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Exploration and Identification of Lichen in the Temon, Depok, and Tegalrejo

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ABSTRACT

This research aims to identify the diversity of lichen species in three different areas: Temon, Kulon Progo; Depok, Sleman; and Tegalrejo, Magelang. Besides that, to analyze their ecological role as environmental bioindicators. The method used was direct field observation with visual documentation using a mobile phone camera, followed by morphological identification. The results of the study successfully identified nine lichen species: *Flavoparmelia caperata*, *Physcia atrostriata*, *Dirinaria applanata*, *Phlyctis argena*, *Acarospora socialis*, *Ropalospora viridis*, *Pyxine sorediata*, *Cryptothecia striata*, and *Graphis* sp. These species exhibited unique adaptations to various substrates (tree bark, rocks, and urban environments) and showed sensitivity to environmental changes, particularly air pollution. The mutualistic symbiosis between fungi and photobionts (algae/cyanobacteria) is key to the resilience of lichens in marginal habitats. These findings strengthen the potential of lichens as natural bioindicators and ecological pioneers, while also highlighting the need for further research to map the distribution and applications of lichens in Indonesia.

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1. INTRODUCTION

Lichens are a highly diverse group of symbiotic organisms that inhabit nearly all terrestrial ecosystems, from polar regions to tropical zones. They grow on a wide variety of surfaces, including rocks, soil, and tree bark. A lichen is composed of a fungal partner (mycobiont) and a photosynthetic partner (photobiont), which may be cyanobacteria, green algae, or both (Sigurbjörnsdóttir et al., 2016). In addition, lichens host a range of other microorganisms, such as bacteria, various fungi including endolichenic and lichenicolous species, yeasts, and even viruses (Hawksworth & Grube, 2020; Merges et al., 2021). The fungal partner relies on the photobiont for carbohydrate-rich nutrients and, in turn, protects against drying out and solar radiation damage (Sigurbjörnsdóttir et al., 2016; Chowdhury et al., 2017). This form of symbiosis has proven to be both evolutionarily and ecologically successful for fungi, with a significant proportion of fungal species forming lichens (Allen & Lendemer, 2022). Lichens often produce a variety of secondary metabolites, some of which contribute to their coloration (Calcott et al., 2018). Certain lichen species are highly responsive to climatic factors and have long been utilized as indicators of air quality (Styburski & Skubała, 2023).

Lichens represent a mutualistic symbiosis between fungi (typically from the Ascomycetes group) and a photobiont (either algae or cyanobacteria), forming a distinctive thallus structure. This association enhances the survival capabilities of both organisms in extreme environments, with an estimated global diversity of approximately 15,000 species (Lumbsch et al., 2017). Although Indonesia hosts around 40,000 species, research on lichens remains limited despite their significant potential due to their ability to grow on various natural and artificial substrates (Andrea et al., 2018).

Lichens are known for their sensitivity to environmental changes, which has made them a valuable tool in biomonitoring research. As a result, the effects of pollutants on their physiological functions have drawn scientific attention over recent decades. Due to their lack of root systems, protective outer layers, and filtering structures, lichens absorb both essential nutrients and harmful substances directly across their entire thallus surface (Asplund & Wardle, 2017). This can lead to the accumulation of toxic elements at concentrations that surpass the organism's tolerance threshold, potentially disrupting metabolic processes (Boonpeng et al., 2023).

Lichens play a vital role as bioindicators of air pollution because of their sensitivity to pollutants (Rola et al., 2019). Their ability to accumulate pollutants can be used as biomonitors through the measurement of the accumulated pollutants in the thallus (Conti & Tudino, 2016). However, their growth is highly influenced by environmental conditions such as temperature, humidity, and light intensity, with pollution-related changes potentially inhibiting their development (Maulani, 2021). This study aims to identify the species, characteristics, and habitats of lichens in three different regions. The findings are expected to contribute to the literature on lichen biodiversity and serve as baseline data for the use of lichens as environmental bioindicators.

2. RESEARCH METHOD

The type of research used is descriptive exploratory. This observation was carried out in three distinct locations (**Fig.** 1) Pasir Kadilangu area, Temon Subdistrict, Kulon Progo; the FMIPA UNY Campus area, Depok Subdistrict, Sleman; and Tumbu area, Tegalrejo Subdistrict, Magelang, within the period of February 19 to April 4, 2025. The exploration site in the Temon area is located at 7°53'38"S 110°01'40"E (6 meters asl); the Depok area is located at 7°46'31"S 110°23'04"E (132 meters asl); and the Tegalrejo area is located at 7°26'51"S 110°14'53"E (410 meters asl).

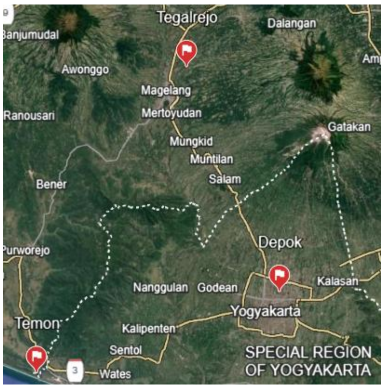

Figure 1. Lichen Observation Area Map

The data collection methods in this study included observation, field exploration, literature review, and documentation (Roziaty & Agyuni, 2024). The research data were analyzed using a qualitative descriptive approach, which involved recording the scientific names, taxonomic classification, and thallus morphology of the lichens. Specimen identification was supported by online biodiversity databases and identification systems, including the Consortium of Lichen Herbaria (LichenPortal), the LIAS multi-access key, and trait databases, complemented with community observations from iNaturalist. The research employed a direct field observation technique, visually documented using a mobile phone camera. Each lichen species observed was then identified based on its visible morphological characteristics.

3. RESULTS AND ANALYSIS

Lichens represent a unique form of mutualistic symbiosis between fungi (typically from the Ascomycetes group) and algae (gonidia), in which both partners benefit through nutrient sharing and mutual protection. The fungus facilitates water and mineral absorption, while the alga provides photosynthetic products, forming a specialized morphological structure known as the thallus. This symbiotic arrangement allows lichens to survive in extreme environments that neither organism could inhabit alone (Roziaty, 2016).

From an ecological perspective, lichens function as pioneer organisms in ecosystem succession (Fitri, 2021). Their ability to colonize hard substrates such as rocks—by secreting organic acids that contribute to weathering and soil formation—marks their ecological importance. Despite their extremely slow growth rate (approximately 1 cm per year), lichens have exceptional longevity, indicating a well-adapted evolutionary strategy for marginal environments. In our exploration, *Flavoparmelia caperata*, *Physcia atrostriata*, and *Dirinaria applanata* discovered in Temon exemplify these adaptive strategies, thriving on tree bark and rocks across diverse conditions.

Temperature plays a critical role in the distribution of lichens, they can withstand extremely hot or low temperatures (Bhagarathi et al., 2022). These organisms exhibit a broad tolerance for thermal fluctuations by entering dormancy during unfavorable conditions and reactivating metabolism when conditions improve. Such mechanisms enable colonization in marginal habitats. However, this thermal tolerance varies across species, resulting in specific distribution patterns (Ulfa et al., 2023). For example, *Phlyctis argena*, found in the relatively shaded and moderately warm environment of Depok, thrives under partial sunlight on hardwood tree bark, reflecting a niche-specific thermal adaptation.

Lichens are highly sensitive to air pollution, particularly sulfur-based compounds, which makes them excellent bioindicators of atmospheric quality. The absence of sensitive lichen species in a given area can signal elevated pollution levels. This natural monitoring system is more practical and cost-effective than instrument-based methods, especially for large-scale, long-term environmental assessment (Roziaty et al., 2021). The presence of *Acarospora socialis*, *Ropalospora viridis*, and *Pyxine sorediata* in Tegalrejo, an area with moderate exposure to open air and sunlight, supports their role as potential bioindicators.

Physiological adaptations in lichens to cope with environmental stress include the production of protective compounds, adjustable metabolic rates, and the ability to enter dormancy (Boruah et al., 2024). These strategies enhance survival in extreme conditions but often come at the cost of reduced growth rates, as seen in the slow expansion of the thallus (Armstrong, 2017). This evolutionary trade-off reflects a balance between resilience and productivity. Reproductive strategies in lichens involve efficient vegetative propagation through soredia and isidia, which contain both symbiotic partners, ensuring the continuity of the mutualistic relationship in new colonies. Sexual reproduction, through fungal fruiting bodies, also occurs but depends heavily on the availability of compatible algal partners in the environment (Turahmi et al., 2022).

Research potential on lichens in Indonesia remains vast, given the country's high but underexplored species diversity. Further studies are necessary to map species distributions, identify bioactive compounds, and optimize their use as bioindicators. Modern molecular approaches can enhance our understanding of symbiotic dynamics and adaptive mechanisms in these unique organisms. The discoveries from Temon, Depok, and Tegalrejo underscore the ecological richness of lichens in different environmental contexts and highlight their relevance for future ecological monitoring and conservation studies (Andrea et al., 2018). The occurrence of each lichen species reflects adaptations to substrate characteristics and environmental conditions across landscape and microsite scales that regulate growth and maintain fungal–photobiont symbiosis (Trobajo et al., 2025). Landscape-scale controls include climate, light exposure, and air quality, whereas microsite-scale regulation depends on substrate chemistry, surface structure, and moisture dynamics (Wutz & Diekmann, 2025).

3.1. *Flavoparmelia caperata*

Figure 2. Personal Documentation of *Flavoparmelia caperata* in Temon

Kingdom : Fungi
Division : Ascomycota
Class : Lecanoromycetes
Order : Lecanorales
Family : Parmeliaceae
Genus : Flavoparmelia
Species : *Flavoparmelia caperata*

Flavoparmelia caperata, commonly referred to as the Common Green Shield Lichen, is a foliose lichen species widely distributed across temperate forests around the world. This lichen displays a distinct growth pattern, forming large sheet-like or mat-like colonies on various substrates. This preference reflects the suitability of broadleaf bark and rock substrates, which provide stable surfaces, favorable moisture dynamics, and minimal competition, thereby supporting thallus attachment, hydration cycles, and sustained physiological activity. (Lõhmus et al., 2023). Notable morphological traits include its ability to adapt to moisture fluctuations (shrinking when dry), relatively large thallus size compared to other lichen species, and a clustered growth habit that results in extensive ground cover.

Its primary habitats include natural forest ecosystems, urban areas (as a bioindicator), natural substrates (such as deciduous tree bark and rocks), and man-made structures (like fence posts). This lichen possesses a broad ecological tolerance, making it one of the most frequently encountered foliose lichen species under diverse environmental conditions. Its adaptability to varying humidity levels and resilience to urban pollutants make it a valuable subject in urban lichenological studies, particularly for assessing pollution levels through biomonitoring (De La Cruz et al., 2018).

3.2. *Physcia atrostriata*

Figure 3. Personal Documentation of *Physcia atrostriata* in Temon

Kingdom : Fungi
Division : Ascomycota
Class : Lecanoromycetes
Order : Physciaceae
Family : Graphidaceae
Genus : Physcia
Species : *Physcia atrostriata*

Physcia atrostriata is a foliose lichen with a gray to brownish-gray coloration, featuring a wavy thallus margin and a somewhat dusty upper surface. Its thallus displays pseudocyphellae (small white spots) and black rhizines (root-like structures) on the lower surface, which aid in attachment to substrates. This species produces black apothecia with a distinctive fringed margin. It is commonly found growing on the bark of broadleaf trees in both urban areas and forests, indicating a tolerance to moderate levels of air pollution (Murningsih & Mafazaa, 2016).

3.3. *Dirinaria applanata*

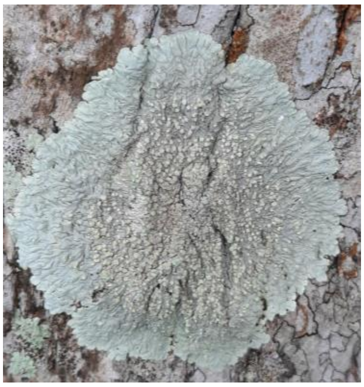

Figure 4. Personal Documentation of *Dirinaria applanata* in Temon

Kingdom : Fungi
Division : Ascomycota
Class : Lecanoromycetes
Order : Teloschistales
Family : Physciaceae
Genus : Dirinaria
Species : *Dirinaria applanata*

Dirinaria applanata is a commonly found foliose lichen that grows on rock surfaces and tree bark across various climatic conditions. This symbiotic organism has a gray to greenish thallus shaped like small, flattened leaves. The lichen maintains a mutualistic relationship with algae and contributes to the ecosystem by breaking down materials and recycling nutrients. It typically inhabits substrates such as bark, wood, and stone (Rohim et al., 2024).

3.4. *Phlyctis argena*

Figure 5. Personal Documentation of *Phlyctis argena* in Depok

Kingdom : Fungi
Division : Ascomycota
Class : Lecanoromycetes
Order : Ostropales
Family : Phlyctidaceae
Genus : Phlyctis
Species : *Phlyctis argena*

Phlyctis argena is a white-colored crustose lichen commonly found growing on tree trunks, especially on hardwood trees located in open areas with adequate sunlight. Its initial color is a bright whitish-green, which gradually turns to grayish-brown as it ages. When fresh, the thallus spreads evenly across the bark surface, resembling a layer of white paint (Suharno et al., 2024).

This lichen is frequently observed in forested regions, densely vegetated areas, along forest trails exposed to sunlight, and other types of wooded habitats. The species primarily grows on the bark of broadleaf trees and is rarely found on coniferous trees (Muliana, 2021).

3.5. *Acarospora socialis*

Figure 6. Personal Documentation of *Acarospora socialis* in Tegalrejo

Kingdom : Fungi
Division : Ascomycota
Class : Lecanoromycetes
Order : Acarosporales
Family : Acarosporaceae
Genus : Acarospora
Species : *Acarospora socialis*

Acarospora socialis is a resilient lichen species with a distinctive appearance, primarily found adhering to exposed rock surfaces in arid regions. Its thallus is crusty and firm in texture, forming a yellow to brown mosaic pattern that resembles small overlapping scales. This lichen grows slowly but forms tightly packed colonies that often appear circular. Over time, these colonies can merge to create larger continuous patches. Its main habitats include various rock types such as sandstone, intrusive and extrusive igneous rocks, as well as artificial surfaces like bricks (Adams et al., 2023).

3.6. *Ropalospora viridis*

Figure 7. Personal Documentation of *Ropalospora viridis* in Tegalrejo

Kingdom : Fungi
Division : Ascomycota
Class : Lecanoromycetes
Order : Umbilicariales
Family : Ropalosporaceae

Genus : Ropalospora
Species : *Ropalospora viridis*

Ropalospora viridis is a distinctive member of the fungal kingdom, easily recognized by its bright green coloration. This species typically grows as an epiphyte on tree bark, where its vivid hue stands out amid the more common browns and grays of forest ecosystems. Despite its striking color, it is often overlooked due to its ability to blend seamlessly into the mossy environments that form its primary habitat. The combination of its glowing green tones and unique thallus texture makes it a notable component of forest lichen diversity. This lichen forms a grayish-green areolate thallus with bright green soralia that are typically fused, emerging from the top of the areoles and producing perlatolic acid as the main chemical compound (Tsurykau et al., 2016).

3.7. *Pyxine sorediata*

Figure 8. Personal Documentation of *Pyxine sorediata* in Tegalrejo

Kingdom : Fungi
Division : Ascomycota
Class : Lecanoromycetes
Order : Teloschistales
Family : Physciaceae
Genus : Pyxine
Species : *Pyxine sorediata*

Pyxine sorediata, commonly known as the Pixine Lichen, is a fascinating example of mutualistic symbiosis between fungi and algae. This lichen features a yellow-green to grayish thallus with lobed, leaf-like structures. A distinctive characteristic is its ability to produce soredia—powdery reproductive structures that play a vital role in its dispersal. This organism displays a clear habitat preference, thriving primarily on tree bark surfaces in open forest areas with sufficient sunlight. Its strong adaptability allows it to spread widely across various environmental conditions (Hutasuhut et al., 2021).

3.8. *Cryptothecia striata*

Figure 9. Personal Documentation of *Cryptothecia striata* in Tegalrejo

Kingdom : Fungi

Division : Ascomycota
Class : Lecanoromycetes
Order : Arthoniales
Family : Arthoniaceae
Genus : Cryptothecia
Species : *Cryptothecia striata*

Cryptothecia striata is a crustose lichen characterized by a white to grayish-white thallus with a distinctive striated pattern on its surface. The thallus is thin and firmly attached to the bark of trees in humid tropical forests. This species produces reproductive structures known as ascomata, which are embedded within the thallus (cryptothecioid), and contain hyaline, septate spores. A unique feature of this species is the presence of calcium oxalate crystals forming a reticulate pattern on the thallus surface. *Cryptothecia striata* is frequently found as an epiphyte on old trees in lowland to montane forests with high humidity (Suniyanti et al., 2022).

3.9. *Graphis* sp.

Figure 10. Personal Documentation of *Graphis* sp. in Tegalrejo

Kingdom : Fungi
Division : Ascomycota
Class : Lecanoromycetes
Order : Graphidales
Family : Graphidaceae
Genus : Graphis
Species : *Graphis* sp.

Graphis sp. exhibits a crustose thallus that is white to grayish-white in color, firmly attached to the bark substrate, generally round in shape, and marked with a speckled surface. The thallus features black isidia in its central area, functioning both as vegetative reproductive structures and as extensions that increase the surface area for assimilation. The thallus typically measures 2–5 cm, with black apothecia about 0.2 mm in length. Graphis is a cosmopolitan genus comprising around 400 species, commonly found in tropical and subtropical regions, including the lower parts of tree trunks as observed (Murningsih & Mafazaa, 2016).

4. CONCLUSION

This study successfully identified nine lichen species (*Flavoparmelia caperata*, *Physcia atrostriata*, *Dirinaria applanata*, *Phlyctis argena*, *Acarospora socialis*, *Ropalospora viridis*, *Pyxine sorediata*, *Cryptothecia striata*, and *Graphis* sp.) across three study sites (Temon, Depok, and Tegalrejo), reflecting the rich lichen diversity in tropical regions of Indonesia. Observations highlight the vital role of lichens as bioindicators of air quality and ecological pioneers, showcasing unique adaptations to marginal environments through mutualistic symbiosis between fungi and photobionts. These findings reinforce the potential of lichens in environmental monitoring and biodiversity studies. Future research is recommended to include broader mapping of lichen species distribution in Indonesia, along with exploration of their applications in bioremediation and ecosystem health assessment.

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