The abundance and diversity of Basidiomycetes fungi in sago bark waste

P D Kasi¹, E P Tenriawaru¹,², S Cambaba¹, and B Triana¹

¹ Departement of Biology, Faculty of Science, Universitas Cokroaminoto Palopo, Palopo, South Sulawesi, Indonesia
² Doctorate Program of Biology, Department of Biology, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, East Java, Indonesia

E-mail: pauline@uncp.ac.id

Abstract. This study was aimed to determine the abundance and diversity of Basidiomycetes fungi on sago bark waste. This research was conducted in January-February 2020 at Tondok Alla village, Telluwanua district, Palopo city (as location I) and Kalotok village, South Sabbang district, North Luwu regency (as location II). Climate data for the study period were obtained from the BMKG online website. The morphology of the fungi obtained from the sago bark waste was observed and identified morphologically for stalk color, cap structure and cap color. The number of identified Basidiomycetes were analyzed to obtain relative abundance, species richness, evenness, Shannon Wiener diversity index, Simpson dominance index, and community similarity index. The climate observation results showed that, the average temperature was 27.74 (° C), 80.36% humidity, 12.37 mm of rainfall, and 4 hours / day of sun exposure. The fungi observation results showed that, several species of Basidiomycetes fungi was observed at both locations. Schizophyllum commune is the dominant species at both sites, and Ganoderma sp. the least. The species richness index, species evenness index, and diversity index at location I were higher than location II, while the Simpson dominance index was the highest in location II. Both locations have the same community structure based on the similarity index.

1. Introduction

One of the sources of biological wealth in Indonesia’s tropical forests is mushroom or macro fungi. The diversity of macro fungi includes the overall of morphology, form, numbers, and properties [1]. Macro fungi are heterotrophic organisms that get their nutrients through absorption. This method of obtaining absorptive nutrients makes the fungus categorized as saprotrophic and saprobic. Saprotrophic fungi include members of most phyla, but members of the phylum Basidiomycota (or basidiomycetes) are the main decomposers of recalcitrant components of plant litter through the production of lignin-modifying enzymes [2]. Saprobic fungi absorb food substances from dead organic matter, such as fallen trees, carcasses of animals, or wastes of living organisms. In this saprobic nutritional process, the fungus breaks down the organic matter. From an ecological perspective, fungi in the forest act as decomposers (saprophytes) along with bacteria and several protozoa species, thus helping a lot in the decomposition of organic matter to accelerate the cycle of matter in the forest ecosystem. Thus, fungi help to fertilize the soil by providing nutrients for plants so that forests could flourish [3].

Sago trunks are washed, debarked, and rasped during sago starch extraction before hammer milling or pulping process. The owners of sago processing sites generally dispose of the sago bark [4]. Sago
bark waste is a suitable medium for fungal growth because it contains an organic compound. Sago bark makes up 17-25% of the total sago stem weight [5] [6]. The sago stem bark is generally wasted as solid waste in the extraction process of sago starch.

Exploration of macro fungi from sago waste is still limited to sago hampas [6], whereas the bark waste has never been reported. Therefore, this study aims to determine the abundance and diversity of Basidiomycetes fungi found on sago bark waste at two different locations of traditional sago processing site.

2. Methods
This research was descriptive research and conducted in January-February 2020 at two locations, Tondok Alla village, Telluwanua district, Palopo city (as location I) and Kalotok village, South Sabbang district, North Luwu regency (as location II) by exploring methods. Climate data during the research implementation period were obtained from the Meteorology and Geophysics Agency's Online Data Website (http://dataonline.bmkg.go.id) and then analyzed descriptively. The morphology was observed for fungi found in sago bark waste, such as stalk color, cap structure and cap colour, then identified using two identification books titled “Edible Mushroom” [7] and “Edible and Poisonous Mushrooms of The World” [8]. The data obtained were analyzed for relative abundance [9], species richness proposed by Gleason, evenness based on the Pielou formula [10], Shannon Wiener diversity index [9], [11], [12], Simpson dominance index [13], and the community similarity index [9].

Figure 1. Map of Research Location.

3. Results and discussion
The climate conditions at the two locations are shown in Table 1. These climate conditions were the average daily climate parameters in the two research locations. Daily climate information online data for Luwu Raya region (including Palopo city and North Luwu regency) were came from BMKG Andi Djemma Luwu Utara Station (http://dataonline.bmkg.go.id). The average daily temperature was in the range of moderate air temperature (neither cold nor too hot) with the range 23.02 - 33.62 °C. The air humidity was quite high (80%) with low rainfall (12.37 mm) and short lighting period (4.71 hours /day). Climate affects the behavior and distribution of spores in the atmosphere. Likewise with Basidiomycetes whose spores were commonly found in temperate climates. The spread of fungal spores was influenced by wind and gusts, while humidity supports the release of fungal spores into the air. Sunlight generally reduces spore resistance [14] and affects the microbial community [15].
Table 1. Climate factors.

| Parameter                          | Result  |
|------------------------------------|---------|
| Maximum temperature (°C)           | 33.62   |
| Minimum temperature (°C)           | 23.02   |
| Average temperature (°C)           | 27.74   |
| Average humidity (%)               | 80.36   |
| Average rainfall (mm)              | 12.37   |
| Average lighting period (hours/day) | 4.71    |

Overall, 8 species from 5 families of Basidiomycetes fungi were found, *Gymnopus* sp, *Marasmius* sp, *Marasmiellus* sp, *Marasmiellus* sp1, *Schizophyllum commune*, *Ganoderma* sp, and two unidentified species (called species A and species B).

Table 2. Basidiomycetes fungi were found at two locations.

| Ordo      | Family            | Spesies            | Number of observed individual | Total numbers of individual |
|-----------|-------------------|--------------------|-------------------------------|----------------------------|
|           |                   |                    | Loc. I | Loc. II |                   |                     |
| Agarical  | Masasmiaceae      | *Gymnopus* sp.     | 6      | 0       | 6                  |                     |
| Agaricales| Agaricaceae       | *Marasmius* sp.    | 4      | 0       | 4                  |                     |
|           | Marasmiaceae      | *Marasmiellus* sp.1| 2      | 1       | 3                  |                     |
|           |                   | *Marasmiellus* sp.2| 20     | 0       | 20                 |                     |
|           | Schizophyllaceae  | *Schizophyllum commune* | 15  | 20      | 35                 |                     |
| Polyporales| Ganodermataceae  | *Ganoderma* sp.    | 1      | 0       | 1                  |                     |
|           |                   | Species A          | 0      | 2       | 2                  |                     |
|           |                   | Species B          | 0      | 2       | 2                  |                     |
|           |                   |                    | 48     | 25      | 73                 |                     |

The most common species was *Schizophyllum commune* with 35 individuals (Table 2) at both observed location, where the relative abundance at location I was 31.25% and location II was 80% (Figure 2). This was probably due to the ability of these species can live in various places. Humid environmental conditions also support this fungus to regenerate, because this species was easy to breed in weathered wood and damp conditions and generally appears during rainy season or in humid places. *S. commune* was a wood rot fungus which commonly used in testing the resistance of wood to weathering fungi [16] because it can degrade lignin [17], lignocellulose [18], and hemicellulose [19], [20]. In addition, *Marasmiellus* sp.2 is the largest numbers of species in location I with a relative abundance of 41.67%.

The species with lowest numbers of individual found in both locations was *Ganoderma* sp. with the number of individuals was 1 and only found in location I with a relative abundance of 2.08% (Table 2 and Figure 2). *Ganoderma* sp. was reported to degrade lignin in wood [21]. Whereas in location II, *Marasmiellus* sp.1 was the species with the lowest relative abundance (4%).

The species richness or species density at location I was higher than location II (Table 3). This was because the number of species found in location I is more than location II (Table 2). The species richness index measures the specificity of a taxa [10]. Some communities can determine the richness of species by counting the number of species in the community and without taking into account the number of individuals for each species [12]. The evenness of species at location I was also higher than location II (Table 3). It indicated by the absence of species that dominate location II. Species evenness compares the uniformity of population sizes of each species found [12].
Figure 2. Relative abundance of Basidiomycetes fungi at two observed location.

Table 3. Ecological parameters

| Ecological parameters              | Location I | Location II |
|-----------------------------------|------------|-------------|
| Species richness index            | 2.97       | 2.15        |
| Shannon-Wiener diversity index    | 0.62       | 0.32        |
| Evenness index                    | 0.79       | 0.53        |
| Simpson dominance index           | 0.30       | 0.65        |
| Similarity index                  | 4.67       |             |

The Shannon-Wiener diversity index at both locations was 0.62 and 0.32 (Table 3). It indicated that the species diversity at both locations were low [9]. The Shannon-Wiener diversity index considers relative abundance between species, species richness and evenness, and species distribution. However, the Shannon-Wiener diversity index focuses more on species richness [12].

Apart from the Shannon-Wiener index, the Simpson index can also be used to describe the diversity of species in a community. However, the Simpson index emphasizes species evenness so that it can also be used to describe the dominance of species in a community. If the Simpson index was high, it means that the diversity in the community was low [12]. The Simpson dominance index value ranges from 0-1, where if the index value was close to zero, means that there are no dominant species and illustrate the stability of the community. Meanwhile, if the index value is close to 1, it means that there are dominant species and indicated that the ecosystem was in an unstable condition and there was ecological pressure [13]. The Simpson dominance index value at both locations were close to zero, so it can be stated that the fungi community structure at both locations were stable and there were no ecological pressures. The dominance index at location II is higher than location I because location II is dominated by *Schizophyllum commune* with a relative abundance of 80% (Figure 2).
The similarity index of Basidiomycetes community between location I and location II was 4.67. If the similarity index value between two communities was lower than 0.50 [22], it can be concluded that the fungi communities of both locations were the same. At location I, 6 species were found and location II 4 species were found, and 2 species were found at both locations (Figure 3). *Gymnopus* sp., *Marasmius* sp., *Marasmiellus* sp., and *Ganoderma* sp. were kind of species that only be found at location I. In location II, two unidentified species (species A and species B) (Figure 4) were specific species. In this research, there were 2 species that have not been identified, the species A and species B. Species A has a cap (*pileus*) like a paddle with hard and thin structure, stiffed when dry, brownish white color, slightly curved at the tip with a wavy edge, on the surface of this fungus was covered with fine hairs, and at the bottom of the cap there were gills-like structure. The diameter of the cap is 3.27 cm and they grow on dead bark and rotten bark (Figure 4g). Species B was white color, the diameter of the cap was 0.21 cm. Cap’s shape was coral-like, with a bit thin slippery surface of the cap, and the edges of the cap were slightly jagged. This fungus has insulated gills-like structure (Figure 4h).

**Table 4.** Morphological identification based on stalk color, cap structure, and cap color of fungi

| Species                  | Stalk color     | Cap structure                                      | Cap color   |
|--------------------------|-----------------|---------------------------------------------------|-------------|
| *Gymnopus* sp            | orange          | thick and round                                   | brownish    |
| *Marasmius* sp           | white with a little brown on the tip | thin and slippery surface                           | pale white  |
| *Marasmiellus* sp        | brown with a little white spot on the tip | thin, striped and wavy at the edges                | yellowish white |
| *Marasmiellus* sp1       | white           | rough cap, slightly curved and wavy at the edges  | white       |
| *Schizophyllum commune*  | -               | fan shaped with white serrated tip                | white       |
| *Ganoderma* sp           | -               | thick and hard with fan shaped and wavy edges     | bright orange |
| Species A                | brownish white  | Thin, hard, paddle-like shape, wavy edges         | brownish white |
| Species B                | pink            | Thin, Coral-like shape, slippery surface, jagged edges | yellowish white |
This research used the morphological identification method (Table 4 and Figure 4), which is compared the morphology of fungi with descriptions and pictures of fungi in reference books. Further species determination needs to be carried out to describe the spores and their genetic characteristics. In addition, the roles and potential uses of each species need to be further analyzed, for example whether the fungi that found on sago bark waste can be consumed.

4. Conclusions
Several species of Basidiomycetes fungi were observed at both locations. *Schizophyllum commune* is the dominant species at both sites, and *Ganoderma* sp. the least. The species richness index, species evenness index, and diversity index at the location I was higher than location II, while the Simpson dominance index was the highest in location II. Both locations have the same community structure based on the similarity index.

5. Appendices
5.1 Relative Abundance (RA)
Formula for relative abundance is:

\[ RA = \frac{n_i}{N} \times 100\% \]  

where \( N \) is the total number of species and \( n_i \) is the number of individuals in species \( i \).
| Species               | Relative Abundance |
|-----------------------|--------------------|
|                       | Location I | Location II |
| Gymnopus sp.          | 12.50       | -           |
| Marasmius sp.         | 8.33        | -           |
| Marasmiellus sp.1     | 4.17        | 4.00        |
| Marasmiellus sp.2     | 41.67       | -           |
| Schizophyllum commune | 31.25       | 80.00       |
| Ganoderma sp.         | 2.08        | -           |
| Species A             | -           | 8.00        |
| Species B             | -           | 8.00        |

5.2. Species richness (SR) index

Formula for species richness (SR) is:

\[ SR = \frac{S-1}{\log_e N} \]  

(2)

Where \( S \) is the number of species, and \( N \) is the total number of individuals in the location.

\[ SR (\text{loc. I}) = \frac{6 - 1}{\log(48)} = 2.97 \]

\[ SR (\text{loc. II}) = \frac{4 - 1}{\log(25)} = 2.15 \]

5.3. Shannon-Wiener Diversity Index (\( H' \))

Formula for Shannon-Wiener diversity index (\( H' \)) is

\[ H' = \sum_{i=1}^{S} \left( \frac{n_i}{N} \log_2 \frac{n_i}{N} \right) \]  

(3)

where \( N \) is the total number of species and \( n_i \) is the number of individuals in species \( i \)

| Species               | ni/N | Log ni/N | ni/N * log ni/N | ni/N | Log ni/N | ni/N * log ni/N |
|-----------------------|------|----------|-----------------|------|----------|-----------------|
| Gymnopus sp.          | 0.13 | -0.89    | -0.12           | 0.00 | 0.00     | 0.00            |
| Marasmius sp.         | 0.08 | -1.09    | -0.09           | 0.00 | 0.00     | 0.00            |
| Marasmiellus sp.1     | 0.04 | -1.39    | -0.06           | 0.04 | -1.39    | -0.06           |
| Marasmiellus sp.2     | 0.41 | -0.39    | -0.16           | 0.00 | 0.00     | 0.00            |
| Schizophyllum commune | 0.31 | -0.51    | -0.16           | 0.80 | -0.10    | -0.08           |
| Ganoderma sp.         | 0.02 | -1.69    | -0.03           | 0.00 | 0.00     | 0.00            |
| Species A             | 0.00 | 0.00     | 0.00            | 0.08 | -1.10    | -0.09           |
| Species B             | 0.00 | 0.00     | 0.00            | 0.08 | -1.10    | -0.09           |

\[ H' = 0.62 \]

\[ 0.32 \]

5.4. Evenness index (\( J \))

Formula for Pielou’s evenness index (\( J \)) is:

\[ J = \frac{H'}{\log_e S} \]  

(4)

Where \( H' \) is Shannon Weiner diversity and \( S \) is the total number of species in a sample.

\[ J (\text{loc. I}) = \frac{0.62}{\log(6)} = 0.79 \]
5.5. Simpson dominance index ($D$)

Formula for Simpson dominance index ($D$) is:

$$D = \sum \left( \frac{n_i}{N} \right)^2$$

where $N$ is the total number of species and $n_i$ is the number of individuals in species $i$.

| Species              | Location I | Location II |
|----------------------|------------|-------------|
|                     | $n_i/N$    | $(n_i/N)^2$ | $n_i/N$ | $(n_i/N)^2$ |
| Gymnopus sp.         | 0.13       | 0.02        | 0.00    | 0.00        |
| Marasmius sp.        | 0.08       | 0.01        | 0.00    | 0.00        |
| Marasmiellus sp. 1  | 0.04       | 0.00        | 0.04    | 0.00        |
| Marasmiellus sp. 2  | 0.41       | 0.17        | 0.00    | 0.00        |
| Schizophyllum commune| 0.31       | 0.10        | 0.80    | 0.64        |
| Ganoderma sp.        | 0.02       | 0.00        | 0.00    | 0.00        |
| Spesies A            | 0.00       | 0.00        | 0.08    | 0.01        |
| Spesies B            | 0.00       | 0.00        | 0.08    | 0.01        |

$D = 0.30$ $0.65$

5.6. Similarity index ($SI$)

Formula for similarity index ($SI$) is:

$$SI = \frac{2C}{A+B}$$

Where, $C$ is the number of shared species between the two location and $A$ and $B$ are the number of species unique to each location.

$$SI = \frac{2 \times 2}{6 + 4} = 4.67$$

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