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Research Article

Foliose Lichen Diversity and Substrate Occurrence in Bukit Baranahu, Bukit Tangkiling Nature Park, Central Kalimantan, Indonesia

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Abstract

Lichen diversity in Indonesia remains unevenly documented, with Kalimantan still underrepresented in current lichenological records. Bukit Baranahu, located within Bukit Tangkiling Nature Park, Central Kalimantan, is a lowland conservation area with socio-ecological importances, but information on its biodiversity, including foliose lichens, remains unavailable. This study aimed to identify foliose lichen taxa and describe their substrate occurrence in Bukit Baranahu. Field collection was conducted from May to October 2023 using an exploratory cruise survey combined with purposive sampling along accessible paths from the foothill toward the upper part of the hill. Specimens were examined based on morphological, anatomical, and chemical characters, including standard spot-test reactions. A total of 22 foliose lichen specimens were recorded and assigned to 17 taxa belonging to Caliciales and Lecanorales. Caliciaceae was the richest family, mainly represented by *Dirinaria*, whereas Parmeliaceae and Physciaceae were represented by fewer taxa. This composition differed from several Indonesian lichen inventories in which Parmeliaceae was commonly reported as a dominant family. Foliose lichens were recorded on living trees, snags or dead standing wood, fallen logs, and rocks, with living trees contributing the highest proportion of substrate records. Several taxa occurred on larger-diameter trees and snags, suggesting that substrate size, bark condition, and substrate stability may support local foliose lichen establishment. These findings provide the first baseline account of foliose lichen diversity and substrate occurrence in Bukit Baranahu and contribute to lichenological documentation in the underexplored lowland forests of Central Kalimantan.

Keywords: caliciaceae, *Dirinaria*, foliose lichens, lowland forest, substrate occurrence

1. INTRODUCTION

Lichens are composite symbiotic organisms formed through the association between a fungal partner, or mycobiont, and one or more photosynthetic partners, commonly green algae and/or cyanobacteria. This association produces a thallus with distinct morphological and physiological traits that allow lichens to colonize various terrestrial substrates, including bark, rock, soil, and dead wood. Among the major lichen growth forms, foliose lichens are characterized by a dorsiventral, leaf-like thallus with distinguishable upper and lower surfaces. Their relatively exposed thallus structure makes them responsive to changes in light, humidity, substrate condition, and atmospheric quality, supporting their frequent use in ecological monitoring and bioindicator studies [1–3]. In tropical forest ecosystems, epiphytic lichens contribute to forest biodiversity and occupy specific microhabitats. Variation in host and substrate conditions may influence lichen assemblage because bark and wood-related traits provided different levels of attachment. Therefore, documenting lichen communities in tropical protected areas is important not only for species inventory but also for understanding the early ecological patterns that may support future monitoring of forest condition [4–6].

Bukit Baranahu is located within Bukit Tangkiling Nature Park, a conservation area managed by the Central Kalimantan Natural Resources Conservation Agency. The area consists of nine low hills, with Bukit Baranahu recognized as the second-highest hill at approximately 140 m a.s.l. It has been recognized as an important site for biodiversity conservation, environmental education, and ecotourism in Central Kalimantan [7]. In addition to its conservation role, the conserved areas also provided ecological and social benefits, including clean water resources, honey bee resources, recreation, and religious services for local

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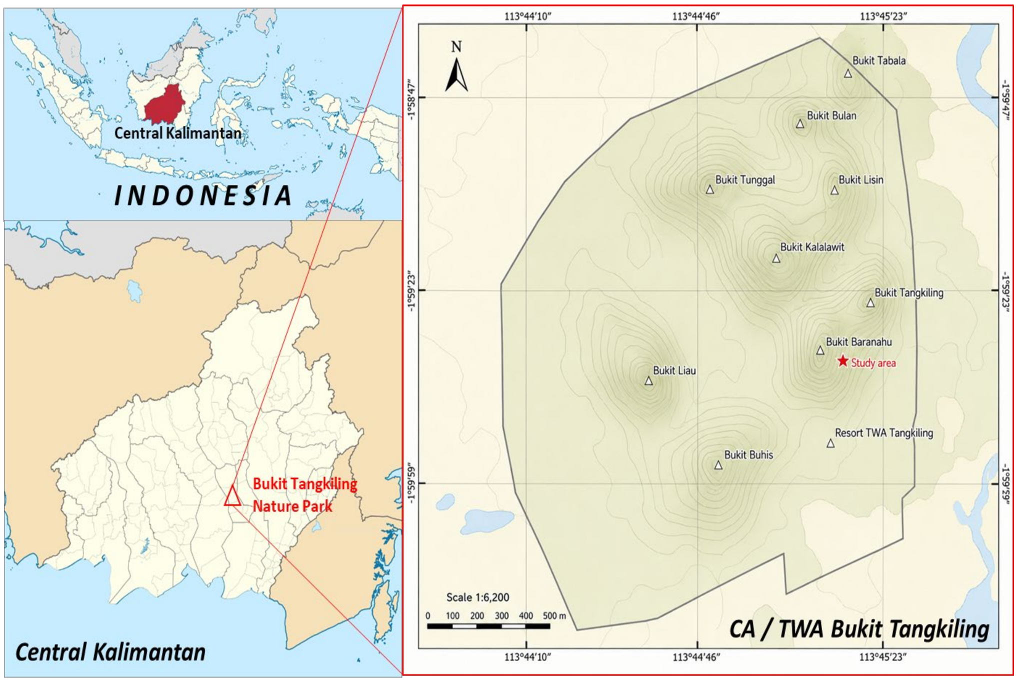

Figure 1. Map location of Bukit Baranahu as the study area for foliose lichens within Bukit Tangkiling Nature Park region of Central Kalimantan, Indonesia.

communities. However, management concerns have been reported in relation to resource-use conflicts, particularly rock mining, which may affect the ecological integrity of the conservation area [8]. Recent mycological work from Bukit Tangkiling reported the isolation of *Perenniporia* sp., a white-rot fungus identified using molecular data, indicating that the area remains insufficiently explored and relevant for fungal biodiversity studies [9].

A recent review by Atni and Pasaribu [10], found that national lichen diversity in Indonesia remains unevenly documented, with 317 valid species recorded mainly from most-studied regions such as Java and Sumatra. In contrast, several large regions, including Kalimantan, remain underexplored. Despite the conservation value and emerging mycological importance, information on foliose lichens from Bukit Baranahu remains limited. No specific account has documented the taxonomic composition, substrate occurrence, and habitat characteristics of foliose lichens in this locality. This knowledge gap restricts the availability of baseline data on lichen diversity in Central Kalimantan and limits the potential use of foliose lichens as supporting indicators in lowland tropical forest monitoring. This study then aimed to identify the foliose lichen taxa recorded in Bukit Baranahu and to describe their associated substrate and habitat characteristics. The results will be valuable to provide baseline information for lichenological documentation and future biodiversity assessment in protected lowland forests of Central Kalimantan.

2. MATERIALS AND METHODS

2.1. Study area

This study was conducted from May to October 2023 in the accessible area of Bukit Baranahu, *Cagar Alam* (CA) and *Taman Wisata Alam* (TWA) Bukit Tangkiling, Central Kalimantan, Indonesia (Figure 1), whereas specimen identification were carried out at the Laboratory of Biology, Faculty of Mathematics and Natural Sciences, University of Palangka Raya (UPR), Central Kalimantan Indonesia. The study was focused on foliose lichen specimens collected through an exploratory cruise survey combined with purposive sampling along existing accessible paths from the foothill toward the upper part of Bukit Baranahu. Field measurements were performed using a thermometer, sling psychrometer, luxmeter, Global Positioning System (GPS) unit, and the Avenza Maps application.

2.2. Field collection, specimen handling, and identification

Field collection and documentation were supported by a smartphone camera, measuring tape, ruler, cutter or knife, writing materials, hand lens, sample labels, and paper envelopes. Foliose lichens found on available substrates, including living trees, snags, fallen logs, and rocks, were documented *in situ* and collected based on substrate accessibility and thallus availability. The collected specimens were air-dried under sunlight and stored in labeled paper envelopes containing relevant field information. Habitat characteristics were recorded at each collection site, including substrate type, host tree species, tree diameter, and tree height. Abiotic variables, including altitude, light intensity, air temperature, and relative humidity, were recorded as an overview of environmental conditions during field sampling.

In the laboratory, morphological characters were examined using a stereo microscope, whereas anatomical characters were observed from thin longitudinal thallus sections prepared using a razor blade and mounted on object glasses with cover glasses. Microscopic observations were performed using an Olympus light-compound microscope, supported by an Optilab imaging system when required. Chemical characterization was carried out using standard spot-test reactions by Hale [11], with potassium hydroxide (K test), sodium hypochlorite (C test), potassium hydroxide followed by sodium hypochlorite (KC test), and paraphenylenediamine (P test). Thin thallus sections or selected thallus fragments were placed on separate spot plates and treated with each reagent using a dropper. The occurrence of color change was recorded as a positive reaction (+), whereas the absence of color change was recorded as a negative reaction (−). The morphological, anatomical, and chemical data obtained from the specimens were compared with published identification references and verified using online taxonomic resources, including Fungi of Great Britain and Ireland [12], ITALIC [13], and the Consortium of Lichen Herbaria Lichen Portal [14].

3. RESULTS AND DISCUSSIONS

3.1. List of foliose lichens recorded in Bukit Baranahu, CA/TWA Bukit Tangkiling

A total of 22 foliose lichen specimens were recorded from Bukit Baranahu, TWA Bukit Tangkiling. Based on morphological, anatomical, and chemical characterizations, these specimens were assigned to 17 taxa distributed in two orders, namely Caliciales and Lecanorales. The order Caliciales was represented by two families, Caliciaceae and Physciaceae. Caliciaceae showed

Table 1. List of foliose lichen species at Bukit Baranahu, CA/TWA Bukit Tangkiling.

No.	Order	Family	Genus	Species
1.	Caliciales	Caliciceae	*Dirinaria*	*Dirinaria aegialita*
2.				*Dirinaria applanata*
3.				*Dirinaria confluens*
4.				*Dirinaria picta*
5.				*Dirinaria subconfluens*
6.				*Dirinaria* sp. 01
7.				*Dirinaria* sp. 02
8.				*Dirinaria* sp. 03
9.				*Dirinaria* sp. 04
10.				*Dirinaria* sp. 05
11.				*Dirinaria* sp. 06
12.				*Dirinaria* sp. 07
13.				*Dirinaria* sp. 08
14.				*Dirinaria* sp. 09
15.		Physciaceae	*Heterodermia*	*Heterodermia albicans*
16.	Lecanorales	Parmeliaceae	*Parmotrema*	*Parmotrema* sp. 01
17.				*Parmotrema* sp. 02

the highest taxon richness, with 15 taxa recorded, whereas Physciaceae was represented by a single taxon. The order Lecanorales was represented by Parmeliaceae, which comprised two taxa (Table 1).

The number of lichen taxa recorded in this study was lower than that recently reported from the Selo Merbabu Hiking Trail, Mount Merbabu, Central Java, where 36 lichen species were reported [15]. However, the richness recorded in the present study was almost similar or slightly higher than that reported from Gunung Banyak Protected Forest, Sragen, Central Java, where 15 lichen species were documented [16], while 19 species from seven families were recorded in Sicikeh-Cikeh Nature Park, North Sumatra [17]. The taxonomic composition in Bukit Baranahu also differed from several Indonesian lichen inventories. In the present study, Caliciaceae was the most species-rich family, mainly due to the high number of *Dirinaria* taxa. This pattern contrasts with several previous studies in which Parmeliaceae was one of the dominant families [15,18]. These differences are likely related to variation in sampling region and sampling efforts.

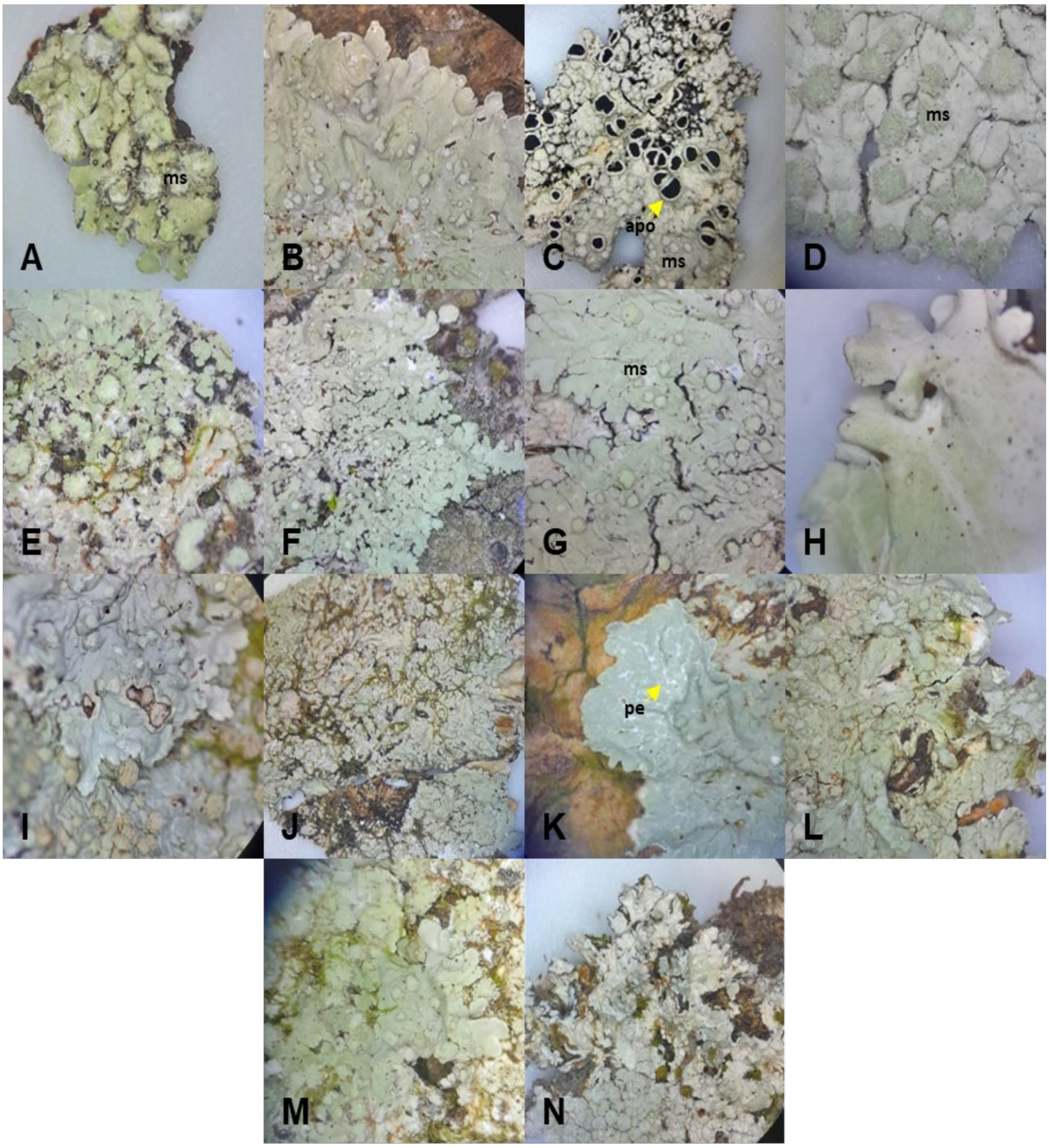

Figure 2. Morphological features of the foliose lichens, genus *Dirinaria* recorded from Bukit Baranahu: A. *Dirinaria aegialita*; B. *Dirinaria applanata*; C. *Dirinaria confluens*; D. *Dirinaria picta*; E. *Dirinaria subconfluens*; F. *Dirinaria* sp. 01; G. *Dirinaria* sp. 02; H. *Dirinaria* sp. 03; I. *Dirinaria* sp. 04; J. *Dirinaria* sp. 05; K. *Dirinaria* sp. 06; L. *Dirinaria* sp. 07; M. *Dirinaria* sp. 08; and N. *Dirinaria* sp. 09. Arrows indicate some diagnostic macromorphological characters: ms, maculiform soralia; apo, apothecia; pe, pseudocyphellae.

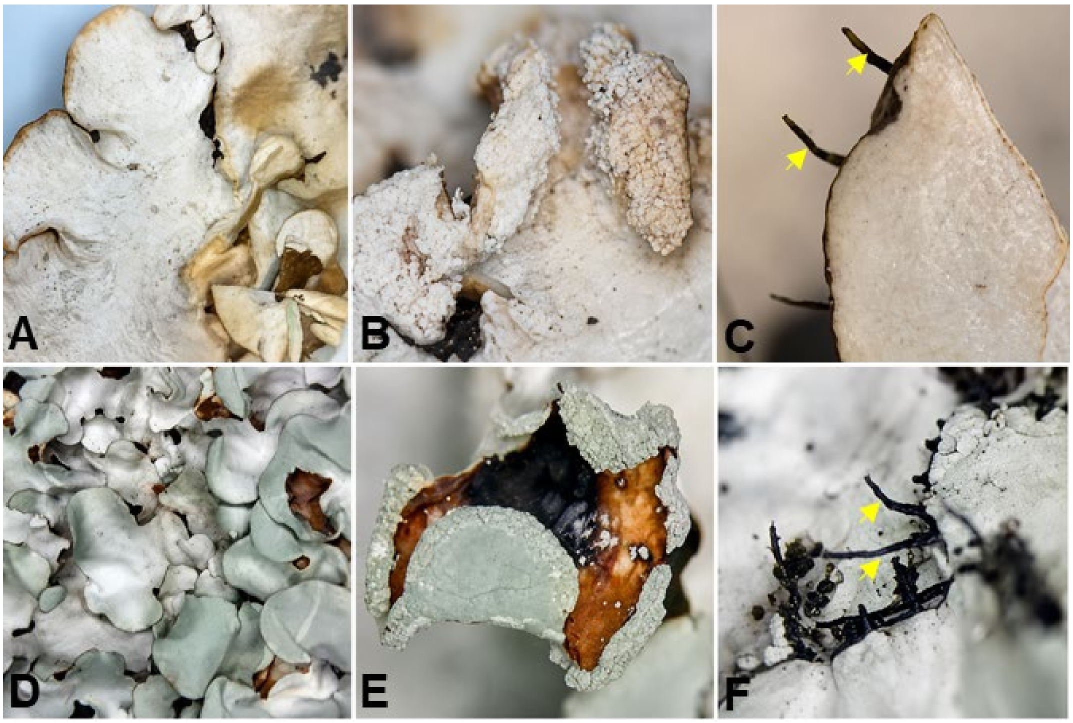

Figure 3. Morphological features of *Parmotrema* spp.: A–C, *Parmotrema* sp. 01; D–F, *Parmotrema* sp. 02. A, D, thallus habit; B, E, labriform soralia; C, F, marginal cilia (arrows).

Dirinaria was the most frequently recorded genus in the study area (Figure 2). The occurrence of this genus in several specimens may reflect its relatively broad ecological tolerance and its common distribution in tropical habitats. Members of *Dirinaria* are generally characterized by a closely appressed thallus with irregular to radiating, eciliate lobes that may occur separately or become coalescent. The upper surface is commonly white, grayish-white, or bluish-gray, whereas the lower surface may vary from pale brown to dark brown or black. Soredia or isidia may be present in some taxa, while apothecia may be present or absent. The medulla is usually white to pale yellow, and the hypothecium is pale brown to dark brown or blackish. The asci are clavate and unitunicate, usually containing eight ascospores. The ascospores are brown, ellipsoid, thick-walled, and 1-septate. The cortex generally shows a K+ yellow reaction and an I+ blue reaction [19,20].

Parmotrema was recorded as the second genus, represented by two taxa in the present study (Figure 3). Although *Parmotrema* is known as one of the largest lichen genera globally (ca. 350 species), its occurrence in Bukit Baranahu was relatively limited during sampling. This low occurrence was related to the limited number of colonies encountered along the sampling route. Members of *Parmotrema* are commonly recognized by a relatively large thallus with broad lobes, with or without marginal cilia. The upper surface is usually gray to yellow-green, whereas the lower surface is black or brown and may show white maculae near the margins. The lower surface may appear smooth, glossy, or dull, and soredia or isidia may occur in some taxa. Rhizines are generally simple to sparsely branched. The medulla is white, while the ascospores are ellipsoid, thick-walled, and sometimes slightly enlarged at one end. The cortex commonly reacts K+ yellow [21, 22].

Heterodermia was represented by a single taxon and was the least frequently recorded genus in this study (Figure 4). Its limited occurrence may indicate that suitable microhabitat conditions for this genus were less common at the sampled sites. The genus is generally distinguished by an adnate to ascending thallus with irregularly branched lobes bearing dense, simple to branched white cilia, often with blackened tips. The upper surface is usually white, gray, or yellowish-gray, whereas the lower surface may be white to grayish-white or

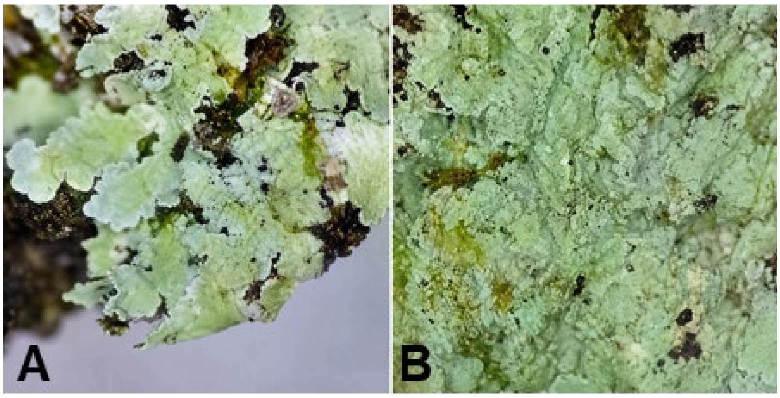

Figure 4. Morphological features of *Heterodermia albicans*: A. thallus habit and B. marginal soralia.

blackish, with or without isidia and soredia. Rhizines may range from white to black, simple to densely branched, and may extend beyond the lobe margins. Apothecia may be present or absent. The asci are hyaline, cylindrical to subclavate or clavate, and contain eight ascospores. The ascospores are brown, thick-walled, and 1-septate. The cortex commonly reacts K+ yellow and I+ blue [22].

3.2. Substrate and microhabitat characteristics in Bukit Baranahu

The substrate–taxon matrix showed that most taxa were associated with one or a few host or substrate types (Figure 5A). Foliose lichens were recorded on several substrate types, including living trees, snags or dead standing wood, fallen logs, and rocks. Living trees accounted for the highest proportion of records, representing 56% of the observed substrate occurrences. Snags or dead standing wood contributed 28%, followed by fallen logs at 11% and rocks at 5% (Figure 5B).

Tree diameter among living and dead woody substrates ranged from 12 to 87.26 cm. Several taxa were collected on larger-diameter substrates, i.e., *Acacia* sp. with a diameter of 87.26 cm, which supported *Dirinaria* sp. 09, and snags of *Acacia* sp. with diameters of 33.43–87.26 cm, which supported *Dirinaria* sp. 03, *Dirinaria* sp. 04, *Parmotrema* sp. 01, and *Parmotrema* sp. 02. Several living trees with moderate to large diameters also supported multiple taxa. *Artocarpus heterophyllus* with a diameter of 42 cm supported *Dirinaria aegialita* and *Dirinaria* sp. 07, whereas *Nephelium lappaceum* with a diameter of 42.03 cm supported *Dirinaria* sp. 01 and *Dirinaria* sp. 08. In contrast, smaller-diameter hosts, such as *Durio zibethinus* at 12.10 cm and *Nephelium lappaceum* at 12 cm, supported fewer colonies. These findings show that host traits may be related to foliose lichen occurrence through differences in bark age, colonization surface, and substrate stability. Larger or older stems may provide more persistent microhabitats for propagule attachment and thallus development, as reported in previous studies on epiphytic lichens [23,24]. However, this pattern was still indicative because the diameter classes were not sampled systematically in the present study.

Tree height varied from 1 to 15 m among the substrates. Foliose lichens were found on both low and taller host trees, indicating that colonization was not restricted to a single tree-height class. Nevertheless, several records with relatively high colony abundance were associated with taller substrates, including *Acacia* sp. at 8–15 m and *Nephelium lappaceum* at 10 m. Tree height may influence foliose lichen occurrence by creating differences in light exposure, bark moisture, and air movement along the trunk. Taller trees can provide broader vertical microhabitats, but in warm lowland tropical forests, greater exposure may also increase thallus desiccation when high light intensity occurs with elevated temperature. Therefore, tree height in this study was perceived more as a potential microhabitat factor rather than a direct predictor of lichen abundance [25,26].

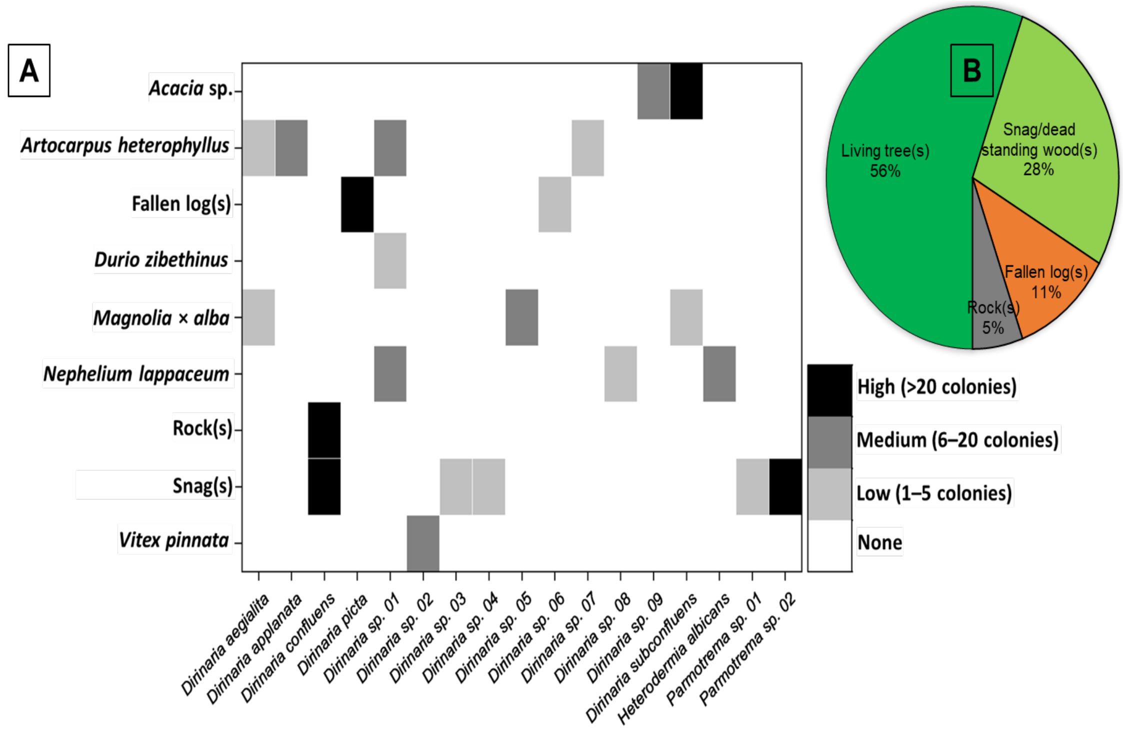

Figure 5. Substrate occurrence and colony abundance of foliose lichens in the study area: A. substrate–taxon matrix of each occurrence across host or substrate types; and B. proportional distribution of foliose lichen records across the main substrate categories.

Most taxa were recorded on living trees, including *Artocarpus heterophyllus*, *Magnolia alba*, *Acacia* sp., *Nephelium lappaceum*, *Durio zibethinus*, and *Vitex pinnata*. Among these, *Artocarpus heterophyllus*, *Magnolia alba*, and *Nephelium lappaceum* supported more than one taxon. *Dirinaria aegialita* was found on both *A. heterophyllus* and *M. alba*, while *Dirinaria* sp. 01 occurred on several hosts, namely *A. heterophyllus*, *D. zibethinus*, and *N. lappaceum*. In contrast, several taxa were represented by low colony numbers, including *Dirinaria subconfluens* on *M. alba*, *Dirinaria* sp. 03 and *Dirinaria* sp. 04 on snags of *Acacia* sp., *Dirinaria* sp. 06 on fallen logs, and *Dirinaria* sp. 08 on *N. lappaceum*. These differences indicate that colony abundance varied among taxa and substrates.

Dead woody substrates also appeared to provide suitable microhabitats for some foliose lichens. Snags of *Acacia* sp. supported *Dirinaria confluens*, *Dirinaria* sp. 03, *Dirinaria* sp. 04, *Parmotrema* sp. 01, and *Parmotrema* sp. 02, whereas fallen logs supported *Dirinaria picta* and *Dirinaria* sp. 06. This occurrence indicates that standing and fallen deadwood may provide additional colonization surfaces besides living tree bark. Deadwood can differ from living bark in surface roughness, exposure, moisture retention, decay stage, and bark persistence, which may create microsites suitable for lichen attachment and thallus development [27]. A recent study on deadwood-dwelling lichens has also shown that both standing and fallen dead trees can function as important survey substrates, with lichen occurrence commonly assessed in relation to diameter, height, decay stage, and standardized substrate area [28].

Light intensity at the study site ranged from 1,145 to 9,464 lux within a very narrow elevation range. Lichen algal photosynthesis may occur at relatively low light levels, with a minimum value of approximately 1,035 lux [29]. However, photosynthetic response may vary among species, photobiont types, thallus hydration, and exposure conditions. Epiphytic lichen richness may increase with elevation [30], whereas another study found no significant correlation between elevation and lichen species richness [31]. Air temperature ranged from 28 to 33 °C. Lichens may tolerate warm conditions, but photosynthetic performance can decline when high temperatures occur together with strong irradiance or thallus desiccation [32]. Relative humidity ranged from 68 to 93%. Moisture availability is essential for lichens because they are poikilohydric organisms whose metabolic activity depends on hydration and drying cycles. Desiccation reduces chlorophyll fluorescence and primary photosynthetic activity [33], while high humidity supports water availability for lichen growth. The relatively high humidity recorded in Bukit Baranahu may therefore support foliose lichen persistence, although long term microclimatic monitoring would be required to confirm its role in colony development.

4. CONCLUSIONS

This study documented 17 foliose lichen taxa from 22 specimens collected in Bukit Baranahu, Bukit Tangkiling Nature Park, Central Kalimantan. The assemblage was dominated by Caliciaceae, particularly *Dirinaria*, whereas *Parmotrema* and *Heterodermia* were represented by fewer taxa. The composition recorded in this study differs from several Indonesian lichen inventories in which Parmeliaceae was commonly reported as a dominant family, indicating that local substrate conditions and sampling scope may influence the observed taxonomic pattern. Foliose lichens were recorded on living trees, snags or dead standing wood, fallen logs, and rocks, with living trees contributing the largest proportion of substrate records. The occurrence of several taxa on larger-diameter trees and snags indicates that substrate size, bark age, surface stability, and available colonization area may support foliose lichen establishment. Dead woody substrates also provided additional microhabitats, particularly for several *Dirinaria* and *Parmotrema* taxa. The environmental conditions reflected a warm and humid lowland habitat with variable light exposure, although these one-time measurements should be interpreted as site-condition data rather than direct predictors of lichen abundance. The findings provide baseline information for lichenological documentation in Central Kalimantan, a region that remains underrepresented in Indonesian lichen studies. Future work should include plot-based sampling, standardized substrate-area measurements, repeated microclimatic observations, and molecular analyses to improve taxonomic resolution and clarify the ecological factors shaping foliose lichen assemblages in Bukit Tangkiling Nature Park.

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Author Contributions

RYPL: Investigation, Data curation, Taxonomic identification, Data Analysis, Writing – original draft; VWW: Supervision, Methodology Writing; FGN: Visualisation analysis (figures, tables), review, and editing of the manuscript; WK: Methodology, Validation, review, and editing of the manuscript; DP: Conceptualization, Supervision, Funding acquisition, Data Analysis, Writing – review & editing.

Conflict of Interest

The authors declare no conflict of interest.

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DECLARATION OF GENERATIVE AI

Not applicable.

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