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Identification of Mosses (Bryophytes) in The Curug Silawe Area Magelang Regency and Their Connection to Environmental Elements

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Abstract
Bryophytes are a group of low-level plants that grow widely and are found in tropical areas. Their distribution is influenced by biotic and abiotic factors such as water, light, temperature, humidity, and altitude. The ecological role of mosses in tropical ecosystems is to maintain water balance, nutrient cycling, bioindicators of environmental change, open space for other plants, and carbon sinks on peatlands. The role of moss is very important for the ecosystem, and there is no data on moss species in the Silawe waterfall area, so researchers conducted this study to identify environmental factors that affect moss diversity. Data collection for moss plants was carried out through a combination of exploration and field observation methods. Based on the results of observations, 7 species of moss, 5 leaf mosses (Bryopsida), and 2 liverworts (Marchantiopsida) were obtained. The identified moss species were *Funaria hygrometrica, Dicranum fuscescens, Fissidens sp., Hypnum cupressiforme, Entodon sp., Marchantia polymorpha, and Bazzania sp.*
Key Words: Bryophytes, environmental factors, identification

INTRODUCTION

Indonesia as a megabiodiversity country has a diversity of moss plants (Bryophyte) as many as 1,500 species or 20-30% of the total species of moss in the world (Irawati et al., 2023). It is estimated that the number of moss species in the world reaches 25,000 with 1,000 genera. The large number of species makes moss the second highest species diversity after seed plants (Spermatophyte) (Ginting et al., 2021). Bryophytes are a group of low-level plants that grow widely and are found in many tropical regions (Endang et al., 2020).

The Bryophytes group includes mosses (Bryopsida or Musci), liverworts (Hepaticopsida or Hepaticae), and hornworts (Anthoceropsida or Anthocerotae). These three groups have distinctive features that separate Bryophytes from vascular plants (Hallingbäck & Hodgetts, 2000). Characterization of morphology, anatomy, habitat, gene diversity, and arrangement are used as guidelines in grouping moss (Ginting et al., 2021). Moss plants are pioneering plants that can be found attached to various moist and wet substrates (Pratama et al., 2022). Substrates include trees, river banks, rock surfaces, and soil surfaces. For mosses, in addition to functioning as a place to attach, the substrate also provides nutrients for growth. Therefore, substrate availability is one of the factors that influence the diversity and composition of moss (Eman et al., 2022).

Other factors that influence moss plant diversity are microclimatic conditions such as light intensity, humidity, ambient temperature, and vegetation type (Eman et al., 2022). The distribution of moss species is strongly influenced by biotic and abiotic factors, such as water, light, temperature, humidity, and altitude (Ginting et al., 2021). The different tolerance of each moss species to environmental factors will affect the level of adaptation, species composition and distribution of moss plants (Husain et al., 2022). Mosses require at least two factors to thrive, namely humidity and temperature. Temperature is affected by altitude. As the altitude increases by about 100 m, the temperature drops by 0,40 to 0,70˚C. The lower temperature prevents water loss. Also, high humidity conditions provide more water for mosses. This is why mosses thrive in places with high humidity, such as waterfalls. Waterfalls are one of the best places for moss to live in the tropics. Many conifers, lichens, and mosses live there (Sidiq et al., 2019).

Curug Silawe is one of the waterfalls located in Sutopati Village, Kajoran District, Magelang Regency with topography of hills (Pradipta & Santoso, 2017). Curug Silawe is at an altitude of ± 500 meters above sea level (Wicaksono, 2024). Elevation as a physiographic factor along with other factors such as climate and soil fertility will determine species richness at the habitat level. Differences in altitude will affect humidity, temperature, light intensity and rainfall. All physiological processes will be affected by temperature and some processes will be light dependent. These environmental factors affect the physiological processes of plants so the physiological characteristics of mosses will vary with altitude. The presence of mosses will increase with altitude and decrease at the highest altitude. This is related to surface area. The larger the surface area, the more susceptible it will be to wind (Fuady Putra et al., 2015).

Figure 1. Research Location Map (Google Earth image, 2024)

Moss plants in tourist areas are vulnerable to damage due to changes in habitat function, potential trampling by visitors, and moss-cleaning activities. Moss plants in tourist areas are strongly influenced by changes in the environment so moss will specifically respond to these changes (Sukmawati et al., 2023). The poikilohydric nature of mosses makes these plants very sensitive to environmental changes and can be used as bioindicators of environmental conditions and microclimate (Hernández-Hernández et al., 2019).

The ecological role of mosses in ecosystems in the tropics is to maintain water balance, nutrient cycling, bioindicators of environmental change, and open space for other plants (Endang et al., 2020), and carbon sinks in peatlands (Hallingbäck & Hodgetts, 2000). The influential role of moss in the ecosystem and the absence of data on moss species in the Curug Silawe area are the basis for this study to identify the types of moss plants and environmental factors that affect lichen diversity.

MATERIAL AND METHODS

The research was conducted in April 2024. Sampling was conducted in the area of Curug Silawe, Sutopati Village, Kajoran District, Magelang Regency, Indonesia 7˚27’29”S and 110˚ 04’2”BT. The map of the research location can be seen in Figure 1.

The tools used in this research are smartphones and stationery. The object of this research is the mosses in the Curug Silawe area.

Data collection of the moss plants was carried out through a combination of exploration and field observation methods. This method was used to collect data by collecting moss species directly at the research site. Each type of moss found at the research site was recorded and documented. The identification process is carried out by analyzing the documentation images by observing the morphology of the plant body, then comparing it with reference books Mosses, Liverworts, and Hornworts: Status Survey and Conservation Action Plan for Bryophytes (Hallingbäck & Hodgetts, 2000), scientific articles, validated websites, and “PlantNet”. Then a search was carried out for plant classification levels based on the Itis.gov website. At the same time, air temperature and humidity were measured. Data on environmental parameters including soil pH, soil temperature, and light intensity were obtained through literature studies with sources such as national and international journals for the last 10 years (2014-2024) from Google and journal sites.

RESULTS AND DISCUSSIONS

Overview of the Research Location

The research site is located in the area of Curug Silawe, Sutopati Village, Kaliangkrik District, Magelang Regency. Geographically, Curug Silawe is located at 7˚27’29”S and 110˚ 04’2”BT with an altitude of about 500 MASL.

Types of Moss Plants Found at the Research Location

There were 7 Bryophytes found in the study site, consisting of 5 Bryopsida and 2 liverworts. Four types of moss were identified at the species level and three others at the genus level.

Table 1. Types of Mosses Found in the Curug Silawe Area

No	Classis	Family	Species Name
1.	Bryopsida	Funariaceae	*Funaria hygrometrica*
2.	Bryopsida	Dicranaceae	*Dicranum fuscescens*
3.	Bryopsida	Fissidentaceae	*Fissidens sp.*
4.	Bryopsida	Hypnaceae	*Hypnum cupressiforme*
5.	Bryopsida	Entodontaceae	*Entodon sp.*
6.	Marchantiopsida	Marchantiaceae	*Marchantia polymorpha*
7.	Marchantiopsida	Lepidoziaceae	*Bazzania sp.*

Environmental Factors Parameters

Table 2. Environmental Factors Parameters

No	Species name	Substrate	Air temperature (˚C)	Humidity (%)
1.	*Funaria hygrometrica*	Concrete road, Rock and Soil	27	72
2.	*Dicranum fuscescens*	Rock and Soil	27	72
3.	*Fissidens sp.*	Concrete road and Soil	27	72
4.	*Hypnum cupressiforme*	Weathered wood	27	72
5.	*Entodon sp.*	Concrete road and Soil	27	72
6.	*Marchantia polymorpha*	Soil and Concrete wall	27	72
7.	*Bazzania sp.*	Soil	27	72

Types of Moss in the Curug Silawe Area

Based on the observation, 7 species of Bryophytes, 5 leaf mosses (Bryopsida) and 2 liverworts (Marchantiopsida) were obtained (Table 1). The identified Bryophytes species were *Funaria hygrometrica* (Figure 2), *Dicranum fuscescens* (Figure 3), *Fissidens sp.* (Figure 4), *Hypnum cupressiforme* (Figure 5), *Entodon sp.* (Figure 6), *Marchantia polymorpha* (Figure 7*)*, and *Bazzania sp* (Figure 8).

1. Funaria hygrometrica

Figure 2. *Funaria hygrometrica*

Funaria hygrometrica is a species of moss belonging to the Funariaceae family, characterized by its green color, soft texture with a vertical growth pattern, leaves and midribs can be clearly distinguished, and has a simple short vertical stem with few branches. Large and wide leaves with distinctive stomata (Rahmi et al., 2023) Members of Funariaceae family have short, orthotropic stems with a narrow central strand of water-conducting cells, sympodial branches with rib-shape unistratose leaves with smooth, thin-walled rhombic cells (Liu et al., 2012). *Funaria hygrometrica* can grow on substrates containing heavy metals such as copper (Cu), zinc (Zn), lead (Pb), and other heavy metals. This moss can also grow on sites recovering from fire (Itouga et al., 2017).

2. Dicranum fuscescens

Figure 3. *Dicranum fuscescens*

Dicranum species are characterized by *falcate-secund*, narrowly lanceolate to ovate-lanceolate, usually unistratose leaves; entire leaf margin serrated; costa narrowly supercurrent to short excurrent smooth or with serrated ridges on the back; subquadrate to elongate, thick-walled, porous laminal cells; well-developed alar cell and haploid-type peristome with a single row of teeth around the capsule's mouth(Lang & Stech, 2014).

Dicranum fuscescens has spreading leaves that are erect to erect, crisp leaves that are keeled, and papillary on the back. Costa is toothed to sharply serrated on the back, upper leaf cells are short, non-porous, and have sharply serrated leaf margins with bistratose cells. Other distinctive features include full-sized, dull, green or yellowish-green above, and brownish below. This species of moss can be found on a variety of substrates, namely humus soil, soil along paths, rocks, decaying stumps, tree bases, shaded forests, swamps, and open places (Allen, 1998).

3. Fissidens sp.

The genus *fissidens* can be recognized by its distinct body morphology with leaves arranged in two rows on the stem. The leaf structure is complex, namely each leaf sheet has a midrid at the base of the apical leaf sheet (Agustiorini & Ariyanti, 2018).

Figure 4. Fissidens sp.

Fissidens sp. has a body length of 3 mm with a short stem and covered with leaves. Dark green leaves are elongated with flat leaf edges and pointed leaf tips, and the edges of the leaf blade are irregularly serrated. The stem is yellowish green, composed of 7 pairs of alternate leaves. This type of moss can be found attached to rocks, soil, ditches, and calcareous soil (Ulfa et al., 2023).

4. Hypnum cupressiforme

Figure 5. *Hypnum cupressiforme*

Hypnum cupressiforme has long, curved green leaves with pointed tips. The spreading or ascending branches are irregularly pinnate. This moss grows tightly on the surface of the substrate (Kartikasari et al., 2023). Members of the genus Hypnum have many branches and there are elongated capsules that are straight or curved. The stem leaves are linear, shiny, and the leaf branches are similar to the stem leaves. The alar cells form distinct clusters with pendant double costa and have reddish setae (Yohendri et al., 2021).

5. Entodon sp.

Members of the genus *Entodon* are characterized by lanceolate ovoid leaves with a short double costa. Alar cells are linear, cylindrical

Figure 6. *Entodon sp.*

capsules with double peristomes. Satae are yellow, lacking annulae and exostomes are generally reddish brown and striolate. This moss is pleurocarpous with creeping stems. Ground leaves on pleurocarps tend to be larger and less differentiated than branch leaves. Leaf arrangement in most taxa is spirally arranged with little difference between dorsal and lateral leaves. Leaves are generally oblong-ovate to oblong-lanceolate. This type of moss is distributed in the tropics and attaches to rocks, tree bark, weathered wood, soil, and humid environments (Zhu et al., 2010).

6. Marchantia polymorpha

Figure 7. *Marchantia polymorpha*

Marchantia polymorpha is the most common cosmopolitan liverwort. This liverwort is a leafy or flattened thalloid with two or more lobes. The lobes are arranged in three parallel rows from the stem. In addition, liverworts do not have a prominent costa. Rhizoids are unicellular, consisting of a single row of cells. Liverwort sporophytes do not have stomata, operculum and columella (Shimamura, 2016).

The sporophytes of many Marchantiales species have a unique configuration of many small sporophytes hanging upside down under an umbrella-shaped sexual branch (*archegoniophore*). The genus *Marchantia* is characterized by presenting a multilayered complex thallus with air space, ventral

scales, two type of rhizoids, gemma cups, *archegoniophore* and pedunculated *antheridiophore*, female receptacles with involucres, and sporophytes individually surrounded by pseudo perianths (Shimamura, 2016).

7. Bazzania sp.

Figure 8. *Bazzania sp.*

Bazzania sp. is distinguished from other genera by morphological features such as Y-shape terminal branches resembling dichotomous branches (pseudo dichotomous), long flagelliform branches emerging from lower leaves and small scale-like leaves, incubate-shape lateral leaves on the stem. Leaf tip 2-3 serrated, ventral underside large. Bazzania sp. can be found attached to bark, damp soil, and rocks overgrown with hummus. At the bottom of trees, Bazzania sp. grows like a carpet, while in the trees and branches of the canopy this moss grows like thick grass. Bazzania sp. is distributed in lowlands to highlands with altitudes reaching 1,300 meters above sea level (Khotimperwati et al., 2018).

Relationship between Environmental Factors and Moss Plants

Air Temperature

Based on Table 2, the identified moss plants have different substrates, ranging from concrete roads, soil, rocks, weathered wood and concrete walls. The measurement results of air temperature and humidity at the observation location were 27˚C and 72% respectively. Based on research by Zechmeister et al., (2023), it was found that the optimal temperature for the most mosses in hydrated conditions is in the range of 15˚C to 25˚C. Most mosses in temperate climates have an optimum temperature of around 20˚C while in tropical climates, the optimum temperature reaches 30˚C. Ambient temperatures above 30˚C can be lethal to mosses in the wet state in the long term. However, in dry conditions, mosses can survive extreme temperatures of -150˚C to 60˚C.

Humidity

Moss growth and development will be optimal at humidity above 50% (Azwad et al., 2020). When the humidity increases, the peristomes close, while when the humidity decreases, the peristomes open. Peristome closure begins when relative humidity reaches 50%-65% while peristome opening begins when relative humidity reaches 90% (Zanatta et al., 2018).

Light Intensity

Light intensity that is too high or too low can affect moss growth. High light intensity can inhibit growth by damaging chlorophyll in unprotected leaves. Meanwhile, at less than optimal light intensity can cause etiolation resulting in long and slender stems (Glime, 2017). Most Bryophytes, especially shade-tolerant species, have a lower light saturation point for photosynthesis than vascular plants and can photosynthesize under very low light conditions (Fan et al., 2020).

The range of optimal light variation depends on the species. However, it appears that for many species the optimal range is between 2,000-4,000 lux. The optimal light intensity is in the range of 700-1,900 lux at 25˚C for woodland species. Light intensities that are too low, i.e. <900 hurt moss growth. Meanwhile, high light intensities of up to 6,000 lux have no negative effect on moss growth (Zechmeister et al., 2023). Light affects the germination process of moss spores. Light will increase moss germination even at low light intensities (1 lux) (Mohanasundaram & Pandey, 2022).

Soil pH

Substrate is one of the factors that influence the diversity and composition of moss. Based on research conducted by Siwach et al., (2021), mosses more often grow in acidic soils with soil pH ranging from 5,40-7,15. This is due the high decomposition of litter and the remaining talus of previous moss which will antibiotics, lipids, flavonoids, terpenoids, lignin, and sterols that provide suitable conditions for moss growth.

CONCLUSIONS

Based on the identification results, mosses found at the research site of the Curug Silawe Area consisted of 7 species consisting of 5 Bryopsida and 1 liverwort. The identified Bryophyte came from 7 different families namely Funariaceae, Dicranaceae, Fissidentaceae, Hypnaceae, Entodontaceae, Marchantiaceae, and Lepidoziaceae. The identified moss species were *Funaria hygrometrica, Dicranum fuscescen, Fissidens sp., Hypnum cupressiforme, Entodon sp., Marchantia polymorpha,* and *Bazzania sp*. The identified moss is attached to different substrates, namely soil, rocks, weathered wood, concrete road, and concrete walls.

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