. In the test areas, the studies were conducted at various degrees of organisation of biological systems, depending on the visible changes (transformations) of the ecosystem and the spread of aphyllophoroid macromycetes: the organ of a woody plant – roots, perianth part, trunk, crown, branch; woody plant species; species (population), tier (biogroup) of coenosis, phytocenosis.

Mycological samples were collected considering the individual characteristics of macromycetes. The aphyllophoroid macromycetes collected on different substrates of the same woody plant were considered to be from one species (this refers to different ecological niches). Therewith, different species of finds included macromycetes that grew (covered) one species of substrate but formed basidiomas of several species. Each find was recorded using a camera.

Under laboratory conditions, using light microscopy methods (MBI-3 microscope and MBS-9 binocular magnifier), species identification of the collected phytopathological material – fruit bodies of aphyllophoroid macromycetes was performed. The examination and analysis of macroscopic structures of the objects under study were conducted on temporary micro-preparations directly under a microscope at a magnification in the range from x8 to x100.

The distribution of aphyllophoroid macromycetes by spatial structure, i.e. by mycological horizons, was conducted. 5 types of mycohorizons were identified (crown, stem, lump, aboveground (including dead wood, fallen trees, dead branches), and ground), the number of aphyllophoroid macromycetes species, and the total number of finds were determined. Morphometrically, the following categories of dead substrates of the edifier of the macromycetes consortium were evaluated and distinguished: stumps of felled trees, large and small branches, dead wood, and fallen trunks.

Desk processing and identification of the collected mycological material was conducted based on the A.V. Tsyliuryk training laboratory of forest pathology of the National University of Life and Environmental Sciences of Ukraine according to generally accepted and special methods (phytopathology, mycology, general ecology, forestry and mensuration, and mycological indication) (Methodology of forestry research, n.d.; Lavrov *et al.,* 2018), using special determinants for individual taxa of aphyllophoroid macromycetes, the search engine of the "The world of mushrooms of Ukraine" (n.d.) website, and the application "Mushroom Identify" (the world of mushrooms, 2023). The taxonomic structure and prevalence of parasitic fungi were determined by the proportion of trees with characteristic fruit bodies from the total number of trees in the study areas (Sanitary rules, 2020). Modern Latin names of aphyllophoroid macromycetes are given in accordance with the nomenclature database (Index Fungorum, 2023). The analysis of the food specialisation of aphyllophoroid macromycetes was conducted considering the trophic adaptability of fungi to specific species of woody plants. Microsoft Excel was used in the process of creating standard charts to graphically display the results obtained.

RESULTS AND DISCUSSION

In the course of the conducted studies, it was identified that most of the species of aphyllophoroid macromycetes are characterised by different levels of food specialisation. In particular, 27 species were identified and identified in the forest stands of Zhytomyr Polissia on woody plant species. Most of the identified aphyllophoroid macromycetes are attributed to xylosaprotrophs, whose life cycle is limited to dead and fallen wood. The largest number of species was recorded on Scots pine, Scots oak, silver birch, white poplar, holly maple, and black alder (Fig. 1).

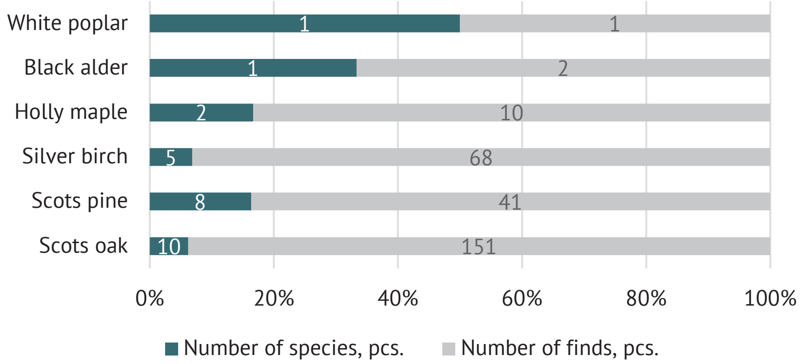

Figure 1. *Specialisation of aphyllophoroid macromycetes of forest stands of Zhytomyr Polissia based on substrate-forming woody plant species*

Thus, for aphyllophoroid macromycetes of forest stands of Zhytomyr Polissia, specialisation is typical for trees-edifiers of the consortium or substrate-forming plants. The largest number of species is recorded on Scots pine (*Pinus sylvestris* L.) (10 species, 37.0% of the total number of finds), Scots oak (*Quercus robur* L.) (8 species, 29.6%), holly maple (*Acer platanoides* L.) (2 species, 7.4%), silver birch (*Betula pendula* Roth.) (5 species, 18.6%), white poplar (*Populus tremula* L.) (1 species, 3.7%), and black alder (*Alnus glutinosa* (L.) Gaerth.) (1 species, 3.7%).

10 species of aphyllophoroid macromycetes were identified on Scots pine. Thus, on the roots, the lower part of the trunks, the stumps and the trunk of living trees, a perennial heterobizidion (*Heterobasidion annosum* (Fr.) develops, which causes variegated central rot of wood on the roots and is one of the most dangerous pathogens of mycotic diseases and mass dieback of coniferous forests. This macromycetes massively affects pine stands and leads to the loss of a substantial amount of wood and reduces the protective properties of forests. Over time, the affected stands are transformed into woodlands, due to the gradual weakening and dieback of woody plants. In infected trees, there is a disruption of the movement and pressure of oleoresin, which performs the function of physiological and mechanical protection against damage by phytophagous insects, the frequency and intensity of reproduction of which takes place at irregular intervals but is usually characteristic of weakened and dieback stands that are under stress, in particular, physiological (Hayova *et al.*, 2020).

On the soil and plant or tree remains, singly and in groups, the mycorrhizal fungus *Thelephora terrestris* Ehrh. was identified (Fig. 2a). Saprotroph on soil, symbiont. Despite the fact that the fungus is not a parasite, it can lead to the death of plants, enveloping seedlings of pine and other species. Such damage is called seedling suffocation. The distribution of red-belted conk (*Fomitopsis pinicola* (Sw.: Fr.)) was identified (Fig. 2b) – causes yellowish-brown in colour core-sapwood type prismatic rot, which leads to complete destruction of wood; shaggy bracket (*Inonotus hispidus* (Bull.)) – causes yellowish-white core trunk rot of a corrosive type; red ring rot (*Phellinus pini* (Brot.)) – causes variegated core stem rot of a corrosive type. On dead and fallen trunks, *Trichaptum fuscoviolaceum* (Ehren.), *Botryobasidium subcoronatum* (Höhn & Lits), *Chondrostereum purpureum* (Pers.) are common (Fig. 2b).

a) b) c)

Figure 2. *Thelephora terrestris Ehrh. (a), Fomitopsis pinicola (Sw.: Fr.) (b), and Chondrostereum purpureum (Pers.) (c)*
Source: *photographed by the authors*

Single fruit bodies of the scaly sawgill were identified on stumps and old fallen tree trunks (*Neolentinus lepideus* (Fr.)) (Fig. 3a). Groups of fruit bodies of strict-branch coral (*Ramaria stricta* (Pers.)) marked on rotten stumps and rotten wood submerged in the soil (Fig. 3b).

a) b) c)

Figure 3. *Neolentinus lepideus (Fr.) (a), Ramaria stricta (Pers.) (b) and Irpex lacteus (Fr.) (c)*
Source: *photographed by the authors*

8 species of aphyllophoroid macromycetes were identified on Scots Oak: crust fungus (*Irpex lacteus* (Fr.) (Fig. 3b), *Peniophora quercina* (Pers.), and *Radulomyces molaris* (Chaillet), which start recycling still-living wood and continue their development on the dead substrate. On the trunks and branches of living trees, *Phellinus robustus* (Karst.) is marked, which causes white and yellowish-white central wood rot, leading to tree death. On fallen trunks, dry branches and stumps of oak, *Hymenochaete rubiginosa* (Dicks.) Lév. is marked, which causes dry corrosion rot of wood. *Stereum hirsutum* (Willd.) and *Trametes versicolor* (L.) are also identified on the fallen trunks (Fig. 4a). In the litter on plant remains an unusual find was identified – the fruit bodies of *Cyathus striatus* (Huds.) (Fig. 4b).

a) b) c)

Figure 4. *Trametes versicolor (L.) (a), Cyathus striatus (Huds.) (b), Exidia glandulosa (Bull.) (c)*
Source: *photographed by the authors*

Aphyllophoroid macromycetes of holly maple consortia are represented by 2 species. Groups of maple tinder fruit bodies were identified on live trunks (*Oxyporus populinus* (Schumach.) Fr.), which is a wound parasite and causes intense yellow-brown stem rot. Basidiomas of the *Polyporus squamosus* (Huds.) Fr. are also noted on dry and fallen wood, causing white wound rot. *Mycoacia fuscoatra* (Fr.) was the only species of aphylophoric macromycetes identified on black alder. Fruit bodies were identified on fallen wood and fallen branches.

On growing trees, stumps, and fallen branches of silver birch, 5 species of aphyllophoroid macromycetes were recorded, the most numerous among them are 3 species: on growing trunks – *Piptoporus betulinus* (Bull.) – causes red-brown core-sapwood trunk rot of a destructive type; *Fomes fomentarius* (L.) – causes white marble-like core-sapwood trunk rot of a corrosive type. *Cerrena unicolor* (Bull.), which causes intense whitish rot of wood was noted on fallen trunks and stumps. Single fruit bodies of *Panus conchatus* (Bull.) were identified on stumps and fallen trunks. *Exidia glandulosa* (Bull.) (Fig. 4b) was observed in autumn from September to the beginning of frosts, usually on dieback, less often – standing, birch trunks, and on dry branches.

1 species of aphyllophoroid macromycetes was identified on the white poplar – *Schizophyllum amplum* (Lév.), trophic specialisation of which is adapted to fallen wood of varying degrees of destruction. It was identified that certain species of aphyllophoroid macromycetes begin the process of utilisation of dead

substrate or wood, directly still being in xerophilic conditions of the tree crown and form groups depending on the trophic and microclimatic needs of specific species belonging to their category.

Among the species composition of aphyllophoroid macromycetes, according to trophic preferences, there are parasitic fungi, saprotrophs, and species capable of forming facultative mycorrhiza. According to the obtained experimental data, in the examined mycoflora of forest stands of Zhytomyr Polissia, the fraction of fungi-saproxilotrophs, the life cycle of which is confined to dead and fallen wood, are most widely represented. A substantially smaller number of species is represented by a group of humus saprotrophs, among which 1 species is identified – *Thelephora terrestris*, which is a typical facultative mycorrhizal agent. A group of parasitic fungi was also noted, the most common among them in the forests of Zhytomyr Polissia were obligate parasites (*Phellinus robustus*, *Heterobasidion annosum*, and *Inonotus hispidus*).

Several species of macromycetes (*Fomes fomentarius*, *Oxyporus populinus*, and *Stereum hirsutum*) were facultative saprotrophs that begin their ontogenesis on living woody plants, and continue – on dead wood. Some species develop mainly on dead wood but are also able to colonise drying weakened woody plants, and that is why they are classified as facultative parasites (for example, *Fomitopsis pinicola*).

Analysis of the taxonomic structure of the identified aphyllophoroid macromycetes showed that these species belong to 27 genera, 17 families, and 8 orders of the *Agaricomycetes* class of the *Basidiomycota* division. Most of the examined species are formed by representatives of the *Polyporales* (11 species, 40.7% of their total number), *Hymenochaetales* (5 species, 18.5%), *Agaricales* (4 species, 14.8%), *Russulales* (3 species, 11.2%), *Cantharellales* (1 specie, 3.7%), and *Thelephorales* (1 species, 3.7%), Auriculariales (1 species, 3.7%), Gomphales (1 species, 3.7%) orders (Fig. 5).

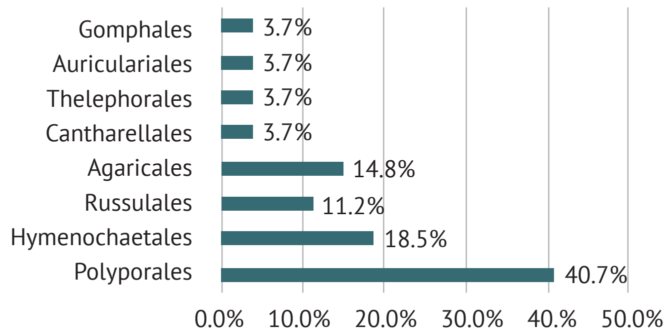

Figure 5. *Taxonomic structure of aphyllophoroid macromycetes of forest stands in Zhytomyr Polissia*

Leading families (*Polyporaceae*, *Hymenochaetaceae*, *Fomitopsidaceae*) cover more than 50% of the species composition of the examined mycoflora, which brings it closer to European forest mycological flora.

The general distribution of aphyllophoroid macromycetes of forest stands of Zhytomyr Polissia by mycohorizons was conducted (Table 1). The species diversity of aphyllophoroid macromycetes in forest stands of Zhytomyr Polissia is 27 species and 273 finds. Overall, 76.2% of all macromycete finds were identified in subsurface mycohorizon. The smallest number of finds and species of macromycetes from the total number is characterised by the root mycohorizon. There were no finds in the crown mycohorizon. A relatively small number of aphyllophoroid macromycetes were identified in trunk and butt wood mycohorizons.

Table 1. *Distribution of aphyllophoroid macromycetes of forest stands in Zhytomyr Polissia by mycohorizons*

No.	Variety of macromycete consort	Number of finds	Species of woody plant-edifier of the consortium	mycological horizons				
				1	2	3	4	5
1	*Heterobasidion annosum* (Fr.) Bref. 1888	39		+	+	-	-	-
2	*Fomitopsis pinicola* (Sw.) P. Karst. 1881	15		-	+	-	-	-
3	*Inonotus hispidus* (Bull.) P. Karst. 1879	3		-	-	-	+	-
4	*Thelephora terrestris* Ehrh. 1793	9	*Pinus sylvestris* L.	-	+	-	-	-
5	*Phellinus pini* (Brot.) Pilát 1941	44		-	-	+	-	-
6	*Trichaptum fuscoviolaceum* (Ehrenb.) Ryvarden 1972	2		-	+	-	-	-
7	*Botryobasidium subcoronatum* (Höhn. & Litsch.) Donk 1931	1		-	+	-	-	-

Table 1, Continued

No.	Variety of macromycete consort	Number of finds	Species of woody plant-edifier of the consortium	mycological horizons				
				1	2	3	4	5
8	*Neolentinus lepideus* (Fr.) Redhead & Ginns, 1985	6	*Pinus sylvestris* L.	-	+	+	-	-
9	*Chondrostereum purpureum* (Pers.) Pouzar, 1959	19		-	+	+	+	-
10	*Ramaria stricta* (Pers.) Quél., 1888	13		-	+	-	-	-
11	*Irpex lacteus* (Fr.) Fr. 1828	3	*Quercus robur* L.	-	+	-	-	-
12	*Peniophora quercina* (Pers.) Cooke 1879	1		-	-	-	+	-
13	*Radulomyces molaris* (Chaillet ex Fr.) M.P. Christ. 1960	1		-	-	-	+	-
14	*Phellinus robustus* (P. Karst.) Bourdot & Galzin 1928	12		-	+	+	-	-
15	*Stereum hirsutum* (Willd.) Pers. 1800	9		-	+	+	+	-
16	*Hymenochaete rubiginosa* (Dicks.) Lév. 1846	1		-	+	-	-	-
17	*Trametes versicolor* (L.) Lloyd, 1921	12		-	+	+	-	-
18	*Cyathus striatus* (Huds.) Willd., 1787	2		-	+	-	-	-
19	*Schizophyllum amplum* (Lév.) Nakasone 1996	1	*Populus tremula* L.	-	+	-	-	-
20	*Oxyporus populinus* (Schumach.) Donk 1933	4	*Acer platanoides* L.	-	-	-	+	-
21	*Polyporus squamosus* (Huds.) Fr. 1821	6		-	+	-	+	-
22	*Mycoacia fuscoatra* (Fr.) Donk 1931	2	*Alnus glutinosa* (L.) Gaerth.	-	+	-	-	-
23	*Piptoporus betulinus* (Bull.) P. Karst. 1881	22	*Betula pendula* Roth.	-	-	-	+	-
24	*Fomes fomentarius* (L.) Fr. 1849	29		-	-	-	+	-
25	*Cerrena unicolor* (Bull.) Murrill 1903	2		-	+	+	-	-
26	*Panus conchatus* (Bull.) Fr., 1838	1		-	+	-	-	-
27	*Exidia glandulosa* (Bull.) Fr., 1822	14		-	+	+	+	-

Source: *compiled by the authors*

Therewith, it was identified that the species diversity of the examined aphyllophoroid macromycetes gradually decreases in the areas of the forest edges, which is presumably caused by the rather unequal sanitary structure of the examined forests. This demonstrates the various phases of the degradation processes of forest stands and the transformation of their structure in the areas of dilution of the mother tent, its natural renewal and transformation of the dominant species of woody plants by synanthropic species, replacement of the stand with shrubs and shrubby thickets, etc. (Slesar & Kulbanska, 2022).

Summarising, it was noted that the aphyllophoroid macromycetes community unites virtually all ecological groups of fungi, including saprotrophs, mycotrophs, xylotrophs, coprotrophs, parasites of higher plants, and mycorrhizal agents, etc. It is aphyllophoroid macromycetes that are most widely used to indicate the general (including sanitary) state of forests. Among the representatives of this group of fungi, there are species represented in the Red lists of different countries of the world that now need protection and conservation.

Thus, the improvement of methods for assessing the anthropic impact on forest biocenoses, in particular, based on mycoindication methods, considering the species composition and distribution of aphyllorophoroid macromycetes, is promising, both in theoretical and practical terms, especially in conditions of complex influence of abiotic and biotic environmental factors, with mechanisms and methods of influence that differ among themselves.

The results obtained in the course of the study correlate with already known studies in this area. In particular, Polishchuk (2017) was able to identify 29 species of macromycetes, which are assigned to 28 genera, 18 families, and 6 orders of the Basidiomycota division (Agaricomycetes class) while investigating the distribution and structure of wood-destroying fungi of the Kyiv Polissia, on various categories of dead and living substrates. The largest number of species (8) and finds (35) of xylotrophic fungi were identified on *Betula pendula* L. and *Quercus robur* L. woody plants. It is noted that wood-destroying fungi are almost equally common on the trunk, the crown, and the butt wood. Accordingly, the studies on aphyllophoroid macromycetes of Zhytomyr Polissia allowed identifying 27 species of macromycetes belonging to 17 families, 8 orders of the Agaricomycetes class of the Basidiomycota division. The largest number of species (10) and finds (151) of xylotrophic fungi were identified on *Pinus sylvestris* L. woody plants.

The findings were also mainly in the subsurface mycohorizon. Lavrov et al. (2019), investigating methods for diagnosing of recreagenic transformation of oak forests by the diversity of groups of xylotrophic fungi and phytobiota, identified that changes in the ecological state of oak forests of the urban plantings in the city of Bila Tserkva are caused by a complex of environmental factors leading to the degradation of middle-aged oak stands. It is confirmed that xylotrophic fungi quite informatively reflect the sanitary condition of plantings and perform a regulatory function in forests. The authors proposed the implementation of xylomycological indication of forest phytocenosis disorders in the forest monitoring system. A similar assumption was made based on this study. Therefore, it can be stated that the biota structure of aphyllophoroid macromycetes is a coded reflection of the structure of the forest stand and under any specific conditions depicts its indicators with high accuracy.

Blinkova & Ivanenko (2016), investigating the coadaptive systems of woody vegetation of wood-destroying (xylotrophic) fungi in artificial phytocenoses, also touched upon the concept of "bioindication". The study analyses the role and functions of xylotrophs in the genesis of cultural phytocenoses and natural forests. Their study concerns exclusively forest stands. Christofides *et al.* (2019) investigated bacterial communities in wood that was colonised by wood-destroying fungi (*Vuilleminia comedens, Trametes versicolor*, and *Hypholoma fasciculare*). It was identified that all three species of fungi substantially delayed bacterial colonisation of wood. The conducted studies did not aim to establish a link between pathogens of bacterial diseases and aphyllophoroid macromycetes.

(Haas *et al.,* 2019) examined wood-destroying fungi in detail, in particular, *Serpula lacrymans*, and their impact on the construction qualities of wood. Notably, the conducted studies included aphyllophoroid macromycetes, whose vital activity is confined to both living and dead substrates. A study by Hayova *et al.* (2020) is dedicated to the Red Book species of wood-destroying fungi – *Fomitopsis officinalis* and its distribution within the Ivano-Frankivsk and Lviv regions. In the course of the conducted studies, not a single species of aphyllophoroid macromycetes was identified, which is classified in the Red Book of Ukraine. However, it was noted that the role of aphyllophoroid macromycetes in forests is quite diverse and therefore, this group of living organisms requires attention and research from the scientific community.

Species richness and composition of macromycetes (168 species identified) on the trunks of *Picea abies* are discussed in detail in the paper (Holec *et al.,* 2020). It is established that the number of wood-destroying fungal species on tree trunks correlated with an increase in tree cover, average decay stages, and a decrease in height. Among the dominant species of macromycetes, the following are highlighted: *Fomitopsis pinicola*, which was also a frequent find on the trunks of *Pinus sylvestris* during the conducted studies. Despite the fact that researchers have formed a large contribution to the study of wood-destroying fungi, none of the available studies has formed a comprehensive approach to the examination of the species composition and distribution of aphyllophoroid macromycetes of forest stands and the use of this knowledge for mycoindication of biocenoses transformed by anthropic factors. This will allow using them in mycoindication of disturbed (weakened, degraded) forest ecosystems in the form of biological indicators of the state, which in the future will allow forming the "maps of disruption of the integrity of forest biocenoses" for analysis of sanitary risks (phytosanitary forecasting).

CONCLUSIONS

Mycoflora of the identified aphyllophoroid macromycetes of forest stands of Zhytomyr Polissia has 27 species belonging to 17 families, 8 orders of the Agaricomycetes class of the Basidiomycota division.

The species diversity of the examined formation was quite characteristic of the European temperate zone. Analysis of the systematic structure of aphyllophoroid macromycetes shows that the largest number of species (11 species, 40.7% of their total number) is represented by the *Polyporales* order, and other orders are represented to a lesser extent. Thus, the *Hymenochaetales* order is represented by 5 species, which is 18.5% of the total number of identified macromycetes; the *Agaricales* order is represented by 4 species, which is 14.8%; the *Russulales* order is represented by 3 species, which is 11.2%. Other orders – *Cantharellales*, *Thelephorale*s, Auriculariales, and Gomphales are represented by 1 species, which is 3.7% of their total number.

Analysis of the food structure of aphyllophoroid macromycetes of forest stands in Zhytomyr Polissia shows that most of the mycoflora is represented by a complex of saproxilotrophic species, to a lesser extent – parasitic fungi and humus saprotrophs are noted.

A characteristic feature of aphyllophoroid macromycetes of forest stands is the specialisation of plants-edifiers of the consortium or substrate-forming species of forest woody plants. The largest number of macromycete species (10 species) was identified on the bodies of *Pinus sylvestris* L. On *Quercus robur* L., 8 species of aphyllophoroid macromycetes were identified. Aphyllophoroid macromycetes of the *Acer platanoides* L. consortia are represented by 2 species. The only species of aphilophoric macromycetes identified on the *Alnus glutinosa* (L.) Gaerth. was *Mycoacia fuscoatra*. 5 species of aphyllophoroid macromycetes were recorded on *Betula pendula* Roth. On *Populus tremula* L., 1 species of aphyllophoroid macromycetes was identified – *Schizophyllum amplum*.

It was established that the mycoflora of aphyllophoroid macromycetes of forest communities of the examined region form groups depending on the microclimatic and trophic species preferences that are directly included in their composition. A promising area for further research is the deepening of methodological approaches to the examination of aphyllophoroid macromycetes of forest stands, in particular, knowledge about the species composition, proximity to trees-edifiers of the consortium, distribution by mycohorizons, etc.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Роль афілофороїдних макроміцетів як індикаторів порушення лісових екосистем та редуцентів накопичення біомаси

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Анотація. Афілофороїдні макроміцети виступають ключовою ланкою природних і штучних біоценозів, зокрема лісових екосистем. Їхня особливість обумовлена різноманіттям морфологічних форм і здатністю до колонізації різних субстратів. Встановлення принципових питань біотичної організації цієї групи грибів, що враховує як їх специфіку, так і інтегрованість у загальноекологічні закономірності, формує необхідну основу їхнього подальшого дослідження, охорони та практичного використання (зокрема при індикації та моніторингу стану лісових біоценозів). Мета роботи полягала у встановленні видового складу, таксономічної структури та поширення (за мікогоризонтами) афілофороїдних макроміцетів лісових насаджень Житомирського Полісся. В ході виконання дослідження використано класичні фітопатологічні та лісівничо-таксаційні методи аналізу. А також використано спеціальні методи мікології, зокрема мікоіндикації, в частині ідентифікації та дослідження афілофороїдних макроміцетів. Мікофлора афілофороїдних макроміцетів лісових насаджень Житомирського Полісся налічує 27 видів, які належать до 17 родин, 8 порядків класу *Agaricomycetes* відділу *Basidiomycota* і є типовою для європейської помірної зони. Систематична складова дослідженого угрупування представлена наступними порядками: *Polyporales* (40,7 % від їх загальної кількості), *Hymenochaetales* (18,5 %), *Agaricales* (14,8 %), *Russulales* (11,2 %), *Cantharellales*, *Thelephorales*, *Auriculariales* та *Gomphales* (по 3,7 % кожна). Аналіз харчової структури афілофороїдних макроміцетів засвідчує, що більша частина мікофлори представлена комплексом сапроксилотрофних видів, у меншій ступені відмічені гриби-паризити (наприклад, *Inonotus hispidus*, *Phellinus robustus*, *Heterobasidion annosum*) та гумусові сапротрофи (*Thelephora terrestris*). Розподіл макроміцетів за мікогоризонтами завсідчує, що понад 70 % усіх знахідок виявлено у надгрунтовому мікогоризонті, а найменшою чисельністю знахідок і видів макроміцетів характеризується кореневий мікогоризонт. Спостерігається поступове зменшення видового різноманіття афілофороїдних макроміцетів у напрямках узлісь, що, демонструє принципово різні етапи процесів деградації лісових екосистем. Дослідження зв'язків, що історично сформовані між деревними видами рослин і афілофороїдними макроміцетами, які виступають біологічними індикаторами стану лісових екосистем, у подальшому дозволить сформувати «карти порушення цілісності лісових біоценозів» для аналізів санітарних ризиків, які доцільно впроваджувати у практику лісозахисту

Ключові слова: дереворуйнівні гриби; мікогоризонти; мікофлора; плодові тіла; дерева-едифікатори; Житомирське Полісся