The diversity of moss in the Cemoro Kandang hiking trail, Mount Lawu and the Baturraden botanical gardens, Central Java

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Abstract. Moss plants in tropical mountain forest areas play an essential role in water balance and the forest's nutrient cycle, serving as a substrate, food source, and a place for forest organisms to live. This study aims to analyze the diversity of moss plants in Mount Lawu and Baturraden Botanical Gardens based on the height of the place and substrate type. Moss plants were observed along the Cemoro Kandang hiking trail and around the Baturraden Botanical Garden. A total of 30 species of mosses consisting of 19 species of true mosses, 10 species of liverworts, 1 species of hornworts. The moss plants on the hiking trail are included in 13 orders and 20 families. There are 13 species of mosses found in the Baturraden Botanical Garden, including 7 orders and 10 families, including 8 species of true mosses, 4 species of liverworts, and 1 species hornworts. The highest moss species diversity at the two locations is true mosses (Bryophyta). Most of the mosses are terrestrial mosses. True mosses are evenly distributed in the highlands rather than the lowlands.

1. Introduction
Mosses are one of the oldest and simplest plants found almost anywhere on earth [1]. Mosses are characterized by a predominantly haploid gametophyte and a persistent gametophyte-dependent sporophyte. Lichens are poikilohydric, so they tend to be tolerant of drought [2]. Mosses in tropical mountain forest areas play an essential role in the forest's water balance and nutrient cycle. Another function of moss is to become a medium for germination of high-level plant seeds and a bioindicator for environmental pollution [3]. Sphagnum is known to play an essential role in controlling carbon flux [4] [5]. Mosses can live on various substrates, around river bodies, living or dead tree bark surfaces, hard rock surfaces, and soil surface layers [6].

Moss's research is vital because moss has significant potential benefits, such as containing secondary alkaloid metabolites (clavatoxins, clavatine, nicotine, and lycopodine), polyphenolic acids (dihydrokor), and flavonoids (apigenin and triterpenes) [7]. These secondary metabolites can be used as antibacterial agents, especially for pathogenic bacteria [8]. Usnea subflorida extract has been shown to inhibit the growth of Staphylococcus aureus FNCC 0047 and Escherichia coli FNCC 0091 [9].
*albidium* is an antibacterial agent for *Staphylococcus edidermidis* and *Pseudomonas aeromonas* [10]. The thick layer of moss and fungi, due to its acidity [11], provides habitat for invertebrates [12], the germination medium for binahong plants [13], and mustard greens due to its N content reaching 0.60% [14].

Tropical forests have higher moss diversity and abundance than other locations [17]. The diversity and abundance of these plants depend on environmental conditions such as temperature, light, air humidity, soil moisture, soil temperature, soil pH, and the area's topographical conditions [18]. Altitude is an environmental condition that can affect climate because it has a lower average air temperature than lowland. The higher the height of a place, the lower the air temperature. A total of 628 species of true mosses [19] and 607 liverworts and hornworts are reported to live in Java [20]. The diversity of moss species in each area needs to be disclosed to complement the moss database so that its distribution can be mapped to optimize ecological and economic benefits. This study aims to identify the diversity of moss species on Cemoro Kandang Gunung Lawu and Baturraden Botanical Garden's hiking trail, Central Java. Both of these areas have elevations from sea level, respectively 1900-2200 m asl and 600-700 m asl, so that it is thought to have high moss diversity.

2. Methods

Along the hiking trail of Cemoro Kandang to post-1 on Mount Lawu and around the Baturraden Botanical Garden office is an exploration location for moss plants. Exploring moss using a persuasive sampling method, plants are taken from various substrates (trees, weathered wood, soil, rocks) in an accessible location. Each hiking trail of moss found was then made a specimen of the herbarium with field data, including collection number, substrate type, habitat type (cliffs, roadside, forest). Plant ordinates are determined by the Global Positioning System (GPS). Plant identification was made by comparing the morphological characteristics of mosses and the key to moss identification "A Handbook of Malesian Mosses Volume I, II.

3. Results and discussion

3.1. Results of field exploration at Cemoro Kandang

There are 30 mosses found on the Cemoro Kandang hiking trail, including 13 orders and 20 families (Table 1).

| Order        | Family           | Species | Order | Family           | Species |
|--------------|------------------|---------|-------|------------------|---------|
| **Real Moss**|                  |         |       |                  |         |
| Dicranales   | Calymperaceae    | 2       |       | Marchantiales    | Marchantiaceae | 1       |
|              | Leucobryaceae    | 4       |       | Aytoniaceae      | 1       |
|              | Dicranaceae      | 2       |       | Dumortieraceae   | 1       |
| Hypopterygiales | Hypopteriygaeae | 1       |       | Pallaviciniales  | Pallaviciniaceae | 1       |
| Bryales      | Bryaceae         | 2       |       | Jungermanniales  | Plagiochilaeae | 2       |
|              | Racopilaceae     | 1       |       | Juengermanniaceae| 2       |
| Polytrichales| Polytrichaceae   | 2       |       | Scapaniaceae     | 1       |
| Hookeriales  | Hypopterygiae    | 1       |       | Metzgeriales     | Metzgeriaceae | 1       |
| Hypnales     | Hypnaceae        | 2       |       |                   |         |
| Hypnodendrales | Racopilaceae    | 1       |       | Notothylaldaes   | Notothyladaceae | 1       |

The results of field exploration on the Cemoro Kandang hiking trail were 30 species consisting of true mosses, liverworts, and hornworts. True mosses were found in 19 species belonging to 8 orders and 11 families. 10 liverworts species belong to 4 orders and eight families, and only one order of hornworts, namely Notothylaldaes and one species of *Phaeoceros laevis*. The highest moss species diversity in Cemoro Kandang is true mosses from the order Dicranales.
3.2. Exploration results from the Baturraden botanical garden field

There are 13 species of moss found in the Baturraden Botanical Garden, including 7 orders and 10 families (Table 2).

| Order       | Family          | Species | Order       | Family          | Species |
|-------------|-----------------|---------|-------------|-----------------|---------|
| Real Moss   | Dicranales      | 1       | Liverworts  | Jungermanniales | 1       |
|             | Leucobryaceae   | 2       |             | Plagiochilaceae | 1       |
| Polytrichales | Polytrichaceae | 3       |             | Lepidoziaceae   | 1       |
| Bryales     | Bartramiaceae   | 1       |             | Metzgeriales    | 1       |
| Hypnales    | Sematophyllaceae| 1       |             | Notothyladaceae | 1       |

The results of field exploration around the Baturraden Botanical Garden office obtained 13 species of mosses, consisting of true mosses, liverworts, and hornworts. True mosses found by 8 species belong to 4 and 5 families, liverworts 4 species belong to 2 orders, 4 families, and hornworts only 1 order, namely Notothyladaceae with one species *Notothylas orbicularis*. The highest moss species diversity in the Baturraden Botanical Garden is true mosses.

3.3. Distribution of mosses

The forest on the Cemoro Kandang hiking trail and the Baturraden Botanical Garden has a relatively high humidity of 20°C. Such conditions are very favorable for moss spore germination. The results of measurements of the biological factors of moss growth are presented in Table 3.

| No. | Area                              | Temperature | Humidity | Soil pH  | Light intensity | Height       |
|-----|-----------------------------------|-------------|----------|----------|-----------------|--------------|
| 1.  | The Cemoro Kandang hiking trail, Mount Lawu | 18-22°C     | 78%      | 5.5 - 6.0| 180.5 lux       | 1900-2200 (m asl) |
| 2.  | Baturraden Botanical Gardens      | 27°C        | 70%      | 7.0      | 195.3 lux       | 600-700 (m asl)  |

The distribution and abundance of moss vegetation are influenced by climatic and edaphic factors and the altitude of an area. Climatic factors are climatic or weather factors that affect moss plants' distribution, air humidity, light intensity, and temperature [21]. The light intensity level on the Cemoro Kandang hiking trail is 180.5 lux and Baturraden Botanical Garden 195.3 lux. Lichens prefer low light intensity. The canopy and clouds influence the low light intensity at Cemoro Kandang. This condition is very suitable as a habitat for moss plants that like low humidity. Air humidity is affected by temperature; the lower the temperature, the higher the humidity. Air humidity affects transpiration; the lower the air humidity, the higher the transpiration. Air temperature on the Cemoro Kandang climbing route 18-22°C, while the temperature in Baturraden Botanical Garden is 27°C. High air temperature causes mosses to wither because the amount of water that evaporates is higher than that which is absorbed by the roots [22].

Apart from climatic factors, the distribution and abundance of mosses are influenced by edaphic factors, such as soil pH [23]. Soil acidity on the Cemoro Kandang hiking trail ranges from pH 5.5 - pH 6.0 and the Baturraden Botanical Garden pH 7. Generally, moss plants can grow and develop in a pH range of 5.0-8.0. The altitude of an area can also affect climate. The Cemoro Kandang hiking trail's height is 1900-2200 m asl, and the Baturraden Botanical Garden is 600-700 m asl. Both areas have an average air temperature lower than the lowlands' temperature (0-500 m asl). The highlands' air density is more tenuous, so it is less able to store heat than the lower plains' air density, which is denser [24].
4. Conclusion
Moss plants in tropical mountain forest areas play an essential role in balancing water and the forest's nutrient cycle, serving as a substrate, food source, and a place for forest organisms to live. The exploration of moss plants along the hiking trail of Cemoro Kandang, Mount Lawu, and around the Baturraden Botanical Garden office were 30 and 13 species of moss, respectively. The species of moss found in both locations consisted of true mosses, liverworts, and hornworts. Bryophyta divisions (true mosses) dominate the mosses at both locations. The mosses that were found were mostly terrestrial moss. True mosses are evenly distributed in the highlands rather than the lowlands.

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