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Diversity, Abundance, and Distribution of Ectomycorrhizal Fungi in Rajo Lelo Forest Park (Tahura), Central Bengkulu Regency

Guswarni Anwar[1]*, Izzatul Jannah[1], Risky Hadi Wibowo[2], Parwito[3]
[1]Department of Forestry, Faculty of Agriculture, University of Bengkulu, Indonesia
[2]Department of Biology, Faculty of Mathematics and Natural Science, University of Bengkulu, Bnegkulu, Indonesia
[3]Departement of Agrotechnology, Faculty of Agriculture, Ratu Samban University, North Bengkulu, Bengkulu, Indonesia
*Corresponding author: ganwar@unib.ac.id

ABSTRACT. Rajo Lelo Forest Park (TAHURA) is located in Tanjung Terdana Village, Pondok Kelapa District, Central Bengkulu Regency. This forest area is overgrown with various trees, including ectomycorrhizal host trees. A purposive sampling plot method was used on each found fungus to determine ectomycorrhizal species' diversity, abundance, and distribution. Five plots were used, each measuring 20 cm by 20 cm. The data collected from these plots revealed important information about the forest's ecological dynamics. We examined the samples to determine the types of ectomycorrhizal species and how they aided tree health and forest biodiversity. Fungi found in the plot were identified morphologically by comparing morphological characters to references. According to the results of the analysis, there are 118 individual fungi from nine species and seven families. The species diversity index is classified as moderate, at 1.61. *Clitopilus* sp. is 33.05% more abundant than any other ectomycorrhizal fungus. However, there are 0.85% fewer species of *Scleroderma* sp., *Lactarius* sp., and *Macrolepiota* sp. than any other species. The distribution index of ectomycorrhizal fungi in Rajo Lelo Forest Park is 1.34, placing them in the clustering category.

Keywords : *Forest park, ectomycorrhiza, diversity index, abundance, distribution index*

INTRODUCTION

The relationships between trees and fungi, especially ectomycorrhizal fungi, in tropical forests demonstrate significant diversity and specialization (Traveset & Richardson, 2014; Valverde-Barrantes, 2017; Terhonen et al., 2019). Ectomycorrhizal fungi are primarily found in most tropical and temperate soils due to specific plant groups forming symbiotic relationships with the fungi during their growth. Rainforests are more susceptible to ectomycorrhizal infections than arid climates ((Bellgard & Williams, 2011; Cardoso et al., 2017; Bernreiter & Teijeir, 2022). Numerous tropical tree species have adapted to rely on it for protection against pathogens. The significance of ectomycorrhizal associations in the distribution of tree plantations is well established (Smith & Read, 2008; Cardoso et al., 2017); nonetheless, their function in tropical ecosystems necessitates additional investigation.

Numerous plant species, ranging from trees to diminutive shrubs, host mycorrhizal fungi in tropical forests (Policelli et al., 2020; Dauphin & Peter, 2023). Molina and Horton (2015) assert that certain ectomycorrhizal species develop on tree roots, categorizing them as specialists within specific ecosystem zones. Nonetheless, additional research indicates a correlation between mycorrhizal species variations and host plant distribution (Tedersoo et al., 2014; Bahram et al., 2015).

Moisture, soil pH, type of vegetation, and soil composition significantly affect the spatial distribution of ectomycorrhiza in tropical forests. Horner-Devine & Bohannan, 2006 Hoghberd & Myrold, 2007 Smith & Read, 2008 Lilleskov et al., 2011 (Zhao & Yang, 2016) showed that the slight acidity of soil encourages higher ectomycorrhizal diversity in its environment. Also, a higher concentration of mycorrhizal fungi was observed in forests with higher humidity, possibly due to improved conditions for growth and reproduction.

Previous studies have demonstrated that certain plant species preferentially associate with specific mycorrhizal species (Brearley, 2012; Graham & Plank, 2015; Veresoglou & Rillig, 2016; Bever et al., 2017; Li & Yang, 2020). Plants of the family Dipterocarpaceae appear to associate with Amanita spp. These species are recognized for aiding plants in enduring drought conditions. This aligns with the findings of Johnson et al. (2014): the interactions between plants and mycorrhizae fluctuate based on the host plant's needs and the mycorrhiza's capacity to supply those nutrients.

For this study, we investigated ectomycorrhizal species' types, numbers, and locations in Rajo Lelo Forest Park (TAHURA), Bengkulu. This TAHURA is a forest area that is naturally overgrown with various types of vegetation and trees, with some regions planted to increase the diversity of tree species. Although this is a conservation area, some areas have been encroached upon for coffee, oil palm cultivation, and illegal logging. This condition significantly impacts the ecosystem and vegetation diversity, including ectomycorrhiza.

MATERIALS AND METHODS

Sampling Site

Sampling was conducted at Rajo Lelo Forest Park, Tanjung Terdana Village, Pondok Kelapa District, Central Bengkulu Regency. Ectomycorrhizal fruiting bodies were identified morphologically in the Forestry Laboratory, while soil analysis was conducted at the Soil Science Laboratory, Faculty of Agriculture, Bengkulu University. Before sampling, a survey was conducted to determine the presence of ectomycorrhizal fungi and their host trees, which helped to determine plot placement. Furthermore, five 20m x 20m plots were placed around the TAHURA area based on the presence of ectomycorrhizal fungi and host trees. The maximum distance between plots in the area is 5 m, which can be adjusted depending on field conditions. Each plot was thoroughly sampled (census), and any fruiting bodies of ectomycorrhizal fungi found were photographed and identified. The sample was placed in a plastic bag and delivered to the laboratory for morphological analysis. Herbarium specimens of ectomycorrhizal fungi were also prepared in the laboratory. Soil from the rhizosphere of host trees and the fruiting bodies of ectomycorrhizal fungi was collected to a depth of 20 cm for pH and nutrient analyses. The soil samples were placed in plastic bags, labeled, and brought to the laboratory. The sampling site is shown in Figure 1.

Data collection

The data of morphological fruiting bodies of the ectomycorrhizal fungi required are:

1. Hood (cap, pileus): size, shape, color, surface, edge, suppleness and moisture/freedom.
2. Blades (gills, lamellae): color
3. Pores: color
4. Stem (stem, stipe): size, shape, color, surface, elasticity, stiffness, elasticity when broken and moisture/freedom.
5. Ring (annulus, cortina): presence or absence and shape.
6. Cup (volva): presence or absence and shape.
7. Odor: weak, strong/sharp.

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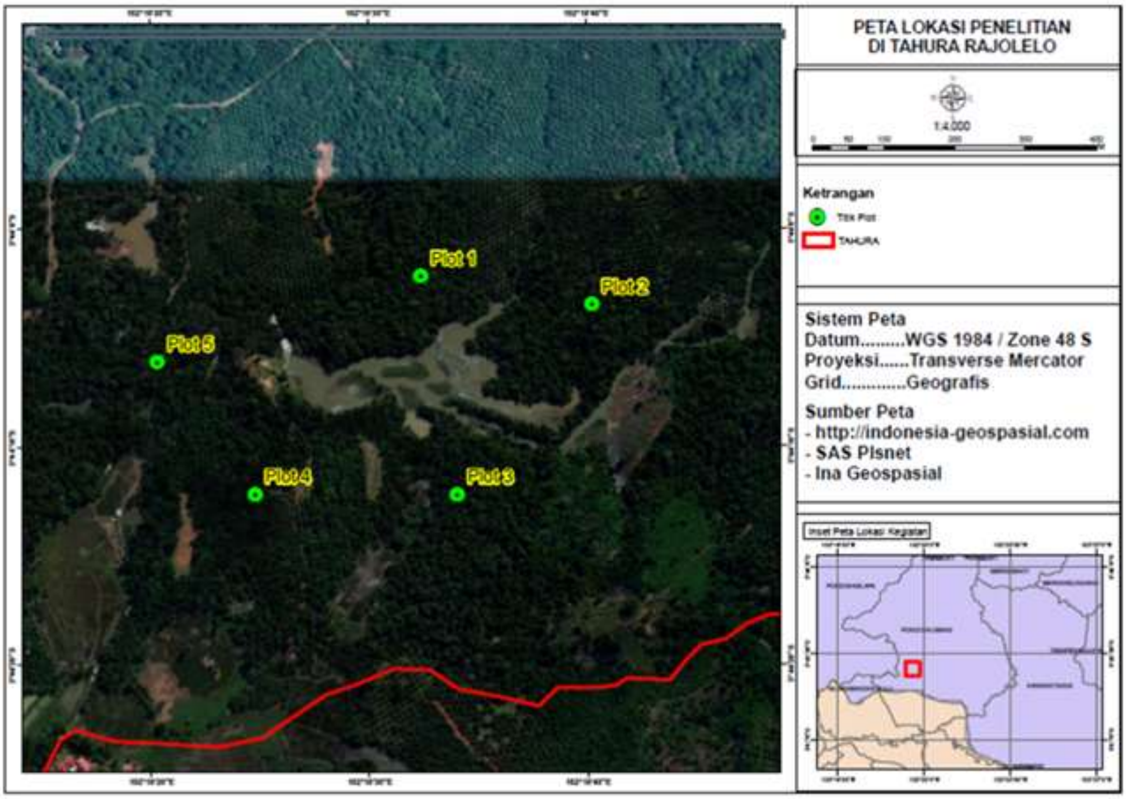

Figure 1. Location Sampling was conducted at Rajo Lelo Forest Park, Tanjung Terdana Village, Pondok Kelapa District, Central Bengkulu Regency.

Data analysis

The Shannon-Wiener Index was employed to analyze species diversity. Based on this formula, we evaluated species abundance using Simpson's Diversity Index. The species distribution was examined using the Morisita Index (Krebs, 2014).

RESULTS AND DISCUSSION

Rajo Lelo Forest Park (TAHURA) covers an area of 1,122 ha, according to Minister of Forestry No. 82/Kpts-II/1995. However, the UPTD TAHURA effectively manages 151 hectares. The TAHURA area has been extensively used for oil palm, coffee, and rice cultivation. As a result, only the eastern portion of the TAHURA area is still being used as a research site.

The Forest Park is a diverse forest area because it is overgrown with many plant species. In five plots were 15 trees associated with ectomycorrhizal fungi, each of which was a different species. However, in plots 1 and 2, mahogany trees were more strongly linked to ectomycorrhizal fungi. On the other hand, other plots were linked to *Senna siamea*, *Pterocarpus indicus*, and *Ficus* sp(banyan) tree species. The average diameter of the trees in the plots was 24.05 - 31.8 cm, and the average total height was 0.25641 - 10 m; all were in good health.

Ferns (Pteridophyta), taro (*Amydrium humble*), coffees (*Psychotria nervosa*), galangal (*Alpinia malacensis*), and bamboos (*Gigantochloa* spp.) make up the understory plants in all of the plots. Understory vegetation can influence environmental parameters, such as temperature and humidity, thereby impacting the growth of ectomycorrhizal fungi.

The association of trees with fungi, as well as climatic conditions and soils found at the research site, are the key factors determining growth patterns of ectomycorrhizal fungal fruiting bodies (truffles) development. For fungi to propagate, certain variables must be met: temperature, humidity, amount of light, and rainfall. As for the environmental conditions at the study site, it has a temperature ranging from 27.5 ^{o}C to 31.5^{o}C, relative humidity of 42.5% to 70%, and light intensity of 399 to 619 lux. The measurement outcomes of these variables remain suited for the proliferation of fungus. Temperature ranges between 22^{o}C and 35^{o}C, with the least humidity of 70%, which is the most favorable for fungal growth and sustaining optimum conditions (Deacon, 2006). A small percentage of the fungus can survive at a 65% humidity level, but the rate is very low.

The rainfall at the research location, obtained from BMKG Bengkulu Province, was moderate intensity. Ectomycorrhizal fungi are often found in high rainfall (Tedersoo & Nilsson, 2014; Lilleskov & Fahey, 2015). The research was conducted in January-February, which was at a low level, so the ectomycorrhizal fungi obtained were not too many.

One of the benefits of ectomycorrhizal fungi is to increase the absorption of nutrients that are good for plant growth so that the content of nutrients in the soil becomes one of the factors for developing ectomycorrhizal fungi. The results of nutrient measurements in the soil taken on each research plot are presented in Table 1.

Table1. Soil nutrient content

Plot	N (%)	P (ppm)	K (me/100)	C (%)	pH
1	0,33	0,82	0,24	4,66	4,77
2	0,37	0,85	0,23	5,73	5,01
3	0,37	0,99	0,17	5,37	4,85
4	0,30	0,76	0,30	4,14	5,58
5	0,51	0,17	0,28	6,71	5,16

Based on the assessment criteria for soil chemical properties, the value of carbon C is included in the high to very high category, namely 3.0-5.0 and >5.0; the P content in the soil is classified as very low, namely <8.0, for the N content in the soil is classified as medium, 0.2-0.5, and for the K content in the soil is classified as low to medium, namely 0.1-0.2 and 0.3-0.5. Likewise, the content of C value, the more soil contains high C value, the more mycorrhizal fungi. According to (Nurhalimah, 2014), the mycorrhizal fungi are also high in soil containing high N and P values. In addition to the C value content, the more soil contains C value, the more mycorrhizal fungi there are. The P content stimulates root growth, especially in young plants. Therefore, the colonization between ectomycorrhizal fungi and plants can increase the reach of plant roots to absorb other nutrients and water. The N element, which plays an important role in photosynthesis, increases the vegetative growth of plants.

Soil pH conditions can also affect the growth of ectomycorrhizal fungal fruiting bodies. The soil pH value obtained in the field is 4.77-5.58, which shows that the soil conditions are acidic. This is good for the growth of ectomycorrhizal fungi, which Feng & Zhang (2016) and Rousk & Baath (2017) stated as a suitable pH for fungal growth ranging from 5 to 7.5.

Based on the research results, the ectomycorrhizal fruiting bodies totaled 118 of 9 species and seven families, all belonging to the Basidiomycota phylum. The number of types

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of fungi found does not dominate; only the Agaricaceae and Russulaceae families are found the most, namely two types, and the rest have one type each. Every kind of fungus in one genus and one family has many similarities. Generally, fungi fruiting bodies live in groups but can also live solitarily.

Description of the ectomycorrhizal fungi found as follows:

1. *Hygrocybe* sp (Family: Hygrophoraceae

Figure 2. *Hygrocybe* sp

It has a reddish-orange smooth hood and a yellow stalk. It has a diameter of 1 cm and a height of 4.5 cm. Lives solitary but more often in small groups. Associated with mahogany (*Swietenia mahagoni*). Nineteen fruit bodies were found.

2. *Lepiota* sp. (Family: Agaricaceae)

Figure 3. *Lepiota* sp.

The white hood has a yellowish-brown center, uneven edges, and a creamy white stalk. This fungus has a diameter of 2-4 cm and a height of 3-5 cm. Six fruiting bodies were found associated with mahogany plants (*Swietenia mahagoni*).

3. *Mycena* sp. (Family: Mycenaceae)

Figure 4. *Mycena* sp

This fungus has a darker brown cap in the center and is slightly slimy. It lives in the soil solitarily. Its diameter is 3 cm and its height is 6 – 8 cm. Five fruiting bodies were found associated with mahogany trees (*Swietenia mahagoni*).

4. *Ramaria* sp. (Family: Gomphaceae)

Figure 5. *Ramaria* sp.

It is brownish and coral-like, branching from the base. The fungi are 7-9 cm tall and live solitary or in groups. Eight fruiting bodies were found among mahogany plants (Swietenia mahagoni).

5. *Scleroderma* sp. (Family: Scelerodermaceae)

It is a creamy yellow, and the fruiting bodies are spongy and unevenly rounded. It is about 2 to 4 cm across and 3.5 cm tall. Only one fruiting body was found connected to mahogany (Swietenia mahagoni).

Figure 6. *Scleroderma* sp.

6. *Russul*a sp. (Family: Russulaceae)

Figure 7. *Russul*a sp.

This fungus has a brown hood, and the cream-colored stalk is paler than the hood attached to the ground. This fungus is 6-10 cm in diameter and 8-9 cm in height. The lamellae are colored like the hood and have a slight odor. There were 38 fruiting bodies associated with Angsana (*Pterocarpus indicus*) plants

7. *Lactarius* sp. (Family: Russulaceae)

This fungus has a creamy yellow hood shaped like a funnel and a colored stalk-like hood. It has a 3-4 cm diameter and a 5-6 cm height. The lamellae are hood-like and tight. One fruiting body was found to be associated with *Cassia siamea* plants.

Figure 8. *Lactarius* sp.

8. *Macrolepiot*a sp. (Family: Agaricaeae)

Figure 9. *Macrolepiot*a sp

This fungus has a flat hood with white edges, a dark brown center, and a white stalk. It is 4-5 cm in diameter and 6-7 cm in height. The lamellae are black, have pungent odors, and have rings. Only one fruiting body was found associated with banyan trees (*Ficus benjamina* L),

9. *Clitopilus* sp. (Family:Entolomataceae)

Figure 10. *Clitopilus* sp.

This fungus has a flat hood, slightly concave in the center, white, and slightly wavy at the edges. It has a 3-4 cm diameter and a height of 4-5 cm.) 39 fruiting bodies were associated with banyan trees (*Ficus benjamina* L.).

Based on the morphological data, ectomycorrhizal fruiting bodies vary in stalk length, color, shape, and smell. Forest type and habitat significantly affect the diversity of ectomycorrhizal fruiting bodies in an area. This can occur due to differences in forest conditions such as the structure of forest **ecosystems**, forest age, plant species composition, climatic factors, decomposition of wood substrates, and so on (Chotima *et al*., 2020). The ectomycorrhizal fungi found at the research site were 118 fruiting bodies from 9 species and seven families. The species diversity obtained in this study is lower when compared to the results of Metriza's research (2021) conducted in the UNIB Education Forest (KHDTK) with a total of 18 species from 9 families with 107 fruiting bodies of ectomycorrhizal fungi. Meanwhile, Alamsjah (2016) found 16 species from 4 families of ectomycorrhizal fungi in the rhizosphere of plants in the UNAND Biology Education and Research Forest (HPPB). These differences can occur due to several factors, such as environmental factors, habitat conditions, and observation time.

The most number fungi found were *Clitopilus* sp 39 fruiting bodies and *Russula* sp 38 fruiting bodies. *Russula* sp was also found in Nanda's research (2021) in the rhizosphere of pine stands with 28 fruiting bodies of ectomycorrhizal fungi. According to Chotima et al. (2020), the Russula genus is easy to identify and find because the hood is usually brightly colored, so it is the most dominant when found. However, identifying *Russula* at the species level is quite tricky because it has a variety of shapes, sizes, hoods, stalks, lamellas, and colors.

Ectomycorrhizal fungi have several essential life roles, including food and decomposers. General characteristics of fungi that can be consumed include odorlessness, inconspicuous color, etc. Striking colors and pungent odors characterize toxic fungi (Annisa *et al.*, 2017). Two of the nine ectomycorrhizal fungi found can be used as food: Hygrocybe sp and *Mycena* sp. Other types are toxic fungi that cannot be consumed but can be utilized for soil fertility.

Diversity, Abundance, and Distribution of Ectomycorrhizal Fungi

The index value of the diversity of ectomycorrhizal fungi species is 1.61; in general, this value is included in the medium category. According to Zhang & Liu (2015) and Sun & Ma (2017), the low diversity of fungi species can be caused by one factor, namely abiotic factors, that can affect the spread and growth of fungi. Moderate diversity indicates a moderate distribution of the number of individuals of each type and moderate stability. This moderate level of species diversity occurs because of the unnatural conditions of the Rajo Lelo TAHURA area due to high human activities such as infrastructure development, ecotourism, and forest conversion into plantation land.

The result of calculating the distribution index of ectomycorrhizal fungi species obtained is 1.34. Based on the distribution index criteria value, if the value (Id> 1 = clustering distribution pattern), the distribution of ectomycorrhizal fungi species in TAHURA Rajo Lelo is included in the clustering category. This can be influenced by environmental conditions such as temperature, rainfall, light intensity, humidity, vegetation, and adaptability of fungi. According to Mardji (2010), ectomycorrhizal fungi can grow in groups, but some usually grow solitarily, in and on the soil's surface. Some competitors and predators can inhibit the growth and loss of fungal fruiting bodies.

The analysis results of abundance and relative types of ectomycorrhizal fungi have different values. Calculating abundance determines the number of individual types of fruiting bodies in the number of plots taken. The highest abundance types are *Russula* sp 32.20% and *Clitopilus* sp 33.05%, while the lowest abundance types are *Scleroderma* sp, *Lactarius* sp, and *Macrolepiot*a sp, with a value of 0.85%. Frequency calculation is used to determine the level of encounter with a type of fungus in each plot taken. The highest frequency type is *Lepiota* sp 21.43% while the others almost dominate with low frequency; the higher frequency value means the species is nearly found in each plot. This result shows that the fungal community in TAHURA Rajo Lelo has high complexity and environmental factors that support fungi growth, so there is a high enough interaction because the community becomes mature when it is more complex and stable.

CONCLUSION

Based on the research results, it can be concluded that:

1. The diversity of ectomycorrhizal fungi in Rajo Lelo Forest Park, Central Bengkulu, is in the medium category, with a value of 1.61. Nine species from seven families were found, totaling 118 individual fungi.
2. *Clitopilu*s sp has the highest relative abundance value of ectomycorrhizal fungi, with 33.05%. In contrast, *Scleroderm*a sp, *Lactarius* sp, *and Macrolepiota* sp have the lowest abundance values, with 0.85%.
3. The distribution index of ectomycorrhizal fungi in Rajo Lelo Forest Park is 1.34, included in the clustering.

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