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Moss from Sumbawa District, Indonesia

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Abstract. *Windadri FI. 2023. Moss from Sumbawa District, Indonesia. Biodiversitas 24: 681-689.* Plant diversity in the Lesser Sunda Islands has been widely studied, but it still needs to be carried out on Sumbawa Island. The study aimed to determine the diversity of moss species from the island, especially in the Sumbawa District. The exploration method was used in this research activity, that is conducting exploration, taking research samples and observing habitats at the research site. The distribution tracking was conducted to determine the status of each moss species from the research site. The results recorded 41 species of mosses from the research site in 24 genera and 14 families. Fissidentaceae is one of the moss families, had the highest species diversity in the study site, and was previously never reported from Sumbawa Island. In contrast, the common species was *Tortula muralis*. The study of moss species from the study site revealed that four species had been found in previous moss collections, namely *Anoectangium aestivum*, *Neckeropsis lepineana*, *Pinnatella alopecuroides*, and *Octoblepharum albidum.* Several mosses from the study site contributed to the moss diversity of Sumbawa Island as new records. The number of moss from the study site and as new records status is 37 species for Sumbawa Island, 18 species for Lesser Sunda Islands, and six species for Indonesia, respectively.

Keywords: Diversity, mosses, new records, rediscovered, Sumbawa

INTRODUCTION

Sumbawa is included one of the largest islands in the Lesser Sunda Islands. The island has an area of 15,448 square kilometers, and the topography is mountainous, with rocky coasts and a few small plains (Britannica 2020). It has four regencies (Bima, Dompu, Sumbawa, West Sumbawa), and a municipality (Bima). Sumbawa District is located in the west part of Sumbawa Island, at positions 116 "42'-118" 22'E and 8"8'- 9"7'S. It has an area of 6,643.98 square kilometers. It is the largest area compared to other regencies of Sumbawa Island. The land surface in the Sumbawa District tends to be a hilly forest with an altitude of up to 1,730 meters above sea level. Semongkat is the capital city of the Batulanteh Sub-district. This town has a Nature Park as a public recreation facility, namely Semongkat Nature Park. This park is a hill forest located 450 m above sea level. The ecological and floristic studies were limited to Gymnosperm, Angiosperms, and ferns but did not include mosses. A floristic survey was undertaken in mountain forests of West Sumbawa and some places surrounding lower forests in 2004 and 2005 (Wiriadinata et al. 2013), while a phytosociology study of a lower montane forest on Mt. Batulanteh, Sumbawa, Indonesia was conducted in 2016 (Mansur and Kartawinata 2017).

Bryophyte is the simplest group of the chlorophyllous plant. Bryophytes consisted of three classes; Hepaticopsida/ Hepaticae, Anthocerotopsida, and Bryopsida/Musci/Mosses. In the ecosystem, mosses serve as resorbing water, retain moisture, produce oxygen via photosynthesis, absorb pollutants, improve the forest's ability to hold water (water holding capacity), function as the habitat of other organisms such as invertebrates, medium for germination of higher plant seeds, and pollution bioindicator. The moss was generally found in the trees' habitat, compared to soil and stones.s. On the other hand, bryophyte was commonly found in areas with little light and moisture and mostly grown in tropical rain forests. It usually grows on trees, stones, logs, litter, and soils.

Mosses are a part of plant diversity. They are the simplest, small and nonflowering plant that grows erect (acrocarpous) or creeping (pleurocarpous) on the substrate as green mats or clumps in the shade and damp areas. They would have no true roots if only found as an attachment organ. Likewise, the stem has a limited role in transporting nutrients and water, so the conduction system is poorly developed. Moss diversity worldwide has reported approximately 12.000 species (Britannica 2022), while Indonesia reported 1.884 species (Windadri 2019). The Indonesian moss diversity has been widely explored, especially in Sumatra, Java, Kalimantan, and Sulawesi, while in the Lesser Sunda Islands areas, few collections were deposited at Herbarium Bogoriense (BO). Touw (1992) reported as many as 357 species of mosses recorded from the Lesser Sunda Islands. Thirty-nine species of them originated from Sumbawa Island and were collected by Zollinger (1847, 14 species), Colfs (between 1879-1881, 3 species), Warburg (1888, 6 species), Grundler (1909, 3 species), Kostermans (1961, 18 species), Balazs (1965, 9 species) and Prawiroatmodjo, S (1978, 5 species). The collection of moss in Sumbawa has been done in some mountains as such Batulanteh (19 species), Pokah (4 species), Tambora, Songkar, Jaran Pusang, and Labuan

Alas (2 species each), Pajo and Sambori (1 species each). Moss collection on this island has yet to be done in detail, so the diversity of moss species is very low. Therefore, it is necessary to do a detailed collection on this island. Collecting mosses on this island will add new information about moss diversity from Sumbawa Island, Lesser Sunda Islands, and Indonesia.

MATERIALS AND METHODS

The recent moss research in Sumbawa Island was carried out in Sumbawa District, the western part of Sumbawa Island, which still has a lot of forests. Three sub-districts were selected as the study area (Batulanteh, Moyo Hulu, and Plampang). In the Batulanteh Sub-district, mosses collecting was carried out on a long roadside from Sumbawa Besar to Batudulang (Brang Pelat and Leseng village), several forest areas (Kuang Strong, Kebun Atas, Q2 block) on altitude 950-1015 m, along Brang Suwir riverside at surrounding Batudulang village with altitude 850 m (Figure 1.A-E), in Moyo Hulu Sub-district moss inventory, was carried out in the Semongkat Nature Park on altitude 450 m above sea level, in the forests surrounding Brang Rea village and Ai Beling waterfall on altitude 427 m (Figure 1.F-H). In the Plampang Sub-district, I collected mosses in the forest surrounding the lake near Jaran Pusang Mount, Selante village (Figure 1.I).

The exploration method (Rugayah et al. 2004) was applied in this research activity by exploring each research area and taking samples. All of mosses in the research site were collected for the research samples and identification. Each moss sample was saved in a paper bag and it was assigned a collection number and the collector's name on the outside bag. The field support data (habitat, substrate, color, altitude and maybe utilization) were recorded in the field book data. In the sampling of mosses, it is attempted in a complete manner, including the gametophyte generation (the moss plant itself) and the sporophyte generation (the part that produces spores). All samples of moss were preserved by air drying to avoid damage (moist and moldy).

All mosses were collected and identified. Identifications were done in Cryptogam Laboratory at BRIN Cibinong, West Java, Indonesia. The tracking of mosses distribution was carried out based on some literature, e.g., Mosses of the Philippines (Bartram 1939); A Survey of Mosses from Lesser Sunda Island, Nusa Tenggara, Indonesia (Touw 1992); A Handbooks of Malesian Mosses volume 1, 2, 3 (Eddy 1988, 1990, 1996); http://www.theplantlist.org/ (2020); http://www.tropicos.org/ (2020); Australian Mosses online (http://www.anbg.gov.au/abrs/Mosses_online/, accessed 2021); An Annotated Checklist and Atlas of the Mosses of Thailand (He 2019), Mosses diversity from Lombok, West Nusa Tenggara (Windadri 2019). The Checklist Flora of Lombok Island (Susan and Windadri 2020). The distribution of moss species from research sites that do not report their presence on Sumbawa Island is proposed as new records.

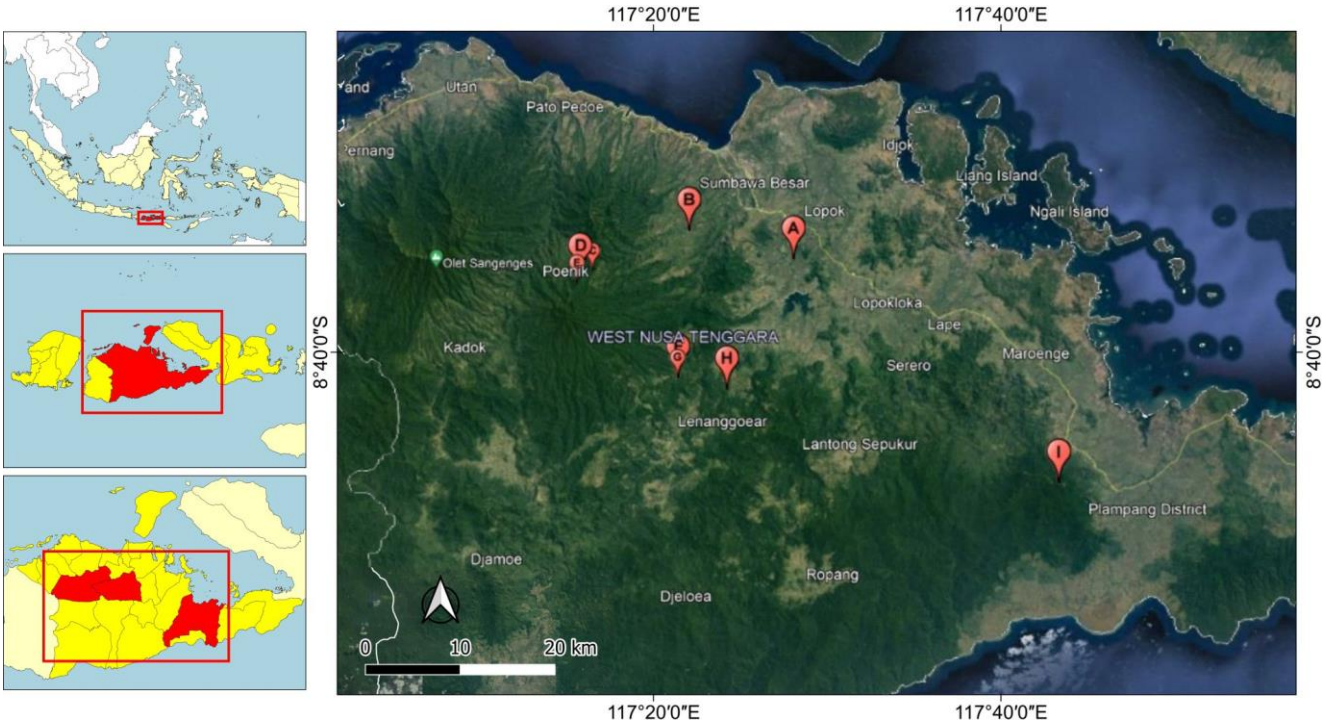

Figure 1. Map of the moss research site in Sumbawa District, West Nusa Tenggara, Indonesia, the detail of the research site was directed by red icons. A. Brang Pelat, B. Leseng, C. Q2 Block, D. Kuang Strong, E. Kebon Atas, F. Ai Beling, G. Semongkat Natural Park, H. Brang Rea, I. Jaran Pusang Mount

RESULTS AND DISCUSSION

Results

The result of moss exploration at the research site collected 63 numbers, including 41 species belonging to 24 genera and 14 families. Compared to the previous Sumbawa mosses collection, there were 4 species rediscovered. Other species, 37 species, have yet to be collected. Based on the tracking of the distribution area, however, it found that 18 species have yet to be reported from the Lesser Sunda Islands, and 6 species in Indonesia mosses collections. Table 1 shows the diversity, rediscovered, and new moss records from the research site with the Malesian distribution areas.

The recent moss diversity from Sumbawa Island based on the grouping of the families were Fissidentaceae and Neckeraceae (9 species each), Pottiaceae (6 species), Bryaceae (4 species), Pterobryaceae (2 species), Bartramiaceae, Brachythesiaceae, Bruchiaceae, Calymperaceae, Dicranaceae, Octoblepharaceae, Orthortichaceae, Rhacopilaceae, Semathophyllaceae (1 species each) and it can be shown in the following diagram (Figure 2).

Distribution pattern of mosses based on their habitat

The research activity on moss in Sumbawa District was conducted on three types of habitats such as the forest (43.3%), along rivers (32.9%), and open areas (natural parks and along the roadside (23.9%). I showed the following percentage of the moss number in the habitat in the study area (Figure 3).

Moss is included in the epiphytic plant group, so it requires a substrate for its growth. Several types of substrates and the number of moss species at the research site were rocks (20 species), soils (8 species), barks (12 species), dead logs (2 species), and decaying woods (2 species). The following diagram shows the relationship between the number of moss species and the type of substrates (Figure 4).

Discussions

Moss diversity from the research site

The mosses inventory from the research site reported as many as 41 species belonging to 24 genera and 14 families (Table 1 and Figure 4). Based on the moss family grouping, Fissidentaceae had the highest species diversity at the research site. This family only has one genus (Fissidens). The genus is characterized by vertically placed distichous leaves, which are differentiated into a vaginant lamina consisting of two lamellae clasping the stems and a dorsal lamina opposite the vaginant lamina. An apical lamina above the vaginant lamina, peristome teeth split into two up to the middle, with longitudinal stripes (Syazwana et al. 2018). The genus has around 450 species widely distributed worldwide (Seppelt and Stone 2016). In Indonesia, 92 species were, and in the Lesser Sunda Islands, 28 species were reported (Susan and Windadri 2020). Nine species of this genus were collected from the research site, namely *Fissidens anomalus* Mont., *F. braunii* (Müll. Hal.) Dozy & Molk., *F. laxus* Sull. & Lesq., *F. nobilis* Griff., *F. robinsonii* Both., *F. serratus* Müll. Hal., *F. hallianus* (Sull. & Lesq.) Mitt., *F. teysmannianus* Dozy & Molk., and *F. zippelianus* Dozy & Molk. Two species of them (*F. braunii* and *F. nobilis*) were never reported before from the Lesser Sunda Islands. These moss species usually grow on the rocks in the shade of lowland forests.

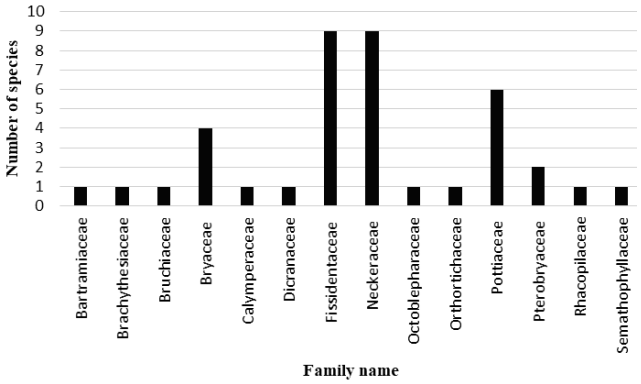

Figure 2. Mosses' diversity based on the family group in the research site

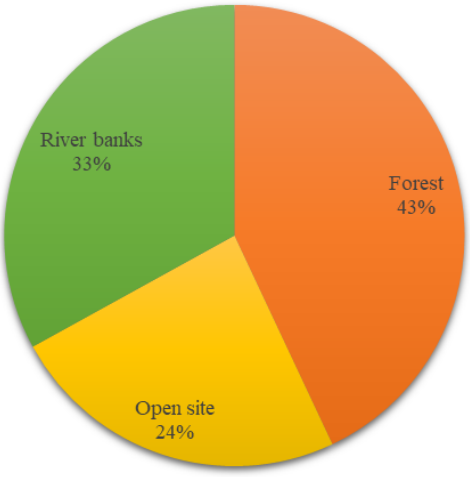

Figure 3. Percentage of moss number in the habitat in the research site

Figure 4. Number of moss species on the substrate in the research site

Table 1. The diversity, recovered, and new moss records from Sumbawa District, West Nusa Tenggara, Indonesia

Family/ species name	Collection number	Malesian distribution areas
Bartramiaceae:		
Philonotis hastata (Duby) Wijk & Margad.	FIW 4505, 4506	Borneo, Celebes, Java, LSI (Bali, Flores, Timor), Sumatra, Philippines (1,2)
Brachytheciaceae:		
Isothecium trichocladon (Dozy & Molk.) M.Fleisch.	FIW 4402	Philippines, LSI (Lombok and Flores) (1.2)
Bruchiaceae:		
Trematodon longicollis Michx.	FIW 4374	Java, LSI (Bali, Flores, Alor), Papua New Guinea, Philippines (1,3)
Bryaceae:		
Bryum argenteum Hedw.	FIW 4310, 4316, 4466	Java, LSI (Bali, Lombok, Flores, Timor), Philippines (2,3)
Bryum pachytheca Müll. Hal.	FIW 4355	LSI (Lombok) (2)
**Rhodobryum aubertii* (Schwägr.) Thér.	FIW 4459	Philippine and New Guinea (1, 7)
**Rhodobryum roseum* (Hedw.) Limpr.	FIW 4384	Throughout the world (8)
Leucophanes glaucum (Schwägr.) Mitt.	FIW4382	Borneo, Celebes, Java, LSI (Flores, Timor, Tanimbar), Malaysia, Philippines, Sumatra (2, 3)
Arthrocormus simperi (Dozy & Molk.) Dozy & Molk.	FIW4427	Sumatra, Java, Borneo, Celebes, LSI (Lombok), Moluccas, Malaysia, New Guinea (2, 3)
Dicranaceae:		
**Dicranoloma laevifolium* (Broth. & Geh.) Paris	FIW4406	New Guinea (1)
Fissidentaceae:		
Fissidens anomalus Mont.	FIW4495	Java, LSI (Flores), Philippines (2,3)
**Fissidens braunii* (Müll. Hal.) Dozy & Molk.	FIW4357, 4462	Sumatra, Java, Borneo, Moluccas, New Guinea, Philippines, Malay Peninsula (1, 4a; 5)
**Fissidens crassinervis* Sande Lac.	FIW4375, 4563, 4360	Malaysia and New Guinea (4a)
Fissidens hallianus (Sull. & Lesq.) Mitt	FIW4335	Java, LSI (Flores), Malaysia, New Guinea, Philippines, Sumatra. (2, 4a)
Fissidens laxus Sull. & Lesq.	FIW 4360, 4363, 4375	Borneo, Java, LSI (Flores), Malaysia, Philippines, Singapore, Sumatra (2, 3)
Fissidens nobilis Griff.	FIW 4421	Borneo, Celebes, Java, LSI (Lombok, Flores), Malay Peninsula, Philippines, Sumatra (2,3)
Fissidens robinsonii Both.	FIW 4311, 4411, 4483	LSI (Lombok, Flores, Sumba), Malay Peninsula and Philippines (2, 3)
Fissidens serratus Müll. Hal.	FIW4326, 4333, 4431, 4449	Java, LSI (Bali, Flores), Philippines (1, 2)
Fissidens teysmannianus Dozy & Molk.	FIW 4312, 4435	Java, LSI (Bali) (2,4a)
Fissidens zippelianus Dozy & Molk.	FIW4361	Borneo, Celebes, Java, Lesser Sunda Islands (Bali, Lombok, Flores), New Guinea, Philippines, Sumatra (1,2, 3)
Neckeraceae:		
* *Himantocladium loriforme* (Bosch & Sande Lac.) M. Fleisch.	FIW4418	Borneo, Celebes, Java, Malaysia, New Guinea, Papua New Guinea, Philippines (3)
* *Himantocladium plumula* (Nees) M. Fleisch.	FIW4409	Borneo, Java, Malaysia, Papua New Guinea, Philippines, Sumatra (3)
Homaliodendron exiguum (Bosch & Sande Lac.) M. Fleisch.	FIW4433	Borneo, Celebes, Java, LSI (Bali, Lombok, Flores), Malay Peninsula, Philippines, New Guinea, Sumatra (2, 3)
* *Homaliodendron scalpellifolium* (Mitt.) M. Fleisch.	FIW4407, 4424	Sumatra, Java, Philippine, New Guinea (6)
Neckeropsis gracilenta (Bosch & Sande Lac.) M. Fleisch.	FIW 4430	Borneo, Java, LSI (Lombok, Flores) Malaysia, New Guinea, Philippines, Sumatra (2, 3)
# *Neckeropsis lepineana* (Mont.) M. Fleisch.	FIW 4392, 4397	Borneo, Celebes, Java, LSI (Bali, Lombok, Sumbawa, Komodo, Flores, Timor), Malaysia, Papua New Guinea, Philippines, Sumatra (2, 3)
# *Pinnatella alopecuroides* (Hook.f.) M. Fleisch.	FIW 4396, 4413	Java, LSI (Sumbawa), Malaysia, Papua New Guinea, Philippine, (2, 3)
**Pinnatella kuehliana* (Bosch & Sande Lac.) M. Fleisch.	FIW4398	Sumatra, Java, , Malaysia, Papua New Guinea, Philippines (3)
Octoblepharaceae:		
# *Octoblepharum albidum* Hedw.	FIW 4468, 4470, 4491	Borneo, Java, LSI (Sumbawa, Timor), New Guinea, Philippine (2, 3)
Orthotrichaceae:		
Desmotheca apiculata (Dozy & Molk.) Lindb.	FIW4354	Borneo. Java, LSI (Flores), Malaysia, Philippine, Sumatra, (1, 2,3)

Pottiaceae:		
# *Anoectangium aestivum* (Hedw.) Mitt.	FIW 4444, 4446	LSI (Bali, Lombok, Sumbawa, Flores), Malaysia, Papua New Guinea, Philippines (1, 2, 3)
***Barbula unguiculata* Hedw.	FIW4438, 4439,4502A	Not found in the Malesian region
** *Mercyopsis minuta* Broth. & Dix.	FIW4436	Philippines (5)
***Tortula muralis* Hedw.	FIW 4322, 4323, 4358, 4440, 4441, 4443, 485, 4502	Philippine (1)
Trichostomum brachydontium Bruch	FIW4356	LSI (Lombok, Flores), Papua New Guinea (1, 2)
***Trichostomum pallidens* (Dixon) R.H. Zander	FIW4484	Not in the Malesian region
***Trichostomum sinuosum* (Mitt.) Müll. Ha	FIW4434	Not in the Malesian region
Pterobryaceae:		
**Endotrichella elegans* (Dozy & Molk.) M. Fleisch.	FIW4350	Sumatra, Java, Borneo, Malacca, LSI (Sumba) Philippine (1, 5, 9)
***Jaegerina luzonensis* Broth.	FIW 4426	Papua New Guinea, Philippine (1,3)
Racopilaceae:		
* *Racopilum schmidi*i (Müll. Hal.) Mitt.	FIW 4368	Borneo, Celebes, Java, Philippines (3)
Sematophyllaceae:		
**Acroporium lamprophyllum* Mitt.	FIW4371	Sumatra, Java, Borneo, Celebes, Malaysia, New Guinea, Philippines (1, 3)

Note**:** The initial of species names: an initial: Sumbawa moss new records; *: LSI moss new records; **: Indonesian moss new records; #: rediscovered of moss. The initial of Malesia distribution area: LSI: Lesser Sunda Islands; 1: www.tropicos.org (2020); 2: Touw (1992); 3: He (2019); 4: Eddy (a:1988, b:1990, c:1996); 5: Bartram (1939); 6: https://www.gbif.org (2020); 7: Koponen and Norris (1984); 8: https://www.britannica.com/plant/rose-moss-Rhodobryum-roseum (2020); 9: Susan and Windadri (2020)

The previous Sumbawa mosses were collected in the hill and mountain forests and rarely in the lowland forest. The differences in habitat caused these mosses did not find in the previous Sumbawa mosses collection. The small size of *F. braunii* (4-10 mm height) also contributed that it is being neglected in the collection, while *F. nobilis* has relatively large leaves resembling palm leaves. It looks like a small fern that grows on the rocks of the river bank. This stature makes it difficult to tell the difference between mosses and ferns, so it is also missing in the moss collection. *F. nobilis* is an excellent moss and is occasionally available in freshwater aquariums as an alternative to Javanese moss. Like plants generally, this moss sucks up CO2 and releases oxygen into the water. In India, the medication of this plant was reported as diuretics, tonics for hair growth stimulation, an antibacterial agent for swollen throats, and other symptoms of bacterial infection (Azuealo et al. 2011). Southeast Asia also reported this species as a rare moss. In the research site, however, it is grown on soil on the riverside at Block Q forest, Batudulang, Batulanteh, altitude 900 m, while the previous Sumbawa moss collection did not report it. This finding can be confusing with small ferns due to their relatively large stature and pinnate leaf arrangement, so the collection is missing in identification. Another possibility is that the new collection area with different conditions will also find other species that have not been collected.

Tortula muralis Hedw. (Pottiaceae) are a cosmopolitan moss that can be recognized in its acrocarpous growth habit, sporophyte terminal of the shoot apex, and the leaves clusters have an extended costa past the blade of the leaf to form a hair point or awn. It is the most common moss on brick and stone, concrete, roof tiles, other artificial structures, and natural outcrops, and less commonly on trees and wood (Lawley 2020). It is included in the poikilohydric plant. It can tolerate desiccation and in the life rely on external water conduction. The traveling of the water in and out of cells depends on the available moisture in the environment. Several physical features help this moss retain water in low-moisture environments (such as brick walls), including leaf extensions (*awns*) which reflect light and increase the laminar boundary layer and short growth (Mosquin 2008; Košnar et al. 2012). It was reported as a good bio-indicator of airborne pollution, especially in extremely high Cu, Fe, and Zn concentrations reaching much higher than harmful for plants (Kosior et al. 2015). In the research site, it is a common species in the same places and inhabits cracked walls, brick or rough stone walls, rough stone, and solid soil in open areas. The previous moss collection in Indonesia was usually conducted in the conservation area, tourism area, and some places with high moisturizing, and the other places were often missed so that this species did not collect. No species were found on the tracking of moss in the Herbarium Bogoriense collections. In the Malesian region, however, this species is only reported from the Philippines (Tropicos 2021). Therefore, it suggested a new record for Indonesia.

Recovered and new records of moss

The previous mosses diversity from Sumbawa Island was reported by Touw (1992), as many as 39 species originating from various places on the island, 20 species of them have been collected from natural forests of Batulanteh and Jaran Pusang Mount at Sumbawa District on the altitude 500-1600 m. The recent collections recorded as many as 41 species, collected along riverside Moyohulu, Plampang, and Batulanteh natural forests, along roadsides from Sumbawa Besar to Batudulang village, and Semongkat tourism park, on an altitude 427-1015 m.

The moss collections from the research site have a larger contribution to the Sumbawa mosses diversity, which is indicated by 37 species (90%) as new records. Some important factors influenced Sumbawa mosses' diversity as (i) there are no moss collections for long periods after Touw's report in 1992, (ii) natural and artificial environmental changes, and (iii) new areas of moss collection.

If the long period of moss collection in a place has yet to be carried out will experience changes in its species diversity, such as on Lombok Island. The moss species diversity has been increased that influenced by the surrounding environmental factors. Some environmental variables such as canopy coverage, altitude, daily temperature, light, total annual rainfall, and slope were used to evaluate the potential relationships between the community and species diversity (Hernández-Rodríguez et al. 2021). The changing of environmental variables occurred during the period of not collecting mosses on the island, so it has an impact on changes in the diversity of moss species. These changes occur both naturally and artificially. Natural forest changes occur due to the fall of old trees or the breaking of tree branches by strong winds.

Meanwhile, artificial forest changes occur due to felling trees for wood or infrastructure facilities from one place to another. This condition causes changes in the canopy's overlapping, leading to gaps in the forest. These gaps make it easy for sunlight to penetrate the forest floor, and it will impact changes in its microclimate, such as changes in temperature and humidity. So, the high new moss records in the study site impacted environmental degradation. The growth and development of moss were influenced by changing micro-habitat factors like humidity, temperature, and light intensity. Moisture is required for all processes in moss life, especially in photosynthesis. Water is an important factor in the growth and development of mosses. Water is usually available as water vapor, measured as air humidity. The temperature and light will influence the photosynthesis process. The optimum temperature for net assimilation under the experimental conditions is about 25-30°C, and the temperature compensation point is about 35-40°C (Dilks and Proctor 1975). When the temperature drops, moss stops growth (dormant), turns brown, and losses its ornamental value on certain mosses. It can recover quickly at room temperature, and it is a very important characteristic (Gong et al. 2019)

The new areas of moss collection are also supported by increasing moss diversity on Sumbawa Island. The previous moss collectors from Sumbawa District were conducted in a small location (Jaran Pusang and Batulanteh forests). In contrast, the new collection of moss was done in some locations with some habit types such as primary forest (Batulanteh Mount valley), secondary forest (near Batudulang village), along the river bank in the Ai Bling waterfall (Moyohulu Subdistrict), and natural park (Semongkat). The research site has differences in the topography, elevation, and landscape. The difference in environmental conditions will influence the mosses' diversity and distribution. It was reported by Belland and Caners (2021) that the important environmental factor for determining species distribution are mean elevation, annual rainfall, and mountain landscape. The differences in area and elevation will influence the moss diversity, as shown in some new records of mosses on Sumbawa Island.

I traced new records of 37 mosses from the research site to their distribution area. As many as 18 species were found as new records of the Lesser Sunda Islands and six species of them were new records for Indonesia (Figure 5). The Indonesian new records are *Barbula unguiculata*, *Jaegerina luzonensis*, *Tortula Muralis*, *Mercyopsis minuta*, *Trichostomum pallidens*, and *Trichostomum sinnuosum*. The emergence of the new record is probably because of the impact of the opening of tourism in Sumbawa district, like Semongkat natural parks and Ai Bling waterfall at Moyohulu. The number of visitors who come from outside the Sumbawa Islands or foreign visitors from outside of Indonesia makes it possible to bring small moss spores to their luggage or clothes, which will be carried to their destination. Suppose these spores fall on suitable substrates and habitats. In that case, they will be able to germinate, grow and develop into adult mosses so that at the time of collection, they can be found and recorded as arrivals species or new records. These moss species generally have a wide range of habitats. It was shown by the tracking results of the distribution of Sumbawa moss new records and Herbarium Bogoriense mosses collection that is never collected from Indonesia. Three species of Indonesian moss new records (*Barbula unguiculata*, *Trichostomum sinuosum* and *T. pallidens*) are never collected from the Malesian region, so those species are suggested as new records for the Malesian region. Blockeel (2020) reported that *Barbula unguiculata* is widespread in the Northern Hemisphere, especially in Central America's temperate zone. Scattered records from Central and South Africa, South America, Australia, and New Zealand (possibly introduced). It often grows with *Barbula convoluta* at about 0-525 m altitude, on the neutral to base-rich soil on roadsides, tracks, paths, and waste ground, in gardens, quarries, and other disturbed habitats, and the crevices of old walls. In the research area, it was collected from the Semongkat Natural Park (450 m altitude) and Ai Beling waterfall (427 m altitude), so the presence at the research site is also an introduced species. *Trichostomum sinuosum* was colleced by Wallace in 1957 from England (Tropicos 2022). This species has many synonym names, and one of them is *Didymodon sinuosum* (Mitt.) Delogne. It has some distribution areas, e.g., Sub Oceanic Mediterranean-Atlantic. In Europe, from north to Sweden and Poland, east to Ukraine and Caucasus, south to the Mediterranean region, Turkey, Lebanon, Georgia, Azerbaijan (Blockeel 2020), and Morocco (Zaza et al. 2021). The tracking result in the Herbarium Bogoriense collection and some references have never been reported from the Malesian region, as well as *Trochostomum pallidens*, and it has been recorded from India (Dhyani et al. 2022).

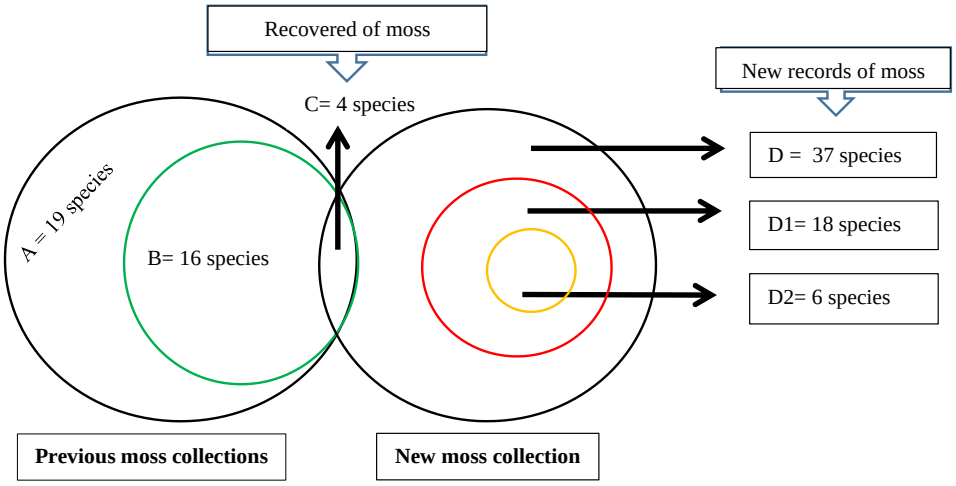

Figure 5. Diversity and new moss records from Sumbawa Island, West Nusa Tenggara, Indonesia. The alphabetic characters show the number of moss: A. non-Sumbawa District; B. Sumbawa District; C. rediscovered; D. new records to Sumbawa Island, D1. new records of LSI, D2. new records in Indonesia

Distribution pattern of mosses based on the habitat

Sumbawa Island is part of the Lesser Sunda Islands that administratively included West Nusa Tenggara Province, Indonesia. This island has five regencies, one of which is Sumbawa District, located in the western part of the island. This area is located in hilly to mountainous forest topography and as an area of Indonesia where limited in biological study. Research on flora diversity has yet to be studied much, including the group of mosses. The previous moss collection from the Batulanteh Sub-district was conducted on Batulanteh and Mount Jaran Pusang and reported 19 species (Touw 1992). The moss collection in this district was done in different habitats and altitudes. The result of this present study indicates that the number of moss collections is different for each habitat (Figure 2.), i.e., 29 (4.3%) in the forest recorded, 22 (32.3%) along river banks, 16 (23.9%) the open site. I collected the highest number of mosses in the secondary forest (around Semongkat and Batudulang villages) and primary forest (Batulanteh mountain valley). The forest floor is humid, particularly in the rainy season.

High humidity and shady areas in the forest are two important factors for the growth and development of mosses on the island. Song et al. (2015) reported each moss species inhabits its habitat and ecological niche. This finding, in combination with its sensitivity to environmental change, makes moss species distribution a useful indicator of vegetation alteration and climate change. The amount and heterogeneity of potential substrates and micro-sites are also important factors in affecting the forest's diversity and bryophyte composition (Mill and Macdonal 2005). In Sumbawa Island, mosses obtain their water supplies from the air humidity and rainwater that flows on tree trunks and rocks or is bound in soil particles and rotten wood, just like mosses from other areas in the world. Water is mainly applied for spore germination and bioregulator, in which the cell bodies directly absorb water. In many species of mosses are found Cancellinae (hyaline cells), which are in the leaves. Cancellinae is a large, empty basal leaf cell, usually hyaline; it may serve as a water storage cell (Glime 2022) during the dry season, and it works well in the climate of this island. It is usually found in Calymperaceae group. The availability of these microsites (dead wood, open patches, pits, and mounds) and microclimatic conditions are considerably influenced by various forest management systems such as logging, opening road access, natural disaster, dead wood management, and management history of the forest.

Mosses are generally epiphytic, so the presence of the substrate becomes very important in moss life. Forest is a suitable habitat for moss, and the environment supports their life. In the forest, it can be found many kinds of substrates (rocks, soils, decaying wood, dead log, and trees) needed for the germination, growth, and development of moss until its maturity. In the research site, mosses inhabit varying substrates such as rocks (20 species), barks (12 species), soil (8 species), dead log (2 species), and decaying wood (2 species). Moss on the research site was commonly found inhabiting rocks (Figure 3). The rocks are found on the forest floor and river banks but rarely on the sloping ground. In the research site, the rocks are usually found in the primary forest floor (block Q forest in the Batulanteh Mount Valley), secondary forest floor (Kuang Strong and Kebon Atas forest near Batudulang village), and along riverbanks (in Semongkat Nature Tourism Park and Brang Suwir River at Batudulang village). Rock is a stable substrate, a big size, has a strong attack on the earth, and has a rough surface. The roughness of rocks occurs in a thin layer of soil or the growth of crust lichen. The existence of a rough surface allows the nesting of small moss spores. On suitable environmental conditions, the moss will germinate, grow and develop into mature moss. In the forest, moss grows on damp rock and soil on the flat forest floor, while on the sloping ground, moss grows on tree trunks. Along river banks, moss growth is on the damp

rock. Moss populations in the research site also grow on forest soil. The soil is classified as a litosol type formed from igneous and sedimentary rock weathering (Zakki 2021). It has red to yellowish-red and usually has low fertility. This soil is generally found in tropical rainforests. The soil's surface generally contains a thin layer of humus dropped from plants and animals in the forests so that it becomes very fertile. However, all nutrients leach away quickly when the forest is felled, and the humus layer is no longer being replaced. This soil type is generally found in mountainous or hilly terrain with steep slopes. The soil does not have a strong grip and is easily washed by rainwater, so rocks generally dominate the land surface in hilly areas. Therefore, moss in hilly areas inhabits the tree trunks more than on the forest floor.

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