Jurnal Silvikultur Tropika
Journal of Tropical Silviculture
Vol. 16 No. 03, Desember 2025, Hal 186-198
p-ISSN: 2086-8277
e-ISSN: 2807-3282

LICHEN DIVERSITY IN TWO LOCATIONS WITH DIFFERENT AIR QUALITY IN BOGOR REGENCY

Lichen Diversity in Two Locations with Different Air Quality in Bogor Regency

Siti Badriyah Rushayati[1], Anggi Febry Setyanie Putri Daulay[1], and Elis Nina Herliyana[2*]

(Diterima 26 Juni 2025 / Disetujui 6 November 2025)

ABSTRACT

Lichen, commonly called crustal moss, is a symbiosis between algae and fungi resistant to extreme temperatures. The purpose of this study was to assess the diversity of lichen species, the composition of lichen species, and the lichen response in two research locations with different air quality. The selected locations were determined by knowing the environmental characteristics, including air temperature, air humidity, and CO_2 air quality. The value of lichen species diversity in Agatis Street (2.03) was higher than in Korps Sukarela (KSR) Dadi Kusmayadi Street, Cibinong (1.86). The composition of lichen found on Agatis Street is 8 species from 6 families, and 6 species from 3 families on Korps Sukarela (KSR) Dadi Kusmayadi Street, Cibinong. Lichen living on Jalan Agatis showed a brighter and clearer coloured talus response, the talus grew well and intact and formed colonies so that it had a wider talus cover. Lichen growing on KSR Dadi Kusmayadi Street has a paler and faded color the talus does not grow optimally so it grows in fragments and does not form large colonies, so it has a smaller talus cover area.

Keywords: air quality, bioindicator, lichen

ABSTRAK

Lichen atau yang biasa disebut lumut kerak merupakan simbiosis antara alga dan fungi yang tahan terhadap suhu ekstrem. Tujuan penelitian ini adalah untuk mengkaji keanekaragaman jenis lichen, komposisi jenis lichen, dan respon lichen pada dua lokasi penelitian dengan kualitas udara yang berbeda. Pemilihan lokasi ditentukan dengan mengetahui karakteristik lingkungan meliputi suhu udara, kelembaban udara, dan kualitas udara CO_2. Nilai keanekaragaman jenis lichen di Jalan Agatis (2,03) lebih tinggi dibandingkan dengan Jalan Korps Sukarela (KSR) Dadi Kusmayadi, Cibinong (1,86). Komposisi lichen yang terdapat di Jalan Agatis sebanyak 8 jenis dari 6 famili, dan di Jalan KSR Dadi Kusmayadi sebanyak 6 jenis dari 3 famili. Lichen yang hidup di Jalan Agatis menunjukkan respon talus yang berwarna lebih cerah dan jernih, talus tumbuh dengan baik dan utuh serta membentuk koloni sehingga memiliki tutupan talus yang lebih luas. Lumut kerak yang tumbuh di Jalan Korps Sukarela (KSR) Dadi Kusmayadi, Cibinong mempunyai warna lebih pucat dan memudar, talusnya tidak tumbuh optimal sehingga tumbuh secara terfragmentasi dan tidak membentuk koloni besar sehingga luas tutupan talusnya semakin mengecil.

Kata kunci: bioindicator, kualitas udara, lichen

1 Departemen Konservasi Sumberdaya Hutan dan Ekowisata, Fakultas Kehutanan dan Lingkungan, IPB University
2 Departemen Silvikultur, Fakultas Kehutanan dan Lingkungan, IPB University
*Penulis Korespondensi:
e-mail : elishe@apps.ipb.ac.id

INTRODUCTION

Increasingly dense urban traffic due to the increasing number of private motor vehicles causes increased air pollution, especially from emissions containing pollutants such as Pb, CO, CO_2, and sulfur. The impact of this increase in air pollution is very detrimental to the environment and human health. Because changes in air quality are often invisible to the naked eye, the use of bioindicators is important to monitor these conditions. Bioindicators, such as lichen and butterflies, can provide biological responses to foreign substances entering the environment.

Lichen or lichens are a symbiosis between algae and fungi that can survive extreme temperatures. By studying the species, number, and distribution of lichen in contaminated areas, we can estimate the level of air pollution. Lichens are resistant to harsh living conditions, including long-term water shortages, and can grow in extreme environments such as deserts and Antarctica with temperatures below 0 ℃. Their morphological structure, which does not have a cuticle layer, stomata, or absorption organs, allows lichens to survive in environments polluted by air pollutants.

Lichen can be used as a bioindicator of air pollution because of its ability to absorb chemicals in the air and rainwater. Although it can live in extreme environmental conditions, lichen remains sensitive to pollution, especially sulfur gas (SO_4) produced by motor vehicles. The sensitivity of lichen to these pollutants makes it an effective bioindicator for monitoring air quality. The use of lichen as a bioindicator is also more efficient compared to ambient indicator is also more efficient compared to ambient indicator devices, which require high costs. However, studies that directly compare lichen diversity and morphological responses across two locations with differing air quality in the Bogor region remain limited. Therefore, this study was conducted to assess the diversity, species composition, and morphological responses of lichen as indicators of air quality in two sites with contrasting environmental characteristics.

RESEARCH METHODS

Time and Place

The research was conducted in February 2024, at two different locations in Bogor Regency, precisely on KSR Dadi Kusmayadi Street, Cibinong, and Agatis Street, Dramaga Campus IPB University, which is presented in Figure 1.

Tools and Materials

The tools used in this study are presented in Table 1. The materials used are lichen that lives on tree bark, trees as a substrate for lichen, and distilled water.

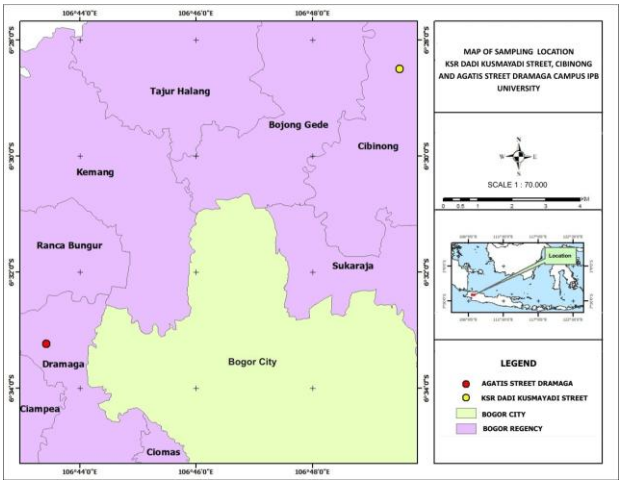


Figure 1 Map of the two research locations, Bogor Regency, precisely on KSR Dadi Kusmayadi Street, Cibinong, and Agatis Street, Dramaga Campus, IPB University.

Selection of Research Locations in The Field

The selection of research locations was carried out by considering various areas that represent different air quality. The first research location chosen was an area with relatively poor air quality, because it is often passed by many motorized vehicles and is one of the main roads in Cibinong, namely KSR Dadi Kusmayadi Street, Cibinong District. The second research location chosen was an area with relatively clean air quality, because it is still below the national ambient air quality standard (Anisah 2021), namely Agatis Street, IPB Dramaga Campus, Dramaga district. The research location chosen was by the quality measurement data, namely on KSR Dadi Kusmayadi Street, Cibinong has a higher air quality standard value than Agatis Street.

Data Collection Procedure

In this study, two types of data were collected, namely primary data and secondary data (Table 2).

Environmental Characteristics

The environmental characteristic parameters used in collecting research data are abiotic environmental characteristics, namely temperature and humidity measurements. Temperatures and humidity measurements were taken three times a day, at 07:30, 13:30, and 17:30 WIB. Measurement of CO and CO2 air quality was conducted over three days, with one repetition at 10:00 WIB at two research locations using CO and CO2 measuring instruments.

Table 1 Tools used in research

No	Name	Function
1	Measuring tape	Measuring the circumference of the tree trunk
2	Envelope	Storing lichen samples
3	Cutter	Taking lichen samples
4	Dry wet thermometer	Measuring air temperature and humidity
5	Transparent plastic and OHP pen	Tracing the area of lichen cover
6	Clear tape and scissors	Stick the transparent plastic
7	Analytical scales	Weighing the area of lichen
8	Stationery and tally sheet	Recording data
9	Carbon meter	Measuring carbon levels in the air

Table 2 Types of data collected in research

Data Type	Description
Primary	Environmental characteristics include air temperature and relative humidity in two research locations Trees as a substrate include diameter, height and surface of tree bark in two research locations Composition, lichen diversity, and frequency of lichen in two research locations Microscopic characteristics of lichen include shape and color of lichen in two research locations Area of lichen cover based on stem height range, facing and gacing away from pollution sources Air quality data CO dan CO2
Secondary	Search for microscopic characteristics and morphology of lichen types WHO ambient air quality standards

Characteristics of Mahogany Trees as Lichen Substrate in KSR Dadi Kusmayadi Street, Cibinong District, and Agatis Street, Dramaga Campur IPB University, Dramaga District

The selection of lichen substrate tree samples used in this study was carried out purposively, namely, large leaf mahogany trees (*Switernia macrophylla*). Large leaf mahogany trees were chosen as sample trees because they were found in two research locations. The number of trees taken at each location was 5 tree samples (a total of 10 trees) with a diameter range of ≥20 cm. The trees used as samples were measured around the top and bottom of the tree, which was 150 cm above ground level (Asih 2013; Mafaza *et al.* 2019).

Composition and Morphology of Lichen Types

Lichen observation began by selecting mahogany trees as lichen substrates in two research locations. Observations were carried out visually by observing the macroscopic characteristics of the lichen thallus on each tree sample, such as shape, color, and condition. Lichen samples were documented with a camera and then identified based on the field guide.

Diversity of Lichen Types

Observations of lichen on trees were carried out at a height range of 0-150 cm from the ground surface by identifying based on the morphological types, namely *squamulose, crustose, foliose,* and *fruticose. Crustose* lichens have small, flat, thin thallus attached to rock surfaces, tree bark, and soil (Ulfa *et al.* 2023). *Squamulose* lichens have squamulus, which are smaller, interlocking, scale-like lobes and fruiting bodies (podetia) (Ertz & Thaler 2017; Ulfa *et al.* 2023). *Fruticose* lichens have a bush-like thallus with ribbon-like branches that grow upright or hang from rocks, leaves, or tree branches. *Foliose* lichens have a leaf-like structure composed of lobes and attached to the substrate. *Foliose* lichens have a flat, slightly wide thallus with indentations resembling a wrinkled leaf (Ulfa *et al.* 2023).

Calculation of Lichen Coverage Percentage

The area of lichen cover on the bark of each tree was measured up to a height of 150 cm. The measurement was divided into three height ranges, namely 0-50 cm, 51-100 cm, and 101-150 cm. The area of the thallus cover was obtained by drawing and tracing lichen thallus on transparent plastic weighed using an analytical scale. Furthermore, it was converted into an area (cm^2) based on the weight of 1 cm^2 of plastic.

Analysis Data

Air Temperature and Relative Humidity

Air Temperature (°C)

$$°C = \frac{(2 \text{ x Tmorning})+(\text{Tafternoon})+(\text{Tevening})}{4}$$

Air humidty (%)

$$\% = \frac{(2 \text{ x RHmorningi})+(\text{RHafternoon})+(\text{RHevening})}{4}$$

Description:
T : Air temperature
KU : Air humidity

Air Samples

CO2 pollutant data analysis was carried out descriptively, qualitatively and quantitatively, then compared with WHO (*World Health Organization*) standards.

Species Diversity Index (H')

The diversity of lichen species is determined using the Shannon-Whiener diversity index (H') with the following formula (Zar 2010; Omayio et al. 2019):

$H' = -\sum pi \ln pi$; $pi = \frac{ni}{n}$ (Odum 1996)

Description:
H' : Shannon-Whiener diversity index
ni : Number of individuals of each species
n : Number of individuals of all species
pi : Abundance of each species

Lichen Encounter Frequency

The frequency of lichen encounters is obtained using the following formula:

$$\text{Frequency of type} = \frac{\text{number of points found of a type}}{\text{total number of observation points}} x\ 100\%$$

(Soerinegara dan Indrawan 1998)

Surface Area of Bark

The surface area of bark is obtained using the following formula:

Surface of bark = 0.5 × (a+b) × c (Noer 2004)

Description:
a : Circumference of the upper tree trunk (cm)
b : Circumference of the lower tree trunk (cm)
c : Height of the observed tree trunk (150 cm from the ground surface)

Lichen Coverage Area

The bark surface area is obtained using the following formula:

$A = (\frac{wt}{wi})$ x 1 cm^2 (Brodo 1961 diacu oleh Leblanc dan Rao 1973)

Description:
A : Lichen cover area (cm^2)
wt : Total weight of transparent plastic measured based on the area of plastic covered by lichen thallys (mg)
wi : Total weight of transparent plastic with an area of 1 cm^2 (mg)

Lichen Coverage Percentage

The lichen coverage percentage is obtained using the following formula:

$$\text{Lichen coverage percentage} = \frac{\text{lichen coverage area}}{\text{bark surface area}} x100\%$$

RESULTS AND DISCUSSION

Environmental Characteristics

General Conditions

This study was conducted in two different locations in Bogor Regency, namely KSR Dadi Kusmayadi Street in Cibinong and Agatis Street in Dramaga. KSR Dadi Kusmayadi Street was chosen because it is a main route that is often used by motorized vehicles, considering the presence of many office buildings, so it is suspected to have poor air quality. On the other hand, Agastis Street was chosen because the air quality at this location is considered better, with data from Anisah (2021) showing that the air quality on Agastis Street is still below the national ambient air quality standard.

According to the Bogor Regency Environmental Service (2021), the air quality index (IKU) in Bogor Regency reached 76.62% which is included in the "good" category based on the Regulation of the Minister of Environment No. 14 of 2019, which stipulates that an IKU value of 51-100 is classified as good air quality.

Air Temperature and Humidity

The average temperature and humidity measurements on KSR Dadi Kusmayadi Street were 27.33 ℃ and 86.69%, while on Agatis Street it was 26.75 ℃ and 88.54% (Table 3). Vegetation around the research location affects temperature and humidity, with the role of the canopy as shade and the evapotranspiration process helping to cool the environment. Urban areas tend to have less vegetation than suburban areas, which causes urban temperatures to be higher.

Air Quality

Lichen, very sensitive to temperature, humidity, and air pollution, can be used as a bioindicator of air pollution. In addition, lichen is also responsive to metal content in the air. The lower the traffic density, the higher the ecosystem diversity in a location.

In this study, CO_2 levels were measured using the WHO reference, which sets clean air standards with CO_2 levels between 310-330 ppm (558,000-594,000 $\mu g/Nm^3$) and polluted air between 350-700 ppm (630,000-1,260,000 $\mu g/Nm^3$). The results of CO2 measurements show that KSR Dadi Kusmayadi Street has polluted air quality, while Agatis Street has clean air quality. Air quality data at both locations can be seen in Table 4.

Characteristics of Trees as Substrates

Mahogany (*Swietenia macrophylla*) is a large tree that can reach a height of 35-40 meters and a

diameter of up to 1.25 meters. This tree is easy to cultivate in various types of soil and grows wild in teak forests or coastal areas, often planted on the side of the road as a shade tree (Prasetyono, 2012). Mahogany is useful in absorbing air pollutants such as carbon dioxide, nitrogen oxide, and sulfur dioxide, which are then converted into harmless compounds. Mahogany leaves also release oxygen, increasing the freshness of the surrounding air (Oliviera *et al.* 2023).

According to Rozianty (2016), factors such as wood stability, wood texture, pH, and water availability affect lichen growth on the surface of the tree. The diameter of the tree trunk affects the area of lichen cover. On KSR Dadi Kusmayadi Street, the diameter of the mahogany tree trunk ranges from 54.14 cm to 76.43 cm, while on Jalan Agatis it is between 50.95 cm and 73.24 cm. Mahogany trees at these two locations can be seen in Figure 3.

The tree canopy on Agatis Street tends to be wider and denser. In this location, there are many types of trees with side canopies that can block direct sunlight. This tree canopy affects the microclimate conditions around it, which in turn affects the survival of lichen growing on the tree bark.

a b

Figure 2 General conditions (a) KSR Dadi Kusmayadi, (b) Agatis Street

Table 3 Results of daily air temperature and relative humidity measurements

Days	KSR Dadi Kusmayadi Street		Agatis Street	
	T (°C)	KU (%)	T (°C)	KU (%)
1	26.67	84.87	25.67	87.30
2	26.17	86.00	25.00	86.97
3	29.17	89.20	28.50	91.37
Mean	27.33	86.69	26.75	88.54

Table 4 Results of CO2 measurements on KSR Dadi Kusmayadi Street and Agatis Street

Parameter	One Hour Quality Standard (ppm)[a]		Location	
	Clean	Polluted	I[b]	I[c]
CO2	310-330	350-700	537	430

Reference: [a]WHO Standard, [b] KSR Dadi Kusmayadi Street, [c] Agatis Street.

a b

Figure 3 Mahony Trees (a) KSR Dadi Kusmayadi Street, (b) Agatis Street

Lichen Composition and Frequency

Lichen Composition on Mahogany Trees as Bioindicators of Air Quality at Two Research Locations in Bogor Regency. *Lichen* is a symbiotic organism consisting of fungi (mycobiont) from the Ascomycetes and Basidiomycetes groups and algae, such as cyanobacteria or blue-green algae (ficobiont). Algae play a role in photosynthesis and provide carbohydrates for lichen. The lichen body consists of several parts, including the thallus, isidia, soredia, *apothecia, pycnidia*, and *rhizines*. Some types of lichen, such as *Parmella, Sticta*, and *Peltigerales*, have special structures on the thallus, such as respiratory pores, syphilis, and sedalodia.

Based on the shape of the thallus, lichen is classified into four types: *crustose* (crust), *foliose* (leaf), *fruticose* (bush or beard), and *squamulose* (scales). *Crustose lichens* are attached to substrates such as tree surfaces or rocks, foliose are leaf-shaped with constricted lobes, fruticose have ribbon-like branches and grow upright or hanging, while squamulose have a thallus in the form of small overlapping lobes.

The composition of *lichen* species found on KSR Dadi Kusmayadi Street and Agatis Street is presented in Table 5. Observations show that 8 types of lichen are from the *crustose* type and 2 from the *foliose* type.

The composition of lichen species on Jalan Agatis is greater than on Jalan KSR Dadi Kusmayadi. On Jalan KSR Dadi Kusmayadi, 6 types of lichen from 3 families were found, while on Jalan Agatis, 8 types of lichen from 6 families were found. These results are in line with the research of Syarif A (2018), which stated that high traffic volume reduces the number of lichens. In addition to pollution, the microclimate influenced by vegetation and air quality also affects the number of lichen species composition.

Lichen growth is influenced by pollutants such as CO_2, SO_2, NO_2, and dust from vehicle exhaust fumes (Rozianty, 2016). Environmental factors such as temperature, humidity, pH, and air quality also play a role. *Lichens* found in both locations include crustose and foliose thallus types, with crustose being more tolerant to air pollution due to its simple thallus structure.

Lichens found in locations with cleaner air quality are called sensitive *lichens*, while those found in both polluted and clean locations are called tolerant *lichens*. The types of *lichens* found in both research locations are *Lepraria incana, Leparia lobificans, Leparia umbricola,* and *Dirinaria picta*. The types of lichens found only on Jalan Agatis *include Cryptothecia scripta, Phlyctis argena, Caloplaca sp.,* and *Parmelia perlata* (Figure 4).

Table 5 Composition of lichen species on mahogany trees on KSR Dadi Kusmayadi Street and Agatis Street

No.	*Lichen*	Family	Talus	Location	
				I	II
1	*Lepraria incana*	Steriocaulaceae	*Crustose*	✓	✓
2	*Cryptothecia scripta*	Arthoriceae	*Crustose*	-	✓
3	*Phlyctis argena*	Phylictidaceae	*Crustose*	-	✓
4	*Graphis cincta*	Graphidaceae	*Crustose*	✓	-
5	*Leparia lobificans*	Steriocaulaceae	*Crustose*	✓	✓
6	*Leparia umbricola*	Steriocaulaceae	*Crustose*	✓	✓
7	*Graphis scripta*	Graphidaceae	*Crustose*	✓	-
8	*Caloplaca* sp.	Teloschistaceae	*Crustose*	-	✓
9	*Parmelia perlata*	Parmeliceae	*Foliose*	-	✓
10	*Dirinaria picta*	Physiaceae	*Foliose*	✓	✓

Description: I) KSR Dadi Kusmayadi Street, II) Agatis Street

a b c d

Figure 4 *Lichen* in Agatis Street (a) *Cryptothecia scipta,* (b) *Phlyctis argena,* (c) *Caloplaca* sp., (d) *Parmelia perlata*

Lichen Diversity

The diversity of lichen species is known from the large number of lichen species found in the two research locations. The diversity of lichens on mahogany trees on Agatis Street is higher than on KSR Dadi Kusmayadi Street. Table 6 presents the diversity of lichen species in the two research locations.

Table 6 Diversity of lichen species on Jalan KSR Dadi Kusmayadi and Jalan Agatis

No	Research Location	Diversity of *lichen* species (H')
1	KSR Dadi Kusmayadi Street	1.86
2	Agatis Street	2.03

The diversity of lichen species on Agatis Street (2.03) is higher than on KSR Dadi Kusmayadi Street (1.86). This is related to the higher humidity on Agatis Street, which supports lichen metabolism and growth. According to Bordeaux (2015), high humidity indicates that the location has a high air content, which is absorbed by the plant for its metabolism and growth. Lichen growth is influenced by temperature and humidity (Hardini *et al.* 2018). Temperature and humidity affect lichen growth. Light intensity is needed for lichen photosynthesis.

Lichen is often found on tree bark, its main substrate (Pratiwi 2006). Lichen diversity is influenced by the type of substrate and its pH, where some species prefer acidic or alkaline conditions. Interactions with other organisms and overall ecosystem conditions also affect the presence of lichen. According to Widodo *et al*. (2023), these factors support lichen growth in various habitats.

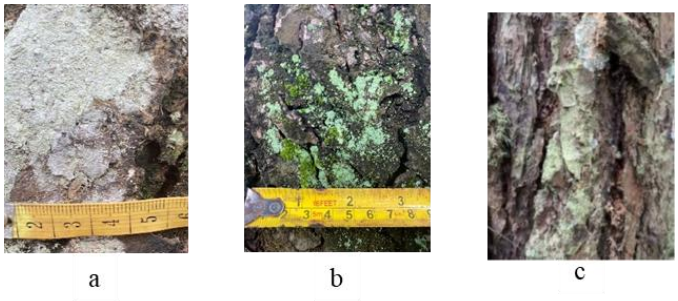
Macroscopic Characteristics of *Lichen*

Lichen growing in locations with different air quality show different responses. *Lichen* in high pollution locations tend to be paler due to the accumulation of pollutants in the thallus. The thallus becomes darker over time due to age and growing conditions. Differences in pollution and air quality affect the macroscopic and morphological characteristics of *lichen*, such as shape, texture, size, and color. Observations at the two locations showed differences in these characteristics.

Lepraria incana has a bright green or grayish green thallus and is often called "leprose" flour lichen because of its flour-like appearance (Waruwu et al., 2022). This lichen is a crustose type that adheres to the substrate and has soredia that are evenly distributed on the surface of the thallus, and easily detached when touched. On Agatis Street, the *L. incana* thallus forms unified colonies in cleaner air locations, while on KSR Dadi Kusmayadi Street, the thallus is irregularly distributed. *Lepraria incana* on KSR Dadi Kusmayadi Street is more grayish, while on Jalan Agatis it is greener and clearer, as seen in Figure 5.

Lepraria umbricola has a thallus with a diameter of 7-12 cm and is included in the crustose type that attaches to the substrate. This lichen has a thin thallus and an irregular shape, usually growing on rocks, wood, soil, and trees. On KSR Dadi Kusmayadi Street, the *L. umbricola* colony is smaller and less dense than that on Agatis Street. On Agatis Street, the texture of the thallus tends to be smoother and flatter, with a clearer bright green color, while on KSR Dadi Kusmayadi Street, it looks dull green, as seen in Figure 6.

Lepraria lobificans is a crustose lichen that grows as granular, layered, or leprose patches on the substrate, especially on tree bark. According to Muvidha (2020), this lichen is widespread and often found in urban areas. *L. lobificans* granules are apple green, faded light green, or greenish gray. On Agatis Street, the *L. lobificans* colonies are larger and more numerous, while on KSR Dadi Kusmayadi Street the colonies are fewer and more scattered, as seen in Figure 7.

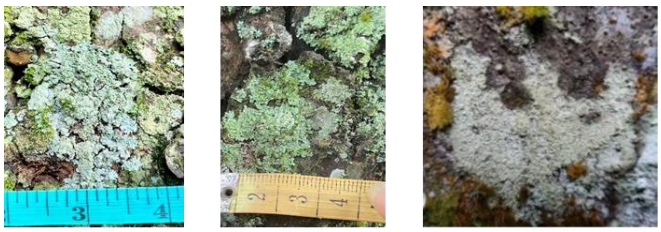


a b c

Figure 5 *Lichen* species *Lepraria incana* on (a) KSR Dadi Kkusmayadi Street, (b) Agatis Street, (c) source: (published by Waruwu 2021)

a b c

Figure 6 *Lichen* species *Lepraria umbricola* on (a) KSR Dadi KUsmayadi Street, (b) Agatis Street, (c) source: https://fungi.myspecies.info/all-fungi/lepraria-umbricola.



a b c

Figure 7 Lichen species Lepraria lobificans on (a) KSR Dadi Kusmayadi Street, (b) Agatis Street, (c)source: (published by Waruwu 2021).

a b

Figure 8 *Lichen* species *Phlyctis argena* on (a) Agatis Street, (b) source: (published by Ulfa et al. 2024).

a b c

Figure 9 *Lichen* species *Dirinaria picta* on (a) KSR Dadi Kusmayadi Street, (b) Agatis Street, (c) source: (published by Setyani 2017).

The difference between *Lepraria incana*, *Lepraria umbricola*, and *Lepraria lobificans* lies in the shape of the thallus and its color. *Lepraria umbricola* has a greener color, while *Lepraria lobificans* have a thicker thallus than the other two types. *Lepraria incana* and *Lepraria lobificans* have soredia, but *Lepraria lobificans* rarely produce apothecia, sexual reproductive structures.

Phlyctis argena has a thin crust-like thallus with varying colors, ranging from grayish green to white. Its characteristic is black *apothecia*, round or slightly elongated in shape with clear edges (Figure 8). This *lichen* is often found on tree bark, especially old trees with rough bark such as mahogany trees. *Phlyctis argena* is found on older trees with rough bark, such as mahogany.

Dirinaria picta, a foliose *lichen*, has a leaf like thallus, grooved at the edges, and grayish green in color. *Dirinaria picta* dominates in areas with high pollution due to a thick algae layer. The foliose thallus has a round shape with irregular lobes, is tightly attached to the center of the substrate, and hangs at the edges. On KSR Dadi Kusmayadi Street, the *Dirinaria picta* is more abundant with a thicker thallus, while on Agatis Street, the thallus is paler, as seen in Figure 9.

a b

Figure 10 *Lichen* species *Cryptothecia scripta* on (a) Agatis Street, (b) source: (published by Waruwu 2021).

a b

Figure 11 *Lichen* species *Graphis cincta* on (a) KSR Dadi Kusmayadi Street, (b) source (published by Waruwu 2021)

Cryptothecia scripta is a crustose lichen with a thallus that is tightly attached to the bark of the tree trunk, grayish-green in color with white edges. The thallus is horizontal and has rhizine, which is a network of hyphae that attach to the substrate. This lichen was found on KSR Dadi Kusmaya di Street, as seen in Figure 10.

Graphis cincta is a crustose lichen with a grayish-white or pale white thallus, 10-15 cm in diameter, and branched submerged black apothecia. This *lichen* colony is 0.3 mm to 2.5 mm long and is often found attached to the surface of tree bark, difficult to remove without damaging the substrate. This *lichen* is only found on KSR Dadi Kusmayadi Street, as seen in Figure 11.

Graphis scripta is a grayish-white crustose lichen with apothecia modified into Lirellae, elongated and curved, black. This lichen is characterized by black lines on the surface of its thallus, as seen in Figure 12. *Graphis scripta* is only found on KSR Dadi Kusmayadi Street.

a b

Figure 12 *Lichen* species *Graphis scripta* on (a) KSR Dadi Kusmayadi Street, (b) source (published by Waruwu 2021).

a b

Figure 13 *Lichen* species *Caloplaca sp.* on (a) Agatis Street, (b) source: https//naturemapr.org/species/2243

a b

Figure 14 *Lichen* species *Parmelia perlata* on (a) Agatis Street, (b) source (published by Waruwu 2021)

Figure 15 *Lichen Parmotrema perlatum* (Ulfa *et al.* 2023)

Caloplaca sp. lives in colonies with variations in thallus color, including yellow, faded yellow, egg yellow, orange yellow, and reddish orange. This lichen is a crustose type that is attached to substrates such as old trees or dead and decaying trees. *Caloplaca* sp. is only found on Agatis Street, as seen in Figure 13.

Parmelia perlata is a *foliose lichen* with a nearly perfectly round thallus, green, sometimes gray, dark brown, or brown. This lichen has an upper and lower cortex, loose attachment to the substrate, and rhizines except around the edge of the thallus. The condition of *Parmelia perlata* on Agatis Street can be seen in Figure 14. This is in accordance with observations made by Ulfa et al. (2023) (Figure 15) that Parmotrema perlatum is also included in the Foliose thallus type because it has a green to gray color with raised edges, usually on the bark of tree trunks.

Lichen Cover Area

The area of *lichen* cover on Agatis Street is greater than on KSR Dadi Kusmayadi Street, which is influenced by differences in air quality, temperature, and humidity. In mahogany trees, the largest *lichen* cover was found at a height of 0-50 cm, where the intensity of exposure to pollutants is lower because it is protected by undergrowth. According to Setyani (2017), lichen cover is greater in areas facing away from pollutant sources than in areas facing the pollutant source. This is because the back of the tree is less exposed to pollutants, while the front of the tree faces the pollutant source, one of which is pollutants from motor vehicles. Lichen growing behind the tree has a larger coverage area than the front, and this occurred at both locations. The results of the calculation of the area of lichen cover at various heights are presented in Table 6.

The area of lichen cover on KSR Dadi Kusmayadi Street was 1268.19 cm², while on Agatis Street it was 2699.47 cm². The calculation results in Table 8 show that the part of the tree trunk facing away from the pollution source has a higher lichen cover than the one facing the pollutant. This finding is in line with Sofyan's research (2017), which states that the part of the tree facing away from the pollutant has better environmental quality. Lichen growth is influenced by internal factors such as tree bark condition, water content, and nutrient availability, as well as external factors such as air quality, humidity, light intensity, and pollution.

Table 7 Area of *lichen* cover on mahogany trees with different height ranges at two research locations

Tree height (cm)	KSR Dadi Kusmayadi Street		Agatis Street	
	Facing pollutant (cm²)	Back to the pollutant (cm²)	Facing pollutant (cm²)	Back to the pollutant (cm²)
0-50	150,63	220,27	331,58	548,47
50-100	225,09	339,21	525,34	735,33
100-150	160,75	226,24	217,5	341,25
Total	482,47	785,72	1074,42	1625,05

Table 8 Percentage of thallus cover area per *lichen* type to tree bark on KSR Dadi Kusmayadi Street

No	*Lichen* species	Coverage area cm²	Coverage (%)
1	*Lepraria incana*	329,21	2,36
2	*Graphis cincta*	118,79	0,85
3	*Lepraria lobificans*	334,17	2,40
4	*Lepraria umbricola*	245,43	1,76
5	*Graphis scripta*	150,12	1,08
6	*Dirinaria picta*	90,47	0,65
Total		1268,19	9,09

Table 9 Percentage of thallus cover area per *lichen* type to tree bark on Agatis Street

No	*Lichen* species	Coverage area cm^2	Coverage (%)
1	*Lepraria incana*	421,16	2,84
2	*Cryptothecia scripta*	375,36	2,53
3	*Phylictis argena*	388,59	2,62
4	*Lepraria lobificans*	531,65	3,58
5	*Lepraria umbricola*	431,98	2,91
6	*Caloplaca* sp.	89,56	0,60
7	*Parmelia perlata*	298,76	2,01
8	*Dirinaria picta*	162,41	1,09
Total		2699,47	18,18

The results of the calculation of the percentage of the thallus cover area of each type of lichen on KSR Dadi Kusmayadi Street are presented in Table 7. *Lepraria lobificans* has the highest cover area, which is 2.40%, indicating good tolerance to environmental factors and pollution at the location. In contrast, *Dirinaria picta* has the lowest percentage, 0.65%, indicating its intolerance to environmental factors and pollution, so its growth is more limited compared to other types of lichen.

The results of the calculation of the percentage of the thallus cover area of each type of *lichen* on Agatis Street are presented in Table 8. *Lepraria lobificans* has the highest cover area, which is 3.58%, indicating tolerance to environmental factors and pollution at the location. In contrast, *Caloplaca* sp. has the lowest percentage, 0.60%, indicating its intolerance to environmental factors and pollution, so its growth is more limited compared to other types of lichen.

Table 10 Percentage of *lichen* cover on tree bark based on height from ground level at two research locations

Height (cm)	KSR Dadi Kusmayadi Street (%)	Agatis Street (%)
0-50	2,66	5,93
50-100	4,05	8,49
100-150	2,39	3,76
Total	9,09	18,18

The calculation results in Table 9 show that Agatis Street has a higher *lichen* cover area (18.18%) compared to KSR Dadi Kusmayadi Street(9.09%). This difference reflects the lichen response to environmental quality. The high concentration of pollutants on KSR Dadi Kusmayadi Street reduces lichen cover because air pollution harms its growth. In addition to pollution, air humidity also affects *lichen* growth, with Agatis Street having higher humidity, supporting better lichen growth. The denser tree conditions on Agatis Street also block light, maintain higher water reserves, and create a more humid environment for *lichen* growth.

CONCLUSIONS AND SUGGESTIONS

Conlusions

The composition of lichen species found along Jalan Agatis consisted of eight species from six families, while six species from three families were identified along Jalan KSR Dadi Kusmayadi. *Lepraria lobificans* showed a frequency of 100% at both locations. The highest thallus cover was recorded at a height of 50–100 cm. The lichen diversity index on mahogany trees was 2.03 on Jalan Agatis and 1.86 on Jalan KSR Dadi Kusmayadi. Lichens on Jalan Agatis exhibited brighter and more distinct thallus coloration, with well-developed and intact growth forming larger colonies, resulting in wider thallus coverage. In contrast, lichens along Jalan KSR Dadi Kusmayadi appeared paler and faded, with fragmented and less optimal growth, leading to smaller thallus cover. The variation in lichen response at the two locations was influenced by differences in air pollution levels and microclimatic factors such as temperature, humidity, and light intensity.

Suggestion

The differences in macroscopic characteristics and lichen responses between the two study sites indicate that lichens can be used as bioindicators of air quality. Further research is needed to compare lichen growth with air quality parameters related to bioindication.

ACKNOWLEDGMENTS

The researchers would like to express their sincere gratitude to the Department of Forest Resources Conservation and Ecotourism, Faculty of Forestry and Environment, IPB University, for providing the facilities and support during the research. Special thanks are extended to the field

assistants and laboratory staff who contributed to data collection and analysis. The researches also thank the local authorities of Cibinong and Dramaga for their permission to conduct the study in the designated areas. Appreciation is also given to Adisti Triani Wandayanti, S.Hut., for her valuable assistance in preparing and writing this journal manuscript.

REFERENCES

Anisah A. 2021. Kajian lumut kerak sebagai bioindikator kualitas udara di dua lokasi berbeda [skripsi] Bogor: Institut Pertanian Bogor.

Asih SM. 2013. Keanekaragaman jenis lichenes epifit pada hutan kopi dan hutan campuran Nglimut Gonoharjo Kendal. [Skripsi]. Semarang: Universitas Diponegoro.

Bordeaux C. 2015 Keanekaragaman lumut kerak sebagai bioindikator kualitas udara di Kebun Raya Cibodas, Kebun Raya Bogor dan *ECOPARK*-LIPI Cibinong [skripsi] Bogor: Institut Pertanian Bogor.

Chandra RH. 2015. Akumulasi timbal (Pb) dan keanekaragaman jenis *lichens* di Taman Kota Medan. *Biolink.* 2(1): 23-37.

Fitri R. 2021. Jenis *lichenes* di Kawasan Seulawah Agam Kecamatan Lembah Seulawah Kabupaten Aceh Besar sebagai referensi mata kuliah botani tumbuhan rendah [skripsi]. Aceh: UIN Ar-Raniry.

Hardianto RI. 2015. Respons lumut kerak pada vegetasi pohon sebagai bioindikator pencemaran udara di Kawasan Industri Jakarta Timur [skripsi]. Bogor: Institut Pertanian Bogor.

Hardini J, Kasiamdari RS, Santosa, Purnomo. 2018. *Diversity of species crustose lichen pf plumeria spp. in Bali Island*. *Jurnal Metamorfosa*. 1:123

Indrawati D M, Widayani P. 2020. Analisis Pengaruh kerapatan vegetasi terhadap suhu permukaan dan keterkaitannya dengan fenomena UHI. *Media Komunikasi Geografi*. 21(1): 99-109.

Jannah H. 2015. Eksplorasi keberadaan *lichen (lichenes)* pada berbagai jenis tanaman di sepanjang Jalan Langko Kota Mataram. *Bioscientist*. 3 (1): 346-349.

Jumaidi, Oki F, dan Mades M. 2013. Keanekaragaman *lichen*es (lumut kerak) di sekitar perkebunan teh ptp nusantara vi Danau Kembar Kecamatan Gunung Talang Kabupaten Solok. *Jurnal Mahasiswa Pendidikan Biologi Genap 2013- 2014*. 2(2):1-6.

Kurniasih S, Munarti, Prasaja D, Lestari AA. 2020. Potensi liken sebagai bioindikator kualitas udara di kawasan Sentul Bogor. *JURNAL Penelitian Ekosistem Dipterokarpa*. 6(1): 17-24.

LeBlanc F dan Rao DN. 1973. *Effects of Sulphur Dioxide on Lichen and Moss Transplants. Ecology*. 5: 612-617.

Loopi S, Ivanov DBR. 2002. *Biodiversity of Epiphytic Lichens and Air Pollution in the Town Siena (Central Italy)*. *Environmental Pollution*. 16(16):123–128.

Mafaza H, Murningsih, Jumari. 2019. Keanekaragaman jenis lichen di Kota Semarang. *Lide Science* 8(1): 10-16.

McCune B, Grenon J, Mutch LS, Martin EP. 2007. *Lichen*s in relation tomanagement issues in the Sierra Nevada national parks. *Pacific Northwest Fungi* 2(3): 1-39.doi: 10.2509/pnwf.2007.002.003.

McMullin RT, Bennett LL, Bjorgan OJ, Bourque DA, Burke CJ, M.A. Clarke MA, Gutgesell MK, Krawiec PL, Malyon R, Mantione A, Piotrowski AT, Tam NY, Van Natto AC, Wiersma YF, Newmaster SG. 2016. *Impact of air pollution density on lichen diversity in the Niagara Escarpment World Biosphere Reserve*. *The Lichenologist*. 48: 593-605.s

Nofrizal, AY. 2018. Identifikasi Urban Heat Island di Kota Solok menggunakan Algoritma Landsat8 OLI Landsurface Temperature. *Media Komunikasi Geografi*. 19(1):31–41.

Omayio D, Mzungu E. 2019. Modification of Shannon-Wiener diversity index towards quantitative estimation of environmental wellenss and biodiversity levels under a non-comparative scenario. *Journal of Environment and Earth Science* 9(9): 46-57.

Oliveira JM, Correia AC, Silva LC. 2023. *The role of mahogany (Swietenia macrophylla) in air pollution mitigation in tropical forests*. *Forest Ecology and Management*. *918*: 102036.

Pelczar MJ, Chan ECS. 2007. *Dasar-Dasar Mikrobiologi*. Jakarta: UI-Pr.

Prasetyono DS. 2012. *A-Z Daftar Tanaman Obat Ampuh di Sekitar Kita*. Jogja: FlashBooks.

Pratiwi ME. 2006. Kajian lumut kerak sebagai bioindikator kualitas udara [skripsi]. Bogor: Institut Pertanian Bogor.

Raharjo HP, Haryanti S, Budihastuti R. 2015. Pengaruh tingkat kepadatan lalu lintas dan waktu pengamatan yang berbeda terhadap ukuran dan jumlah stomata daun glodokan. *J Biologi*. 4(1):73-84.

Rasyidah. 2018. Kelimpahan *lichen* (*Lichen*s) sebagai bioindicator kualitas udara di kawasan perkotaan Kota Medan. *Klorofil*. 1(2):88-92.

Roziaty E. 2016. Kajian *lichen*: morfologi, habitat, dan bioindikator kualitas udara ambien akibat

polusi kendaraan bermotor. *Bioeksperimen*. 2(1):54–66.

Setyani BA. 2017. Keanekaragaman lumut kerak di pohon mahoni pada tiga lokasi dengan kualitas udara berbeda di Kota Bandung [skripsi]. Bogor: Institut Pertanian Bogor.

Soerianegara I dan Indrawan A. 1998. *Ekologi Hutan Indonesia.* Bogor (ID): IPB Pres.

Sofyan N. 2017. Keanekaragaman lumut kerak sebagai bioindikator kualitas udara di Kawasan Industri Citeureup dan Hutan Penelitian Dramaga [skripsi].Bogor: Institut Pertanian Bogor.

Syarif A. 2018. Inventarisasi *Lichen* sebagai bioindikator pencemaran udara di Kecamatan Serengan Kota Surakarta [skripsi]. Surakarta: Universitas Muhammadiyah Surakarta.

Ulfa SW, Afdan RK, Nabilla M, Achyari PR, Nayla. 2023. Identifikasi jenis lumut kerak (*Lichenes*) di Kecamatan Percut Sei Tuan pada Desa Bandar Setia, Sampali dan Tembung. *Jurnal Ilmiah Wahana Pendidikan* 9(18): 683-692.

Waruwu FBNA, Hasairin A, Sudibyo M. 2022. *Keanekaragaman Jenis Liken (Lumut Kerak) di Kawasan Tahura Bukit Barisan*. Medan: CV. Global Aksara Per.

Widodo GA, Kartikasari D, Ichyaiddina AN, Pitaloka D. 2023. Keragaman *lichen* di Kawasan wisata Alam Kandung Kabupaten Tulungagung. *RADIKULA: Jurnal Ilmu Pertanian.* 2(1): 47-59.

Zar HJ. 2010. "Biostatistical analysis". 5th Edition, Prentice Hall Inc. Upper Saddle River, New Jersey.