Inventory and Characterization of Mosses Diversity (Bryophyta) in Sewu Temple Yogyakarta

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ABSTRACT
The Sewu Temple area, which is located in Prambanan Yogyakarta, is a tourism site that has unique environment conditions where stone temple piles are humid and an open area. These conditions make it possible for Bryophyte to grow surrounding the area. This research aims to identify the species of Bryophyte grow in Sewu Temple Prambanan Yogyakarta and to know characteristics. The method of this research is the exploration method, which includes site investigation, identification, inventory, and descriptive analysis for both morphology and anatomy every specimen. The diversity species of mosses in the Sewu Tempel area was obtained 16 species, consisting 4 species in class Hepaticopsida, Anthocerotopsida, there are 2 species, and Bryopsida 10 species; which include : Hepaticopsida are *Fossombronia other* Aust., *Fossombronia* sp., *Preissia* sp., *Riccia hasskarliana* Steph.; Anthocerotopsida are *Anthoceros two* (L.) Prosk., *Anthoceros punctatus* L. and Bryopsidaa are *Bryum coronatum* Schwaegr., *Bryum include:* fleisch., *Bryum apiculatum* Schwaegr., *Fissidens braunii* (C.Molk) Dozy. & Molk., *Fissidens ceylonensis* Dozy. & Molk., *Fissidens intromarginatulus* Bartr., *Hyophila involute* (Hook.) Jaeg.,*Barbula consanguinea* (Thw. & Mitt) Jaeg., *Campylopus umbellatus* (Arn.) Par., *Garckea comosa* (Dozy. & Molk.) Wijk. & Marg.
Keywords: *Inventory, Bryophyte, Sewu Temple.*

1. INTRODUCTION

Bryophyte is one of the plant species that have wide diversity, and it is considered as primitive plants with various kinds. Bryophyte can be divided into three main classes which are Hepaticae (Liverworts), Anthocerotae (Hornworts), and Musci (Mosses) [1]. It is considered as one of primitive vegetations due to its earlier appearance compared to Pteridophyte and Spermatophyte. There are more than 25,000 species of Bryophyte throughout the world [2]. Their ability to live on most of the earth's surface is because Bryophyte has a certain level of physiological endurance or dry environment, in which this species can withstand and have the endurance of a completely dry climate [3,4].

Bryophyta can be found growing on any and various substrates, assist the soil stabilization through open-field colonization, play an important role in the nutrient recycling process [5]. They can withstand an extreme environment like in a hot, humid, with less supply of nutrition and water shortage. These kinds of conditions can be found in barks, woods, roof tiles, and even stones with no supply of nutrition. Candi Sewu (or Sewu Temple) is a cluster of temples located in Candi Prambanan complex, approximately 800 metres north of Roro Jonggrang Statue [6]. Many stones and statues –which is a part of the Candi Sewu temple— are found collapsed due to the increase of humidity. The humidity level on the stones triggers the spread of Bryophyte, and it also affected the stones aging process.

Some research has been done about the diversity of Bryophyte in a different habitat. The result found that there are ten kinds of Bryophyte found on location within waterfall environment [7]. Moreover, other research-proven that there are

14 species found on another temple: Candi Sukuh, Candi Borobudur, and Candi Dieng [8].

A research on the diversity of Bryophyta on Candi Sewu, according to preceding researches and publications, has never been conducted before. Especially, considering specific topics about its morphology and anatomy. This research is essential to be done in order to organise inventories of the variety of Bryophyta on the observed location. The record of species discovered in this research will give benefit even for the future, to determine the relationship between the collapse of the temple stones due to the growth of Bryophyte or to examine the ability of Bryophyte to live under a nutrition- shortage location.

2. MATERIAL AND METHODS

2.1. Equipment and Material

During the collection of the specimens, the following equipment and materials were used such as field lens, field

note, knife, camera, pencil and pen, plastic bags, cutters, marker, and cellular phones. While during the microscopy examination, the following were used: dissecting set, dissecting microscope, binocular microscope, and glass slides, with cover slips, blades, and beaker, syringe, optilab, medicine droppers, and chloral hydrate.

2.2. Procedure

2.2.1. Observation within Candi Sewu Complex

Field observation has been done to determine the location of observation, to understand the field condition (temperature, humidity, light intensity, and soil pH level), and to observe the availability of Bryophyte species (liverworts, hornworts, and mosses) which has grown on the temple complex.

2.2.2. Specimen Data Collection

Bryophyte sample collection was completed by exploring and observing the temple area to get various types of Bryophyte. The sample was taken using spades and then was kept inside an enclosed container. Bryophyte that were discovered on the site were numerically labeled for every each of it with different morphology. Documentation was being made, as well.

2.2.3. Observation of Morphology Characteristics

The sample that has been collected is being cleaned gently using brushes to avoid damaging the plant structure. Morphology observation for this research consists of filloid, cauloid, and substrate type. The observed filloid organs are including colour, shape, length, edge type, and the tip filloid type. On the other hand, the parameters for cauloid organs are the length and width of cauloid.

2.2.4. Observation of Anatomy Structure

Plant specimen is being cleaned and placed inside a flacon tube, to soak it with chloral hydrate soluble for about two weeks to decay the chlorophyll. After that, the filloid cells of the plant are observed, including cell shape and dimension.

2.2.5. Identification

Identification is conducted by both morphology and anatomy observation and by matching the description of the samples to some reference about identifying Bryophyte species, which are *Handbook of Malesian Mosses* Vol I, *Handbook of Malesian Mosses* Vol 2, *Handbook of Malesian Mosses* Vol 3 [9], *Moss Flora of The National Botanic Garden Quezon Province, Philipines*, *Introduction to Bryophytes* [10], and references from plant taxonomy book (*Schyzophyta, Thallophyta, Bryophyte, Pteridophyta*) [11].

3. RESULT AND DISCUSSION

3.1. Result

Table 1. Result of morphology observation

No	Name of Species	Organ	Characters	Results	Substrate Type
1	*Fossombronia cristula* Aust	Thallus	Colour Shape Length Width Edge type	Green *Frondose* 1108,296± 111,972 µm 877,394 ± 69,204µm Wavy (*repandus*)	Stones
2	*Fossombronia sp.*	Thallus	Colour Shape Length Width Edge type	Green *Frondose* 1296,473±66,944µm 754,374±63,520µm Wavy (*repandus*)	Stones
3	*Preissia sp.*	Thallus	Colour Shape Length Width Edge type Tip type	Green *Frondose* 6800± 1316,561µm 3300± 674,948µm Wavy (*repandus*) Split (*retusus*)	Stones
4	*Riccia hasskarliana* Steph.	Thallus	Colour Shape Length Width Edge type Tip type	Green *Frondose* 8950±1802,005µm 2600 ± 459,468µm Wavy (*repandus*) Split (*retusus*)	Stones
5	*Anthoceros leavis* (L.) Prosk.	Thallus	Colour Shape Length Width Edge type	Green *Frondose* 7200 ± 918,936µm 5800 ± 788,810µm Wavy (*repandus*)	Stones
6	*Anthoceros punctatus* L.	Thallus	Colour Shape Length Width Edge type	Green *Frondose* 5600 ± 966,091µm 3600 ± 843,274µm Wavy (*repandus*)	Stones
7	*Bryum coronatum* Schwaegr.	Filloid	Colour Shape Length Width Edge type Tip type Presence of midrib	Green *Lanceolate* (Eddy,1990) 1702,524± 9,120µm 471,778±51,309µm Flat (*integer*) Pointed (*acutus*) Yes	Stones
8	*Bryum erytropus* fleisch.	Filloid	Colour Shape Length Width Edge type Tip type Presence of midrib	Green *Lance* (McKnight,2013) 1627,952 ±16,866µm 386,959 ± 51,426µm Flat (*integer*) Tapered (*acuminatus*) Yes	Stones

9	*Bryum apiculatum* Schwaegr.	Filloid	Colour	Green	Stones
			Shape	*Peat moss*	
			Length	1838,61± 56,228µm	
			Width	560,728 ±33,430µm	
			Edge type	Flat (*integer*)	
			Tip type	Tapered (*acuminatus*)	
			Presence of midrib	Yes	
10	*Fissidens braunii* (C.Molk) Dozy. &Molk.	Filloid	Colour	Green	Stones
			Shape	*Tongue*	
			Length	1158,462 ± 25,798µm	
			Width	352,117± 10,404µm	
			Edge type	Flat (*integer*)	
			Tip type	Pointed (*acutus*)	
			Presence of midrib	Yes	
11	*Fissidens ceylonensis* Dozy. &Molk.	Filloid	Colour	Green	Soils
			Shape	*Lancet*	
			Length	2198,892± 320,931µm	
			Width	448,816± 52,193µm	
			Edge type	Flat (*integer*)	
			Tip type	Pointed (*acutus*)	
			Presence of midrib	Yes	
12	*Fissidens intromarginatulus* Bartr.	Filloid	Colour	Green	Stones
			Shape	*Tongue*	
			Length	1918,154 ± 72,949 µm	
			Width	450,115 ± 29,053 µm	
			Edge type	Flat (*integer*)	
			Tip type	Pointed (*acutus*)	
			Presence of midrib	Yes	
13	*Hyophila involute* (Hook.) Jaeg.	Filloid	Colour	Pale Green	Stones
			Shape	*Tongue* (Alain,2009)	
			Length	2320,043 ± 12,283 µm	
			Width	728,084 ± 19,506 µm	
			Edge type	Flat (*integer*)	
			Tip type	Pointed (*acutus*)	
			Presence of midrib	Yes	
14	*Barbula consanguinea* (Thw. & Mitt) Jaeg.	Filloid	Colour	Green	Stones
			Shape	*Lancet* (McKnight,2013)	
			Length	1456,124 ± 30,587µm	
			Width	609,97 ±29,418µm	
			Edge type	Flat (*integer*)	
			Tip type	Pointed (*acutus*)	
			Presence of midrib	Yes	
15	*Campylopus umbellatus* (Arn.) Par.	Filloid	Colour	Green	Stones
			Shape	*Lancet* (McKnight,2013)	
			Length	2736,29 ± 20,222 µm	
			Width	320,737 ± 32,228 µm	
			Edge type	Flat (*integer*)	
			Tip type	Tapered (*acuminatus*)	
			Presence of midrib	Yes	
16	*Garckea comosa*	Filloid	Colour	Green	Stones

	(Dozy. &Molk.) Wijk. & Marg.	Shape	*Lancet* (McKnight,2013)
		Length	2439,942 ± 45,029 µm
		Width	500,946 ± 16,320 µm
		Edge type	Flat (*integer*)
		Tip type	Pointed (*acutus*)
		Presence of midrib	Yes

Table 2. Results of anatomical structure observation

No	Name of Species	Organ	Cell shapes	Dimensions				Length/ Width (µm)
				Length (µm)	$\bar{X}$ Length (µm)	Width(µm)	$\bar{X}$ Width (µm)	
1	*Fossombronia cristula* Aust	Thallus	Hexagonal	42,16 ± 7,30	42,16	26,75 ± 3,22	26,75	1,57
		Midrib	-	-	-	-	-	-
2	*Fossombronia sp.*	Thallus	Hexagonal	31,77 ± 8,04	31,77	21,64 ± 4,98	21,64	1,46
		Midrib	-	-	-	-	-	-
3	*Preissia sp.*	Thallus	Hexagonal	30,99 ± 3,87	30,99	22,45 ± 2,36	22,45	1,38
		Midrib	-	-	-	-	-	-
4	*Riccia hasskarliana* Steph.	Thallus	Oval	43,47 ± 5,05	43,47	22,29 ± 7,53	22,29	1,95
		Midrib	-	-	-	-	-	-
5	*Anthoceros leavis* (L.) Prosk.	Thallus	Heksagonal	36,46 ± 4,30	36,46	25,11 ± 6,20	25,11	1,45
		Midrib	-	-	-	-	-	-
6	*Anthoceros punctatus* L.	Thallus	Heksagonal	26,27 ± 3,15	26,27	20,21 ± 2,04	20,21	1,29
		Midrib	-	-	-	-	-	-
7	*Bryum coronatum* Schwaegr.	Filloid	Rectangular	26,24 ± 7,95	26,24	8,58 ± 2,25	8,58	3,05
		Midrib	Rectangular	37,83 ± 9,44	37,83	7,17 ± 1,82	7,17	5,27
8	*Bryum erytropus* fleisch.	Filloid	Rectangular	58,22 ± 12,07	58,22	11,32 ± 3,07	11,32	5,14
		Midrib	Rectangular	46,98 ± 9,23	46,98	5,45 ± 1,76	5,45	8,62
9	*Bryum apiculatum* Schwaegr.	Filloid	Rectangular	26,90 ±7,91	26,90	10,82 ± 1,91	10,82	2,48
		Midrib	Flat longitudinal	42,56 ± 8,58	42,56	4,62 ± 0,78	4,62	9,21
10	*Fissidens braunii* (C.Molk) Dozy. &Molk.	Filloid	Hexagonal	8,95 ± 1,46	8,95	4,99 ± 0,90	4,99	1,79
		Midrib	Rectangular	33,73 ± 3,63	33,73	4,02 ± 0,64	4,02	8,39
11	*Fissidens ceylonensis* Dozy. &Molk.	Filloid	Rectangular	37,43 ± 10,49	37,43	9,54 ± 2,03	9,54	3,92
		Midrib	Rectangular	10,17 ± 2,16	10,17	2,59 ± 0,39	2,59	3,92
12	*Fissidens intromarginatulus* Bartr.	Filloid	Isodiametrics	6,70 ± 1,01	6,70	5,65 ± 0,87	5,65	1,18
		Midrib	Rectangular	44,41 ± 9,03	44,41	3,53 ± 0,65	3,53	12,58
13	*Hyophila involute* (Hook.) Jaeg.	Filloid	Square	9,97 ± 1,48	9,97	7,83 ± 1,44	7,83	1,27
		Midrib	Rectangular	22,58 ± 5,14	22,58	4,91 ± 0,82	4,91	4,59
14	*Barbula consanguinea* (Thw. & Mitt) Jaeg.	Filloid	Rectangular	19,80 ± 1,93	19,80	6,85 ± 1,25	6,85	2,89
		Midrib	Rectangular	24,78 ± 5,31	24,78	3,35 ± 0,46	3,35	7,39
15	*Campylopus umbellatus* (Arn.) Par.	Filloid	Rectangular	34,30 ± 9,32	34,30	14,90 ± 2,37	14,90	2,30
		Midrib	Rectangular	22,92 ± 5,59	22,92	7,83 ± 1,11	7,83	2,92
16	*Garckea comosa* (Dozy. &Molk.) Wijk. & Marg.	Filloid	Rectangular	43,60 ± 10,62	43,60	5,59 ± 1,15	5,59	7,79
		Midrib	Rectangular	46,50 ± 9,69	46,50	6,42 ± 0,66	6,42	7,24

Tabel 3. Identification results

No	Species	Genera	Family	Order	Class
1	*Fossombronia cristula* Aust	*Fossombronia*	Fossombroniaceae	Metzgeriales	Hepaticopsida
2	*Fossombronia* sp.				
3	*Preissia* sp.	*Preissia*	Marchantiaceae	Marchantiales	
4	*Riccia hasskarliana* Steph.	*Riccia*	Ricciaceae		
5	*Anthoceros leavis* (L.) Prosk.	*Anthoceros*	Anthocerotaceae	Anthocerotales	Anthocerotopsida
6	*Anthoceros punctatus* L.				
7	*Bryum coronatum* Schwaegr.	*Bryum*	Bryaceae	Bryales	Bryopsida
8	*Bryum erytropus* fleisch.				
9	*Bryum apiculatum* Schwaegr.				
10	*Fissidens braunii* (C.Molk) Dozy. &Molk.	*Fissidens*	Fissidentaceae	Fissidentales	
11	*Fissidens ceylonensis* Dozy. &Molk.				
12	*Fissidens intromarginatulus* Bartr.				
13	*Hyophila involute* (Hook.) Jaeg.	*Hyophila*	Pottiaceae	Pottiales	
14	*Barbula consanguinea* (Thw. & Mitt) Jaeg.	*Barbula*			
15	*Campylopus umbellatus* (Arn.) Par.	*Campylopus*	Dicranaceae	Dicranales	
16	*Garckea comosa* (Dozy. &Molk.) Wijk. & Marg.	*Garckea*			

3.2. Discussion

The observation results show that within the Candi Sewu complex there are several Bryophyte species that belong to hornworts, liverworts, and mosses classes. This research collected 16 species of those three different groups (refer to Table 3). Most of the plants found in the location are belong to Bryopsida because the species of Bryophyte are dominated by this group. Following this group is Hepaticopsida. There are only two species of Anthocerotopsida class found on the site, mostly on the substrate area where the least species found.

The variation of Bryophyte grow on Candi Sewu can be affected by abiotic factors such as humidity, light intensity, temperature, and the pH level of soil or substrate. Based on the measurement result, the numbers for these mentioned parameters are obtained, which are 76% for humidity, 2475 lux of light intensity, 32oC temperature, and the average pH level of 6.2 for soil or substrate. Bryophyte, whether it is liverworts, hornworts, or mosses, can grow well under enough exposure of sunlight and a low substrate pH (alkali environment) [12, 13]. According to the result of this observation, the most common type of Bryophytes found on Candi Sewu is mosses. This division is mostly found on stones, and only one species was found in soil, which is *Fissidens cevlonensis* Dozy. & Molk. Subsequently, the other species are found on a concaved side of stones and in a gap or cracks between stones. These conditions are possible due to enough level of exposure and humidity; therefore bryophytes were thriving in the area. That indicates that bryophytes are found well-grown on the environment condition of Candi Sewu.

Based on the result of descriptive analysis, it is ascertainable that there are similarities between species under the same division. Similarities found between the four species of liverworts are their *frondose* thallus shape, wavy edge thallus, and pleurocarp growth direction. The differences found for liverworts are on their length and width, which are for both morphology and anatomy structure (refer to Table 1). *Preissia* sp. is a liverwort which the habitat is in a humid place, sticking to soil or rocks. The talus is like a ribbon, rather thick, branched, scratched and has a middle rib that is not too prominent. The bottom side has a ventral scale and rhizoid[14].

Similarities between 2 discovered hornworts are they have frondose thallus shape, wavy thallus edge, and have horn-shaped features. The difference between these types is that they have different thallus sizes and different cell dimensions. As for *Anthoxeros punctatus* L and *Anthoceros leavis* (L.) Prosk., it is found that they have a gravel-like thallus shape, but the thallus is thicker for Anthoceros Leavis L. Prosk.

Likenesses between ten mosses specimens found on Candi Sewu complex are that they have ascocarp (upright) growth direction, and their filloid, cauloid, and rhizoid are distinguishable. The difference between these specimens is the shape of their filloid. They have different types of filloid, for example, lancet, peat moss, and tongue. The tip filloid is different as well: they got pointed and tapered tip type. The other difference is that they got different dimensions (length and width) for both filloid features and cell features.

The cell size ratio of filloid is varied, but when observed it appears that for the Hepaticopsida and Anthocerotopsida were around one and not more than 2. While for Bryopsida (mosses), the ratio of between the length and width of the cells making up the Filloid mostly are greater than 2, and for *Fissidens intromarginatulus* Bartr. species it is escalated up to 12.

4. CONCLUSION

The results of the study obtained 16 species of bryophytes, which belong to 3 classes, *Hepaticopsida* (4 species), *Anthocerotopsida* (2 species), and *Bryopsida* (10 species). Characteristics found on Bryophyte are as follows: Hepaticopsida formed of frondose thallus (like sheets), has the wavy thallus edge type and has a pleurocarp growth direction (creep). Anthocerotopsida has frondose thallus, wavy thallus edge, and has horns. In Bryopsida, it has an ascocarp type growth direction.

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