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Research Article

DIVERSITY OF WOOD-INHABITING FUNGI IN TĂTĂRUŞI FOREST RESERVE

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Abstract: The article presents the results of a mycological study carried out in the Tătăruși Forest Reserve, where there were recorded 44 species of wood-inhabiting macromycetes, in 31 plots with beech trunks in different stages of decomposition. The relationships between fungal diversity and trunk parameters, forest cover were analyzed using multivariate statistical methods. The number of species ranged between 5-19 species per sample plot. The highest diversity was recorded in plots with trunks without bark, with larger volume, not exposed to the sun. Most fungal taxa were recorded on woody debris in the IV degree of decomposition. The lignicolous macromycetes were separated into two groups mainly depending on the degree of substrate decomposition.

Keywords: diversity, ecology, *Fagus sylvatica* forest, lignicolous fungi, wood decomposition.

Introduction

The beech (*Fagus sylvatica* L.) is a tree species that occupies large areas in the northern hemisphere, forming forests in Europe, both in pure stands and in various combinations with conifers at higher altitudes. The beech forests of Europe represent some of the most valuable ecosystems on the continent, highlighted both for their unique beauty and for the essential roles they play in the balance of the environment. Beyond their aesthetic appearance, these forests are true sanctuaries of biodiversity, protecting an impressive variety of plant, animal and micro-organism species that depend on the stability and resources they offer. At the same time, *Fagus* sp. forests are subjected to great anthropogenic pressures. Their importance is therefore complex and significant. Preserving these forests means preserving a priceless natural heritage, and treasure of biodiversity.

A significant number of beech forests are included in protected areas or even UNESCO World Heritage Sites due to their unique value and high degree of naturalness. However, beech forests are currently facing numerous challenges. Human activities, such as intensive logging or habitat destruction through fragmentation, reduce the capacity of these ecosystems to regenerate and maintain their natural functions. The ecological amplitude of beech is greater compared to other deciduous species in Europe in the context of natural regeneration [AXER & al. 2021; FANG & LECHOWICZ, 2006; WAGNER & al. 2010].

In Romania, protection of beech forests is a major priority, focused on their conservation, in order to maintain this natural heritage, a refuge for countless species and an essential factor for the stability of the environment. The beech forests are not just natural

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resources, but they are part of Romania's identity, history and future, and their protection represents an indispensable commitment for next generations [MILESCU & al. 1967; BIRIȘ & al. 2016].

The beech forests in the northeastern part of Moldova (Romania) represent valuable temperate ecosystems, with remarkable biodiversity, including the Tătăruși forest (Photo 1) as well as those in the surrounding areas such as Humosu and Codrii Pașcanilor. These habitats offer optimal conditions for the development of a large number of fungi species due to the slightly acidic soil, consistent litter of decaying leaves, and a significant quantity of dead wood. The Tătăruși Forest (Iași County) was declared a protected area of national interest (according to the decision of the County Council no. 8/1994) for the conservation of more than 130 years old *Fagus sylvatica* specimens and the presence of *Fagus taurica* individuals with impressive dimensions (heights of 32-33 m and diameters of over 50 cm). The protected area has 49.9 ha [NICOARĂ & BOMHER, 2004].

Photo 1. Aerial view of *Fagus sylvatica* phytocoenoses in Tătăruși Forest Reserve (original)

Fungi species are fundamental components of forest ecosystems with essential ecological roles in the decomposition of organic matter, formation of mycorrhizae with host trees, and contributions to the soil nutrients cycles. At the same time, the presence of dead wood, characteristic of natural and old-growth forests, creates microhabitats necessary for many rare species of insects, birds and fungi. Forest microhabitats create conditions for increased biodiversity; thus they are important for the complexity of forest habitats, whose structural diversity is enriched. In general, for the existence of microhabitats, large trees (especially of large diameters), but also an adequate density of these large trees are required. [LARRIEU & al. 2014].

There are numerous studies focused on the influence of quantity and quality of dead wood on wood inhabiting fungi diversity, on the influence of the contact area of dead wood with the soil, on the humidity and light exposure of wood residues and the importance of the accessibility of the wood surface for the colonization of fungi [ABREGO & SALCEDO, 2011; HEILMANN-CLAUSEN, 2001; HEILMANN-CLAUSEN & al. 2014]. Similar studies on fungi from beech forests in northeastern Romania have been carried out in order to identify the main environmental factors influencing the diversity of these groups of organisms [BÎRSAN & al. 2014; COPOŢ & al. 2018; COPOŢ & al. 2020]. The current contribution was focused on the diversity and on the influence of wood characteristics and forest cover on wood-inhabiting fungi in Tătăruși forest.

Material and methods

The mycological investigations were carried out over two successive years, in 31 sample plots, each containing *Fagus sylvatica* trunks of different diameters and sizes. For all plots were registered the geographical coordinates, altitude, forest (canopy) cover, degree of bark coverage and contact with the soil of each trunk, because they are among the most important factors influencing the composition of wood-inhabiting fungi (Table 1). The stage of wood decay was estimated in accordance with the scale defined by HEILMANN-CLAUSEN (2001) and summarily presented below:

1 - fallen or standing trunks with no visible signs of decay, hard wood, intact bark (0-20%);

2 - trunks with minor signs of decay, wood still quite hard, bark starting to break (21-40%);

3 - trunks with moderate signs of decay, with distinctly weak surface of wood, bark partially lost (41-60%);

4 - trunks with strong signs of decay, but still with ± original shape, with heavily decayed surface of wood, and bark lost in most places (61-80%);

5 - completely rotted, wood very strongly decayed, either to a very soft brittle substance or to a very fragile structure (81-100%).

Table 1. Characteristics of studied plots used in the analysis of lignicolous fungal assemblages in *Fagus sylvatica* stands from Tătăruşi Forest Reserve

Plots	Altitude m a.s.l.	Wood decay (%)	Forest cover (%)	Bark cover (%)	Contact with soil
S1	352	80	85	40	100
S2	352	60	85	60	100
S3	352	85	85	50	100
S4	352	65	85	40	100
S5	352	80	85	40	65
S6	352	60	85	60	100
S7	352	40	85	80	75
S8	352	30	85	80	80
S9	376	80	90	40	100
S10	376	80	90	40	80
S11	376	80	90	40	100
S12	376	60	90	60	60
S13	376	70	90	40	100
S14	376	60	90	60	80
S15	376	75	90	40	90
S16	430	20	70	90	10
S17	430	60	70	60	70

S18	430	30	70	80	10
S19	430	80	70	40	100
S20	430	60	70	60	80
S21	430	30	70	80	10
S22	430	30	70	80	10
S23	430	30	70	100	10
S24	390	75	80	40	90
S25	390	60	80	40	80
S26	390	80	80	40	100
S27	390	60	80	60	80
S28	390	60	80	60	80
S29	390	80	80	40	100
S30	390	75	80	40	90
S31	390	60	80	60	80

The fungi species were identified based on macroscopic and microscopic characters, both in the field and in the laboratory, using well-known monographs [SĂLĂGEANU & SĂLĂGEANU, 1985; BREITENBACH & KRÄNZLIN, 1986; GERHARDT, 1999; BERNICCHIA, 2005; TĂNASE & al. 2009; COURTECUISSE & DUHEM, 2013]. The scientific names were updated according to INDEX FUNGORUM database [http://www.indexfungorum.org/Names/Names.asp]. The species statistically significant associated to the clusters were identified based on indicator value index [DUFRÊNE & LEGENDRE, 1997; DE CÁCERES & LEGENDRE, 2009].

In order to observe similarities among plots, a hierarchical agglomerative clustering procedure was used, based on the Sorensen presence-absence index, in GINKGO software [DE CÁCERES & al. 2003; BOUXIN, 2005]. In addition, in order to identify the ecological factors influencing the composition of wood-inhabiting fungi, a detrended correspondence analysis was performed, in CANOCO 5 program [TER BRAAK & ŠMILAUER, 2012].

Results and discussions

A number of 44 species of lignicolous fungi species, classified into 36 genera, were identified in the investigated sample plots with beech trunks. The species list includes: *Auricularia auricula-judae* (Bull.) Quél., *Auricularia mesenterica* (Dicks.) Pers., *Bjerkandera adusta* (Willd.) P. Karst., *Calycina citrina* (Hedw.) Gray, *Chlorociboria aeruginascens* (Nyl.) Kanouse, *Chondrostereum purpureum* (Pers.) Pouzar, *Clavulina coralloides* (L.) J. Schröt., *Exidia glandulosa* (Bull.) Fr., *Flammulina velutipes* (Curtis) Singer, *Fomes fomentarius* (L.) Fr., *Gymnopus dryophilus* (Bull.) Murrill, *Hericium coralloides* (Scop.) Pers., *Hymenopellis radicata* (Relhan) R.H. Petersen, *Hypholoma fasciculare* (Huds.) P. Kumm., *Hypholoma lateritium* (Schaeff.) P. Kumm., *Hypoxylon fragiforme* (Pers.) J. Kickx f., *Jackrogersella cohaerens* (Pers.) L. Wendt, Kuhnert & M. Stadler, *Legaliana badia* (Pers.) Van Vooren, *Lentinus arcularius* (Batsch) Zmitr., *Lycogala epidendrum* (J.C. Buxb. ex L.) Fr., *Meripilus giganteus* (Pers.) P. Karst., *Mucidula mucida* (Schrad.) Pat., *Mycena aetites* (Fr.) Quél., *Mycena haematopus* (Pers.) P. Kumm., *Mycoacia livida* (Pers.) Zmitr., *Nectria cinnabarina* (Tode) Fr., *Peziza varia* (Hedw.) Alb. & Schwein., *Pleurotus cornucopiae* (Paulet) Quél., *Plicaturopsis crispa* (Pers.) D.A. Reid, *Pluteus cervinus* (Schaeff.) P. Kumm., *Pluteus salicinus* (Pers.) P. Kumm., *Ramaria stricta* (Pers.) Quél., *Sarcoscypha coccinea* (Jacq.) Lambotte, *Schizophyllum* *commune* Fr., *Scutellinia scutellata* (L.) Lambotte, *Stereum hirsutum* (Willd.) Pers., *Trametes hirsuta* (Wulfen) Lloyd, *Trametes pubescens* (Schumach.) Pilát, *Trametes versicolor* (L.) Lloyd, *Tremella mesenterica* (Schaeff.) Pers., *Typhula fistulosa* (Holmsk.) Olariaga, *Ustulina deusta* (Hoffm.) Maire, *Volvariella bombycina* (Schaeff.) Singer, *Vuilleminia comedens* (Nees) Maire.

The most frequent species were *Fomes fomentarius*, *Schizophyllum commune*, *Mucidula mucida*, and *Hypholoma fasciculare*, species found on over 80% of the trunks.

On individual trunks were identified from 5 to 19 fungal species. The beech trunk with the highest number of lignicolous taxa (19 species), presented significant dimensions, with a soil contact of 60% and a bark coverage of 60%. On trunks with higher soil contact, more species of fungi were identified compared to trunks with lower soil contact, because the humidity is maintained for a longer time. The less frequent species, occurring on 1-4 trunks, represented 13.63% of the total identified species.

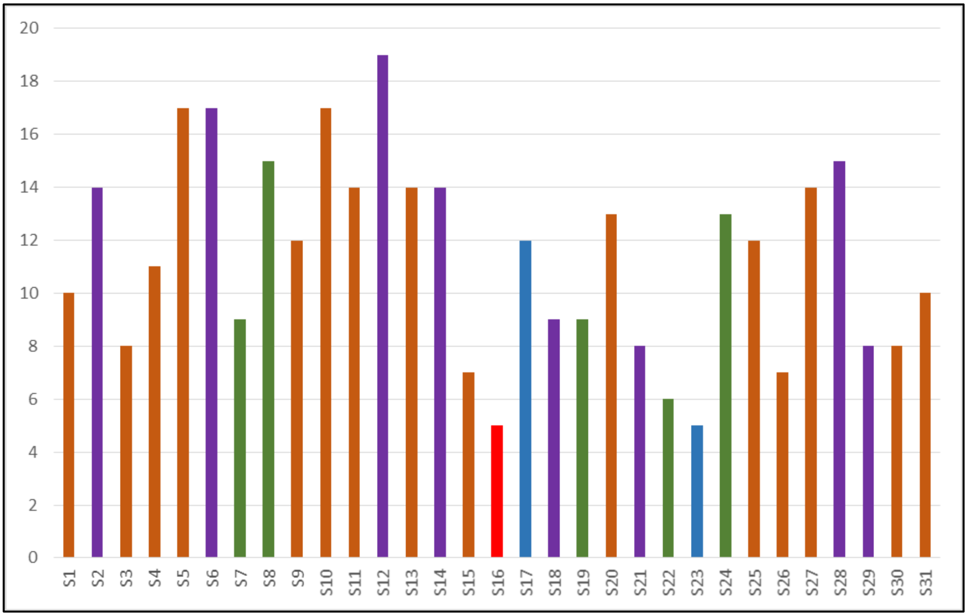

Figure 1. Diversity of lignicolous fungi depending on sample plot and degree of decomposition of dead wood (class I – blue, II – green, III – violet, IV – orange and V – red)

Trunks in different degrees of decomposition and which come from different tree species can provide a different quality of substrate, sustaining different fungal communities. The number of logs per individual decomposition class was as follows: class I – 2 logs, II – 5 logs, III – 8 logs, IV – 15 logs and V – 1 log. Differences regarding the number of fungal species depending on the degree of decomposition of trunks were also recorded. Thus, on trunks in stage IV of decomposition were identified 17 species of lignicolous fungi each (among the most frequent species there were *Bjerkandera adusta*, *Exidia glandulosa*, *Pluteus cervinus*, *Trametes pubescens*, *Fomes fomentarius*, etc.). The total and average richness of wood-inhabiting fungi taxa on trunks in stage V of decomposition as well as on those in stages I and II of decomposition was lower compared to trunks in stage IV of decomposition (Figure 1).

In both clustering procedure (Figure 2) and detrended correspondence analysis (Figure 3) two major groups of lignicolous fungi can be observed, depending on the decomposition stage of the studied trunks, on the degree of bark coverage, on the forest canopy cover and the area of contact with the soil of trunks. Some fungi species were more common (e.g. *Fomes* sp., *Trametes* sp. and *Stereum* sp., etc.) in the early stages of wood decay, while in the advanced decomposition stages, species of *Mycena*, *Hypholoma* and corticioide species were more frequent. These differences in respect to wood properties and characteristics favor the existence of different microhabitats, with a higher species richness and specialization of wood fungal communities. In addition, a higher degree of insolation due to some gaps in forest canopy can inhibit fungal species development and favor a richer herbaceous layer. Wood degradation is also influenced by the tree species and the fungal species that initially colonize the log. This process is mediated by multiple biotic interactions and environmental factors [MÜLLER-USING & BARTSCH, 2009].

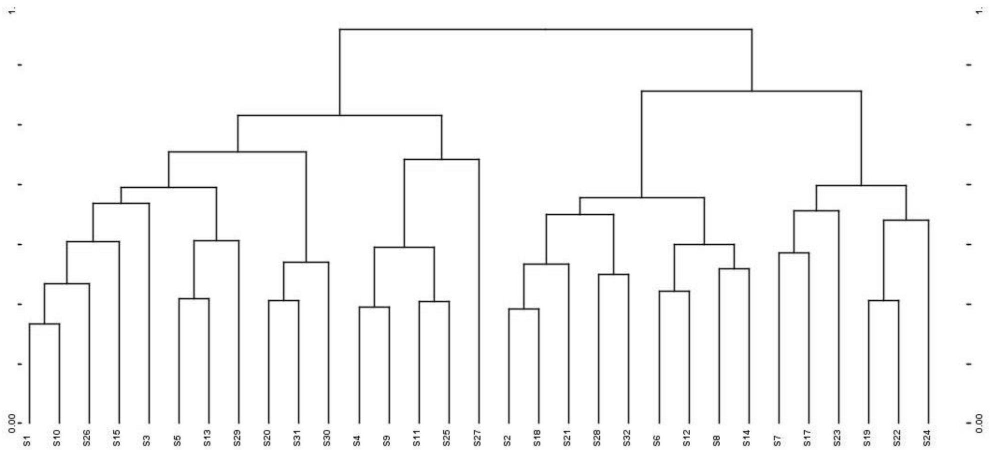

Figure 2. Dendrogram showing the results of the cluster analysis of the 32 trunks based on the Flexible β and Bray-Curtis distance.

Dead woody debris of different sizes, abundantly present in protected forest areas, is a determining factor for the biodiversity of lignocellulosic fungi by providing a wide range of niches. A higher variability of trunks, branches or small woody debris tends to provide more favorable conditions for the establishment of different species-rich lignocellulosic fungal communities [HEILMANN-CLAUSEN & CHRISTENSEN, 2003; HEILMANN-CLAUSEN & CHRISTENSEN, 2004; KÜFFER & al. 2004; KÜFFER & SENN-IRLET, 2005]. The beech forests in protected natural areas harbor numerous fungal species in their mycobiota, some of them rare in Western Europe due to high anthropogenic pressures, such as *Hericium* sp. Species that develop on old and well-rotted trunks, in advanced stages of decomposition, such as *Volvariella bombycina*, are particularly sensitive to forest management activities [TĂNASE & POP, 2005]. Moreover, numerous wood-inhabiting fungi are indicator species for the conditions in old-growth forests, the availability of dead wood, as well as for conservation value of beech forests. Species such as *Hericium coralloides* or *Volvariella bombycina* often signal long-term ecological continuity.

Cluster 1 – this group includes fungal species that prefer wood in advanced stages of decay (stages III-IV), the trunks have a high degree of contact with the ground, and a low degree of bark cover. These trunks are located under trees that provide a high degree of shade. The species significantly associated are: *Mucidula mucida* (0.696*), *Pleurotus cornucopiae* (0.683**), *Trametes pubescens* (0.632**), *Hypoxylon fragiforme* (0.577*), *Nectria cinnabarina* (0.577*), *Chondrostereum purpureum* (0.516*) - (*$p < 0.05$; **$p < 0.01$). In this group of wood-inhabiting fungi, are highlighted the species preferring substratum in IV degree of decomposition. In addition, due to the higher degree of canopy cover and the high contact of the logs with the soil, the humidity conditions are maintained for a longer time, favoring the development of the fungi.

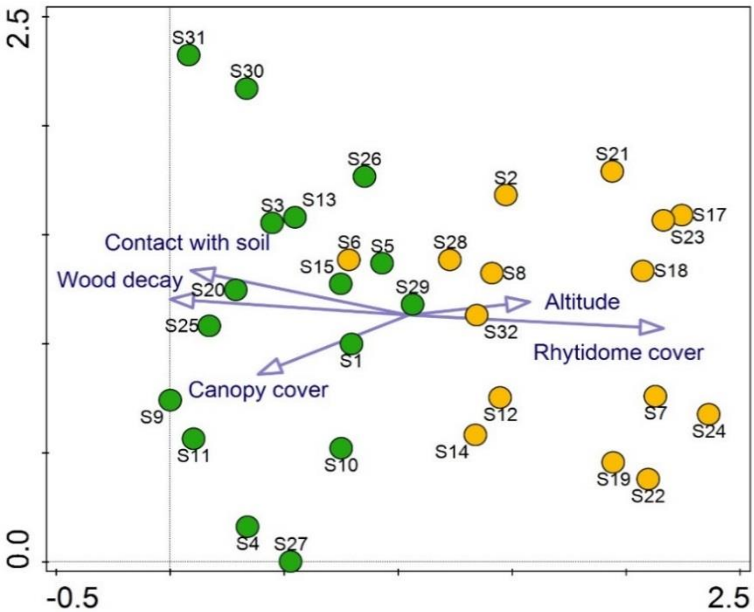

Figure 3. DCA ordination diagram of the 32 investigated plots. Only first two axes are presented. Explained variation: 44.1%. Eigenvalues: Axis 1 – 0.412, Axis 2 – 0.223. Fungal assemblages resulted from hierarchical clustering are: cluster 1 – green circles, cluster 2 – yellow circles.

Cluster 2 – this group includes species of fungi that prefer to colonize trunks in an incipient state of decomposition (stages I-II-III), with more or less intact rhytidome, reduced contact with the soil, and located in areas of the forest more exposed to solar radiation. The species significantly associated are: *Legaliana badia* (0.707**), *Hymenopellis radicata* (0.707**), *Hypholoma lateririum* (0.688*), *Calycina citrina* (0.612*), *Meripilus giganteus* (0.559*) - (*$p < 0.05$; **$p < 0.01$). In the second group it is highlighted the presence of fungi colonizing trunks in early decay stages, trunks broken by mechanical factors, etc. Richness of fungal species is low compared to the first cluster. Also, due to the occurrence of gaps in the forest canopy, the degree of isolation is higher and the number of fungi species per sampled plot was lower.

Conclusions

In beech forests, the wood-inhabiting fungi play an essential role by recycling nutrients, stimulating wood decomposition, supporting biodiversity, influencing carbon storage, shaping forest structure and regeneration, and serving as ecological indicators. In the Tătăruși Forest Reserve were identified numerous lignicolous fungi species developed on beech trunks, with the highest richness on trunks characterized by high wood decay and with higher contact with soil, distributed in shaded places. The lignicolous macromycetes were separated into two groups mainly depending on the degree of substrate decomposition. This contribution improves the knowledge of this group of organisms in studied area, because wood-inhabiting fungi were insufficiently considered in the biodiversity studies carried out in this forest reserve.

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