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The macrofungal diversity and its potential from the karst forest of Kalipoh Village, Kebumen District, Indonesia

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Abstract. *Armadhan WS, Sari SP, Aji MYMB, Permatasari DP, Amalia BW, Berlin GE, Aszar AS, Indrawan M, Pradhan P, Setyawan AD. 2023. The macrofungal diversity and its potential from the karst forest of Kalipoh Village, Kebumen District, Indonesia. Intl J Trop Drylands 7: 99-106.* Indonesia is one of the world's most biodiverse countries, with fungi being one of its most diverse groups of organisms. Many fungi species have been identified and have potential benefits for both living things and the environment. Kalipoh Village Forest, located in the karst area of Ayah Sub-district, Kebumen District, Central Java, Indonesia, offers suitable environmental conditions that provide habitat for various species of fungi. The objective of this study was to determine the diversity and potential use of macrofungi in Kalipoh Village Forest. Data collection was carried out using the survey method, where every encountered fungus was observed and its cap, gills, stalk, color, odor, substrate, and growth habits were recorded. Macrofungal diversity was calculated using the Shannon-Wiener Diversity Index, Simpson's Diversity Index, Richness Index, and Evenness Index Formula. The exploration results obtained 34 species of macrofungi from 22 genera and 18 families, with most of the species found on weathered logs and leaf litter. Two genera, namely *Marasmius* and *Marasmiellus*, were quite common. Based on the index value calculation, the diversity of macrofungi in this area was in the medium category (H'=2.695). It had a high index of richness (R=5.252) and evenness (E=0.764). The high evenness of the species indicates lower dominance, which can also be observed from the results of the high Simpson's Diversity Index value (0.910). A total of 24 species of macrofungi were known to have the potential as food and medicine.

Keywords: Evenness, Kalipoh Village forest, mushrooms, richness, survey

INTRODUCTION

Indonesia has the highest biodiversity in the world, following Brazil. This fact has significant implications for global climate, as well as human health and welfare (Rintelen et al. 2017). One of the many biodiverse groups found in Indonesia is fungi. Fungi are eukaryotic microorganisms that lack chlorophyll and rely on spores for their transmission. These spores may take the form of single cells (unicellular) that then grow into filamentous or branched structures. Fungi are heterotrophic organisms, among which macrofungi or mushrooms produce large basidiomas (fruiting bodies) that make them easy to locate without specialized tools (Dutta et al. 2011a,b,c; Pradhan et al. 2011; Putra and Astuti 2021). However, some fungi produce small fruiting bodies, known as microscopic fungi, that require special tools for detection of their physical form (Ramadianty et al. 2022). The heterotrophic nature of fungi causes these organisms to be highly dependent on the surrounding environmental conditions. Environmental factors such as temperature, pH, humidity, and light intensity greatly affect the growth of fungi. Fungal habitat is usually moist, such as litter or dead logs, where they can grow either in groups or individually. Fungi are classified into five major groups: Ascomycota, Basidiomycota, Chytridiomycota, Glomeromycota, and Zygomycota (Hibbett et al. 2007).

The global number of fungi has been estimated to be around 1.5 million, of which approximately 300 species are known to have the potential to cause disease in humans (Putra and Hermawan 2021). Fungi are important indicators of environmental health in ecosystems, and they also have potential medicinal, food, and other uses that have yet to be fully explored (Paloi et al. 2016; Mayasari et al. 2018). In forest ecosystems, fungi play an important role in the decomposing organic matter alongside with bacteria and protozoa, thus accelerating the recycling of materials (Situmorang et al. 2019). However, several species of fungi are also pathogenic to humans and attack various organ systems, especially the skin and respiratory system, causing various signs and symptoms of disease (Faturrachman and Mulyana 2019).

Karst is a unique landscape formed by the dissolution of easily soluble rocks such as limestone, resulting in distinctive hole-shaped landforms due to weathering of rock by water (Pertiwi et al. 2020). The karst terrain is characterized by numerous passages and caves that can be found at the bottom of the land due to carbonate dissolving process (Kalhor et al. 2019). The soil in karst areas is typically infertile and barren due to the rock's secondary porosity characteristics and easy solubility (Wisnuaji and Pamungkas 2022). Rainwater flows into the rock, not being accommodated for long periods, and is channeled directly into the aisle before flowing out into springs. This feature makes it challenging to find water on the karst's surface area, but high-quality water resources are available at the bottom of the surface due to runoff water being stored beneath the surface of the karst land.

Indonesia has quite extensive karst land, estimated at approximately 15.4 million hectares (Has and Sulistiawaty 2018). One such karst area is located in Kebumen District, Central Java, which is locally known as the South Gombong Karst Area (KKGS). This area encompasses an area of approximately 8 km (north to south) with a width of 3 km, spanning three sub-districts in Kebumen District, including Ayah, Buayan, and Rowokele. The South Gombong Karst Area is characterized by numerous caves and karst forests, including one in Kalipoh Village.

The objective of this study is to determine the diversity of macrofungi and their potential use in the karst forest of Kalipoh Village, Ayah, Kebumen, Indonesia. The choice of the karst forest area in Kalipoh Village was based on its dense cover canopy and diverse vegetation. Besides, the region is dominated by teak trees, which promote the growth of various fungal species due to the teak leaf litter serving as organic material for fungal growth (A'yun et al. 2022).

MATERIALS AND METHODS

Study area

Data collection was carried out in November 2022, in the karst forest of Kalipoh Village, Ayah Sub-district, Kebumen District, Central Java Province, Indonesia (Figure 1). Kalipoh Village is a natural habitat forkarst forests that host a various biodiversity components. This karst forest is a part of the South Gombong Karst Area (KKGS) and is situated at an altitude of 101.3 m asl, not far from the coast. The location of this karst forest is quite distant from residential areas, which allows the forest environment to remain undisturbed and retain its natural beauty. Despite being a karst area, this forest has various types of vegetation, with teak trees dominating the region (Suhendar et al. 2018).

Procedures

Research methods

The research was conducted using the survey method by exploring all accessible forest areas (Lingga et al. 2019). Thismethod is considered more effective for observing and collecting data that are not evenly distributed in large forest areas (Arif and Al-Banna 2020). The exploration was conducted based on the direction of cruising, which is adjusted to the direction of the route (Pardosi et al. 2019).

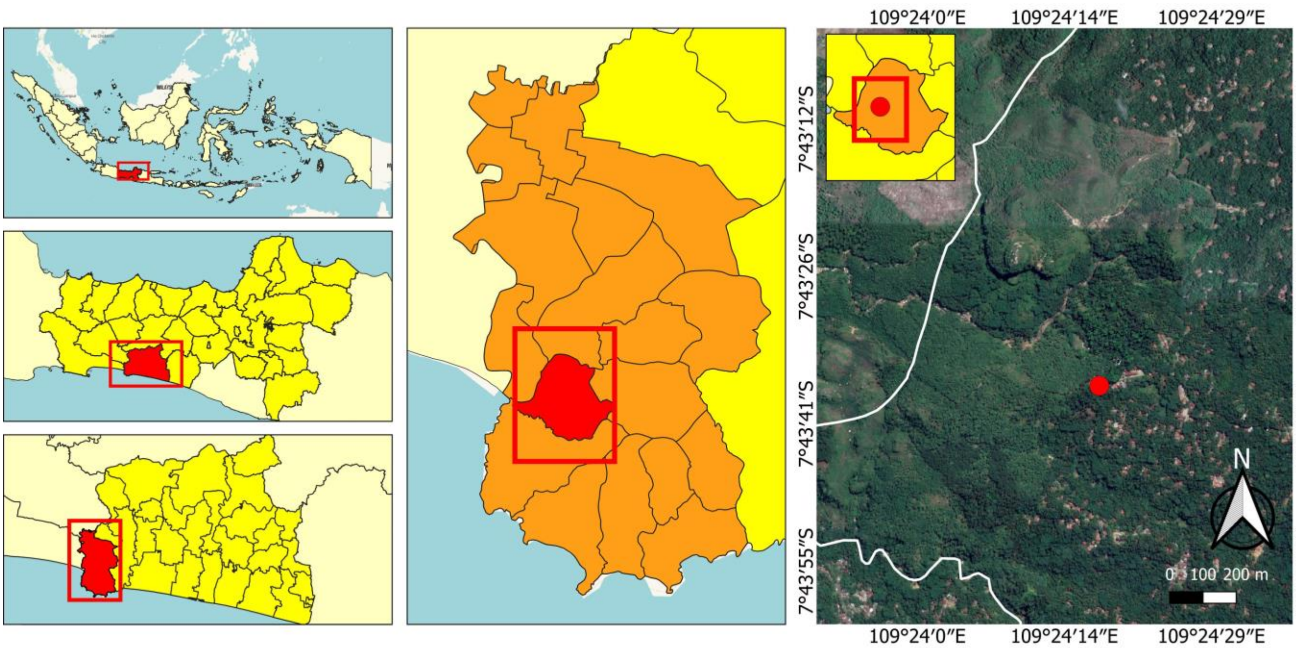

Figure 1. Map of data collection locations in Kalipoh Village Forest, Ayah, Kebumen, Central Java, Indonesia

Data collections

The macrofungi studied were observed for the cap (pileus), gills (lamellae), stalk (stipe), substrate, growth habit, and other information such as the color and smell of the fungi (Aqilah et al. 2020). The characteristics of the specimens were recorded and documented after observation. If the condition of the specimen was in good condition, spore prints were made to determine the color of the spore print. The abiotic factors, including temperature, pH, humidity, light intensity, and wind speed were measured, as they affect the development and growth of fungi (Nasution et al. 2018; Wati et al. 2019).

Identification

Macrofungal specimens were characterized according to standard procedures outlined by Largent et al. (1977). Their identification were carried out based on literature studies using books, monographs, journals, and websites. Suryani and Cahyanto (2022) was followed for identification of fungal species, and the names of fungal species were validated based on references to www.indexfungorum.org (Redhead and Norvell 2012).

Data analysis

According to Rozak et al. (2020), the diversity of fungi can be assessed using two indices: the Shannon-Wiener Diversity Index (1963) and Simpson's Diversity Index (1949). The Shannon-Wiener index (H') can be calculated using the formula $H' = -\sum(ni/N) \ln (ni/N)$, where ni is the number of individuals of the ith species, N is the total number of individuals, and ln is the natural logarithm. The value of H' ranges from 1.5 to 3.5 and rarely exceeds 4, with a higher value indicating a higher diversity. Simpson's Diversity Index (D) can be calculated using the formula $D= 1-\sum(ni/N)^2$, where ni is the number of individuals of the ith species, N is the total number of individuals, and $\sum$ is the sum. The value of D ranges from 0 to 1, with a value of 0 indicating a homogeneous community and a value of 1 indicating high diversity. The richness of fungal species can be calculated using the formula $R= (S-1)/\ln N$, where S is the total number of species and ln is the natural logarithm. The value of R ranges from 2.5 to 4. The evenness of fungal species can be calculated using the formula $E= \sum(H'/\ln S)$, where $\sum$ is the sum, H' is the Shannon-Wiener index, and S is the total number of species. Evenness index values range from 0 to 1.

RESULTS AND DISCUSSION

Macrofungi found in the karst forest of Kalipoh Village, Kebumen

The exploration of macrofungi in Kalipoh Village Forest yielded 34 species from 22 genera and 18 families, with the majority of specimens belonging to Basidiomycota. Two species were identified from the Ascomycota, namely *Exidia* sp. and *Xylaria* sp. Among the families, the Marasmiaceae, Omphalotaceae, and Polyporaceae exhibited the highest species diversity, with six, seven, and four species, respectively (Figure 2).

Based on the data presented in Table 1, the most commonly found macrofungi belong to the genera *Marasmius* and *Marasmiellus* (Marasmioid fungi). These fungi are typically found in the leaf litter on the forest floor and have good adaptability to changing environmental conditions (Kuo 2013). Figure 3 indicates that the majority of the fungi were found on substrate such as rotten wood, dead tree trunks, and litter. This may be due to the fact that logging activities had left many logs in the forest, and the teak leaf litter was observed to be in the stage of decomposition.

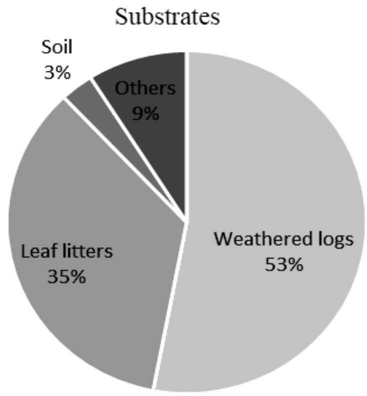

Figure 3. Variation of macrofungal substrates found in Kalipoh Village Forest, Ayah, Kebumen, Central Java, Indonesia

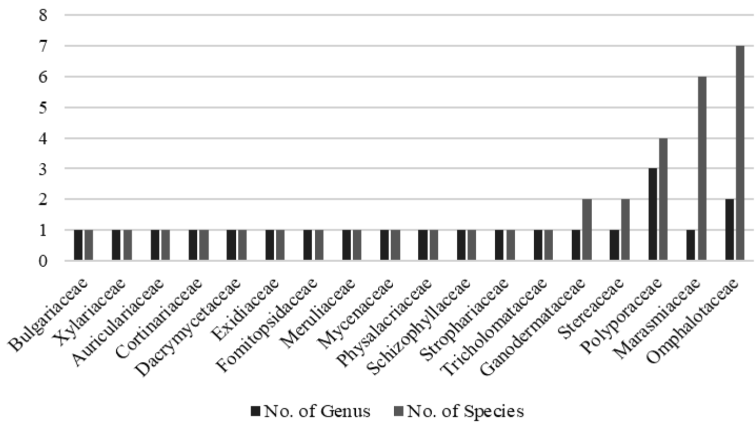

Figure 2. The composition of the genus and species of macrofungi obtained from each family

Table 1. Macrofungi found in the karst forest of Kalipoh Village, Ayah, Kebumen, Indonesia

Phylum	Family	Species	Substrates
Ascomycota	Bulgariaceae	*Bulgaria* sp.	Weathered logs
Ascomycota	Xylariaceae	*Xylaria* sp.	Weathered logs
Basidiomycota	Auriculariaceae	*Auricularia polytricha* (Mont.) Sacc.	Weathered logs
Basidiomycota	Cortinariaceae	*Cortinarius* sp.	Weathered logs
Basidiomycota	Dacrymycetaceae	*Dacryopinax spathularia* (Schwein.) Alvarenga	Weathered logs
Basidiomycota	Exidiaceae	*Exidia* sp.	Weathered logs
Basidiomycota	Fomitopsidaceae	*Fomitopsis* sp.	Weathered logs
Basidiomycota	Ganodermataceae	*Ganoderma lucidum* (Curtis) P. Karst.	Weathered logs
Basidiomycota	Ganodermataceae	*Ganoderma* sp.	Weathered logs
Basidiomycota	Marasmiaceae	*Marasmius delectans* Morgan	Weathered logs
Basidiomycota	Marasmiaceae	*Marasmius elegans* (Cleland) Grgur.	Dry grass
Basidiomycota	Marasmiaceae	*Marasmius haematocephalus* (Mont.) Fr.	Leaf litters
Basidiomycota	Marasmiaceae	*Marasmius siccus* (Schwein.) Fr.	Leaf litter, dry grass
Basidiomycota	Marasmiaceae	*Marasmius* sp. 1	Leaf litters
Basidiomycota	Marasmiaceae	*Marasmius* sp. 2	Soil
Basidiomycota	Meruliaceae	*Ceriporiopsis* sp.	Weathered logs
Basidiomycota	Mycenaceae	*Mycena chlorophos* (Berk. & M.A. Curtis) Sacc.	Weathered logs
Basidiomycota	Omphalotaceae	*Gymnopus dryophilus* (Bull.) Murrill	Weathered logs
Basidiomycota	Omphalotaceae	*Gymnopus* sp.	Weathered logs
Basidiomycota	Omphalotaceae	*Marasmiellus candidus* (Fr.) Singer	Weathered logs
Basidiomycota	Omphalotaceae	*Marasmiellus ramealis* (Bull.) Singer	Dry grass
Basidiomycota	Omphalotaceae	*Marasmiellus reniformis* Retn.	Leaf litters
Basidiomycota	Omphalotaceae	*Marasmiellus* sp. 1	Weathered logs
Basidiomycota	Omphalotaceae	*Marasmiellus* sp. 2	Leaf litters
Basidiomycota	Physalacriaceae	*Rhizomarasmius setosus* (Sowerby) Antonin & A. Urb	Leaf litters
Basidiomycota	Polyporaceae	*Polyporus arcularius* (Batch) Fr.	Weathered logs
Basidiomycota	Polyporaceae	*Pycnoporus* sp.	Weathered logs
Basidiomycota	Polyporaceae	*Trametes* sp. 1	Weathered logs
Basidiomycota	Polyporaceae	*Trametes* sp. 2	Weathered logs
Basidiomycota	Schizophyllaceae	*Schizophyllum commune* Fr.	Weathered logs
Basidiomycota	Stereaceae	*Stereum ostrea* (Blume & T. Nees) Fr.	Live plant stems
Basidiomycota	Stereaceae	*Stereum* sp.	Weathered logs
Basidiomycota	Strophariaceae	*Pholiota* sp.	Weathered logs
Basidiomycota	Tricholomataceae	*Collybia* sp.	Weathered logs

Table 2. Results of measurements of abiotic factors in Kalipoh Village Forest, Ayah, Kebumen, Indonesia

Parameter	Average
Soil temperature (˚C)	35,67
Soil pH	7.0
Soil moisture (RH)	5,67
Air temperature (˚C)	29,4
Humidity (%)	85.5
Light intensity (lux)	664x10A 20000
Wind speed (m/s)	0.4
Altitude (masl)	100.33

Table 3. The results of the calculation of the Shannon-Wiener Diversity Index, Simpson's Diversity Index, Richness Index, and evenness index

Calculated index	Index value	Category
Shannon-Wiener Diversity Index (H')	2,695	Moderate
Simpson's Diversity Index (D)	0.910	High
Richness Index (R)	5,252	High
Evenness index (E)	0.764	High

Macrofungal diversity in Kalipoh Village Forest, Ayah, Kebumen

The Kalipoh Village Forest is a biodiverse location for fungi, supported by abiotic factors that facilitate fungal growth in the forest environment (Table 2). The soil pH in the forest is around 7, which falls within the optimum pH range (4.5 to 8) for fungal growth (Noerhandayani et al. 2022). The high humidity in the air and soil, with an average of 85.5% and 5.67, respectively, further promotes fungal growth in the karst forest of Kalipoh Village. High light intensity inhibits fungal growth, while low light intensity encourages fungal growth (Noverita et al. 2019). The light intensity in the forest area is 664x10 lux, which is not too high due to the dense vegetation cover from teak and other plants. The litter from the existing vegetation serves as a substrate for fungal growth, contributing to the high fungal species diversity found in the area (Figure 4).

The Shannon-Wiener Diversity Index indicates that the Kalipoh Village forest has a moderate level of species diversity (H'=2.695), which can be attributed to the presence of a high number of fungal species in the area. Additionally, the forest has a high species richness (R=5.252) and good evenness (E=0.764). The Simpson's Diversity Index also suggests a high level of diversity

(D=0.910), which can be attributed to a balanced distribution of individuals among different species in the area (Table 3). These results are supported by the favorable biotic and abiotic conditions in the forest that facilitate fungal growth. According to Rahmawati et al. (2018), the biotic and abiotic factors significantly influence the growth and survival of fungi. Niem and Baldovino (2015) reported the presence of fungi from the phyla Ascomycota and Basidiomycota in the CURCC karst area, which is consistent with the phyla found in the karst forest of Kalipoh Village. However, the species diversity in the two locations differs due to differences in the biotic and abiotic factors that affect fungal growth.

Potential use of macrofungi found in Kalipoh Village Forest, Ayah, Kebumen

The study of fungi in Kalipoh Village forest identified a total of 34 species, of which 23 have been analyzed for their potential applications, including use as food, medicine, for ecological and environmental purposes, and toxicity. However, 11 species have yet to be assessed for their potential uses (Table 4).

Potential as a food

Fungi are a biological resourcewith potential as food due to their high protein and nutritional content, as well as the presence of compounds such as polysaccharides (glycans), triterpenoids, nucleotides, mannitol, and alkaloids (Bahar et al. 2022). Certain fungal species found in Kalipoh karst forests, including *A. polytricha*, *M. ramealis*, *Marasmiellus* sp., and *S. commune*, have potential as food sources (De Kesel et al. 2008; Noverita et al. 2016; Noverita et al. 2019; Nurlita et al. 2021). Among these, *A. polytricha*, commonly known as black ear fungus and belonging to the Heterobasidiomycetes class, is often used in Chinese cuisine. Its distinctive ear-like shape and dark brown color make it a popular ingredient in food preparations. Cultivation of this fungus can be carried out for use as a food source or as a mixture of food ingredients.

Table 4. Potential use of macrofungi found in Kalipoh Village forest, Ayah, Kebumen, Indonesia

Species	Food	Medicine	Poisonous	Unknown	References
Exidia sp.				✓	-
Xylaria sp.		✓			Fauzi et al. 2018
Auricularia polytricha	✓				De Kesel et al. 2008
Bulgaria sp.				✓	-
Cortinarius sp.		✓			Putra 2020
Dacryopinax spathularia	✓				Bitzer et al. 2017
Fomitopsis sp.		✓			Muszyńska et al. 2020
Marasmius delectans		✓			Fauzi et al. 2018
Marasmius elegans				✓	-
Marasmius haematocephalus				✓	-
Marasmius siccus				✓	-
Marasmius sp. 1				✓	-
Marasmius sp. 2				✓	-
Ceriporiopsis sp.	✓				
Mycenae chlorophos		✓			Fauzi et al. 2018
Collybia sp.	✓				Mahardhika et al. 2021
Gymnopus dryophilus			✓		Suryani and Cahyanto 2022
Gymnopus sp.			✓		Suharjo 2007
Marasmiellus candidus				✓	-
Marasmiellus ramealis	✓				Noverita et al. 2016
Marasmiellus reniformis				✓	-
Marasmiellus sp. 1	✓				Noverita et al. 2019
Marasmiellus sp. 2	✓				Noverita et al. 2019
Rhizomarasmius setosus				✓	-
Ganoderma lucidum		✓			Sudarwati and Fernanda 2021
Ganoderma sp.		✓			Noverita et al. 2016
Polyporus arcularius		✓			Fauzi et al. 2018
Pycnoporus sp.				✓	-
Trametes sp. 1		✓			Fauzi et al. 2018
Trametes sp. 2		✓			Fauzi et al. 2018
Schizophyllum commune	✓				Nurlita et al. 2021
Stereum ostrea		✓			Akata 2020
Stereum sp.				✓	-
Pholiota sp.				✓	-

Figure 4. Kalipoh Village Karst Forest, Ayah, Kebumen, Central Java, Indonesia

Potential as a medicine

Macrofungi are valuable sources of pharmacologically active ingredients, and their use as medicine provides a wide range of benefits, such as antibacterial and antioxidant properties. Several species of fungi have potential as medicine, including *Cortinarius* sp., *D. spathularia*, *Fomitopsis* sp., *G. lucidum*, *Ganoderma* sp., *M. candidus*, *M. delectans*, *M. chlorophos*, *P. arcularius*, *S. ostrea*, *Trametes* sp., and *Xylaria* sp. While some of these fungi are known to contain specific drugs, others have yet to be fully characterized. For instance, *Cortinarius* sp. has exhibited antibacterial and anticancer properties; *D. spathularia* contains bioactive compounds with potential antibacterial properties; *G. lucidum* contains polysaccharides and proteins and is used as an antimicrobial; *Ganoderma* sp. contains Ganoderic acid, which can neutralize and reduce compounds that cause various diseases; *M. delectans* has demonstrated both antibacterial and antioxidant effects; *M. chlorophos* is an antimicrobial agent; *P. arcularius* exhibits antibacterial and antifungal activity; *Trametes* sp. has antioxidant properties, and *Xylaria* sp. is an antibacterial agent (Fauzi et al. 2018; Kumar et al. 2019; Putra 2020; Qi et al. 2021; Sudarwati and Fernanda 2021).

Poisonous fungi

This study has identified *G. dryophilus*, a poisonous and inedible fungus due to its tough texture that makes it unsuitable for human consumption and harmful to health (Suryani and Cahyanto 2022). Additionally, the fungus has the ability to accumulate Cadmium (Cd) compounds from the soil, which, if ingested, can lead to adverse health effects in humans, such as chronic kidney failure and increased risk of cancer (Yamaç et al. 2007; Wulandari et al. 2021).

Potential for ecology or environment

From an ecological perspective, macrofungi play a crucial role in maintaining ecosystems by improving soil fertility and overall environmental conditions. Certain fungal species, such as *Ceriporiopsis* sp., *Collybia* sp., and *Pholiota* sp., have demonstrated significant potential for improving ecological and environmental health. For instance, *Ceriporiopsis* sp. produces enzymes like lignin peroxidase, manganese peroxidase, and laccase, which have been utilized in waste treatment and bioethanol production (Sari et al. 2016). *Collybia* sp. is known for its ability to decompose litter effectively (Putra et al. 2018). Similarly, *Pholiota* sp. has been found to contain enzymes capable of decolorizing the color components in textile industry waste (Hadi et al. 2020), thereby reducing environmental pollution.

Fungi with undiscovered potential

In this study, there were several species of macrofungi, including *Bulgaria* sp., *Exidia* sp., *M. reniformis*, *M. elegans*, *M. haematocephallus*, *M. siccus*, *Marasmius* sp., *Pycnoporus* sp., *R. setosus*, and *Stereum* sp., whose potential is not known yet, hence further research is needed to determine the potential of these species.

This study concludes that the Kalipoh Village forest in Ayah, Kebumen provides good biotic and abiotic conditions for macrofungal growth. Based on the diversity index values, the area has moderate diversity, good richness, and evenness. Macrofungi in this area commonly inhabit dead tree trunks and litter. Of the 34 species identified, 24 have known potential while the remaining 10 species require further study. Some species were known to have potential benefits such as food, medicine, poisonous, and environmental stability, while other were known to be toxic to living things. Consequently, caution is advised when dealing with unknown macrofungi.

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