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# Diversity of bryophyte at junior and senior high schools environment in Yogyakarta city for supporting the implementation of curriculum 2013 in applicative biology learning FREE

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# Diversity of Bryophyte at Junior and Senior High Schools Environment in Yogyakarta City for Supporting the Implementation of Curriculum 2013 in Applicative Biology Learning

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**Abstract.** The orientation of curriculum 2013 is based on science application. Some of the basic competence in biology are identification and classification to support learning activities. Bryophyte has a unique morphology and ecology, but the information about their diversity at junior and senior high school environment of Yogyakarta as the education city has not been available. This research was aimed to determine the diversity, classification, and distribution of bryophyte species at junior and senior high school environment of Yogyakarta and its potential use to support the implementation of curriculum 2013 in applicative biology learning. This research was conducted in Aug 2016. The samples collections were done in 15 junior high schools and 15 senior high schools in Yogyakarta. The samples were then preserved as dried herbarium and were identified in Laboratory of Plant Systematics, Universitas Gadjah Mada (UGM). Variation of bryophyte species diversity was analyzed by the Shannon-Wiener diversity index. The distribution analysis of bryophyte was obtained based on comparing diversity index on 15 junior and senior high schools and also determined with importance values. The results showed the total of 13 bryophytes, i.e. *Cheilolejeunea intertexta* (Lindenb.) Steph., *Cyathodium spruceanum* Porsk., *Riccia haskarliana* Steph., *Trocholejeunea sandvicensis* Schiffn., *Barbula javanica* Dozy & Molk., *Bryum coronatum* Schwaegr., *Calymperes tenerum* C. Mull., *Ectropothecium buitenzorgii* (Bel.) Jaeg., *Fissidens atroviridis* Besch., *Gymnostomiella vernicosa* (Hook.) Fleisch., *Hyophila involuta* (Hook.) Jaeg., *Octoblepharum albidum* Hedw., and *Vesicularia dubyana* (C. Mull.) Broth. They could be classified into two classes, as Hepaticopsida and Bryopsida, which can be found on soil, rock surfaces, concrete walls, and also trees. *Barbula javanica* from Class Bryopsida has been broadly distributed at those area based on importance values. This preliminary study should be used for introduction diversity of bryophyte and support the implementation of curriculum 2013, especially in applicative biology learning for junior and senior high school students in Yogyakarta.

**Keywords:** applicative biology, bryophyte, curriculum 2013, Yogyakarta



## INTRODUCTION

The orientation of curriculum 2013 is based on science application. Integration of applicative science learning was developed as a sustainable process from junior high school to senior high school. Some of the basic competence in biology are identification and classification [1]. Bryophyte, as the non-vascular plants, has a unique morphology and ecology but seldom explored. Based on gametophyte and sporophyte characters, bryophyte comprises three classes; Hepaticopsida (liverworts), Anthocerotopsida (hornworts), and Bryopsida (mosses). Bryophyte can grow in various climate and environmental conditions, so it has a wide distribution [2].

Yogyakarta is the capital city of Daerah Istimewa Yogyakarta located between 7°49'26"−7°15'24"S and 110°24'19"−110°28'53"E. It is divided into 14 sub-districts with the northern boundary is Sleman, Sleman and Bantul at the east, Bantul at the south, and Sleman and Bantul at the west [3]. Yogyakarta has 544 schools from various levels with 65 junior high schools and 53 senior high schools [4]. As education city, Yogyakarta is suitable to be the initiator area for bryophytes species diversity study. Several studies about bryophytes have been done in Yogyakarta with various locations such as temples, Merapi Mountain, forests, and caves. However, the information about bryophyte species diversity study in school environment to support applicative

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biology learning activities has not been available. This research was aimed to determine the diversity on the species level, classification, and the distribution of bryophyte species at junior and senior high schools environment of Yogyakarta and its potential use to support the implementation of curriculum 2013 in applicative biology learning.

## MATERIALS AND METHODS

This research was conducted in Aug 2016. Researcher divided Yogyakarta city into two main area based on elevation and selected 15 schools consisting of junior and senior high schools in each area as bryophytes sampling location (Table 1). Sample collections were done in 15 junior high schools and 15 senior high schools, located in various sub-districts (Fig. 1).

**TABLE 1**. List of Junior and Senior High Schools in Yogyakarta city as the location of bryophyte sampling.

| Altitude (MASL) | Location | |
|---|---|---|
| | SMP (Junior High School) | SMA (Senior High School) |
| ±75 to 100 | SMPN 2<br>SMPN 9<br>SMPN 10<br>SMPN 16<br>SMP Bopkri 5<br>SMP Muhammadiyah 9<br>SMP Stella Duce 2 | SMAN 5<br>SMAN 7<br>SMAN 8<br>SMAN 10<br>SMA Muhammadiyah 7<br>SMA Sang Timur<br>SMA Santa Maria<br>SMA Taman Madya Ibu Pawiyatan |
| ±100 to 200 | SMPN 1<br>SMPN 3<br>SMPN 5<br>SMPN 11<br>SMPN 12<br>SMPN 15<br>SMP Muhammadiyah 1<br>SMP Muhammadiyah 4 | SMAN 2<br>SMAN 3<br>SMAN 4<br>SMAN 6<br>SMAN 11<br>SMA Muhammadiyah 5<br>SMA Ma'arif |

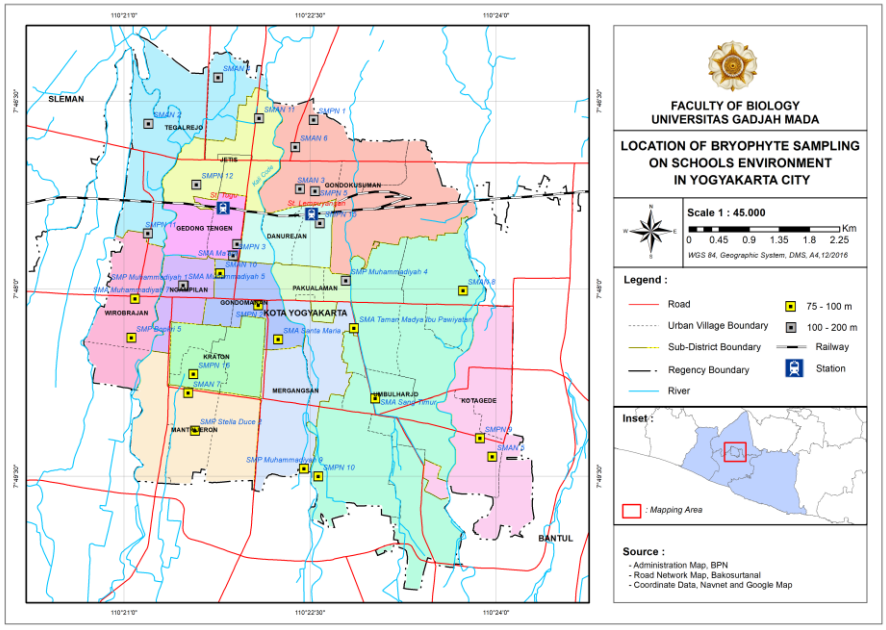


**FIGURE 1**. Detailed map location of bryophyte sampling at Junior and Senior High Schools environment in Yogyakarta city.

Bryophytes samples were taken from grid plot (15 cm × 15 cm) placed inside and outside (± 10 m) of schools environment, collected from soil, rock surfaces, concrete walls, and trees. The samples were then preserved as dried herbarium and were identified in Laboratory of Plant Systematics, UGM. Sample identification was identified from morphological (gametophyte-sporophyte shaped, colour, texture) and

anatomical (gametophyte-sporophyte cell) characters using literatures such as Mosses of the Philippines [4], A Handbook of Malesian Mosses [5–7], Guide to the Liverworts and Hornworts of Java [8], and Mosses and Liverworts of Hong Kong [9]. Data of vegetation analysis were comprised of species diversity and environmental parameters. Variation of bryophyte species diversity was analyzed by the Shannon-Wiener Index [10].

$$H = -\sum p_i ln\, p_i$$

pi: n/N
n: the number of I individual
N: the total number of observed individual

The distribution analysis of bryophyte was obtained based on importance values.

## RESULTS AND DISCUSSION

### Bryophytes Species Diversity

A total of 13 collections of bryophytes at 15 junior high schools and 15 senior high schools environment in Yogyakarta city was identified. Morphology and anatomy of bryophytes species were shown and described below.


**FIGURE 2**. Morphology and anatomy of bryophyte species at Junior and Senior High Schools environment in Yogyakarta city. A&E. *Cyathodium spruceanum*; B&F. *Riccia hasskarliana*; C&G. *Cheilolejeunea intertexta;* D&H. *Trocholejeunea sandvicensis*.

***Cyathodium spruceanum*** Prosk. [8]. (Fig. 2. A and Fig. 2. E)

Thalloid liverworts; upper surface with pores (appearing as tiny, whitish or dark dots, visible with handles); gemmae cups absent; thallus up to 1 cm to 1.8 cm long, 0.3 cm to 0.6 cm wide, very thin 2 to 4 cell-layers thick, green, broadened towards apex; fresh plants sometimes with a bad smell; thallus margin entire. Dioicous; sporophytes embedded in a notch at the thallus apex. Common on wet, shaded, banks of creeks and rivers. Widely distributed throughout Asia to America.

***Riccia hasskarliana*** Steph. [8]. (Fig. 2. B and Fig. 2. F)

Thalloid liverworts; thallus surface without pores; thallus smaller, pale green to glossy fresh green; thallus margins without rudimentary leaves; thallus with large and conspicuous air chambers; thallus about 1 mm wide, forming rosettes. Dioicous; spore with six to eight reticulae across the outer surface. Locally common on wet soil along rivers, ponds, and in ditches. Widely distributed in both tropical and temperate regions of the world.

***Cheilolejeunea intertexta*** (Lindenb.) Steph. [9]. (Fig. 2. C and Fig. 2. G)

Leafy liverworts, mats, light green to yellowish in colour; stems creeping, loosely appressed to the substrate, up to 12 mm long, 0.6 mm to 0.76 mm wide with leaves, irregularly and densely branched; leaf-lobe orbicular; leaf-lobule ovate, small about 1/3 as long as the leaf-lobe, with a celled angular tooth at apex; underleaves orbicular, small, two to three times as wide as the stem, slightly two lobed; oil bodies two to three per leaf cell, elliptical or spherical; median leaf cells thin walled, with small trigones and without intermediate thickenings. Monoicous; sporophyte consist of setae, and capsule. Locally common forming dense colonies on tree trunks, scrambling over each other in a tangled moss. Widely distributed throughout Asia.

***Trocholejeunea sandvicensis*** Schiffn. [9]. (Fig. 2. D and Fig. H)

Leafy liverworts, mats, stems long creeping, irregularly branched; green but becoming brown when old, to 30 mm long; leaf-lobes ovate and scale-like, densely arranged along the stem, margins entire and apices rounded; leaf-lobules semicircular in shape, about half as long as the lobe; underleaves imbricate, also large and broadly ovate with incurved upper margins; leaf cells rhomboid, thick-walled, oil-bodies small and homogenous. Monoecious; sporophyte consists of seta and capsule. Locally epiphytic on trees or moist rocks. Widely distributed throughout Asia.

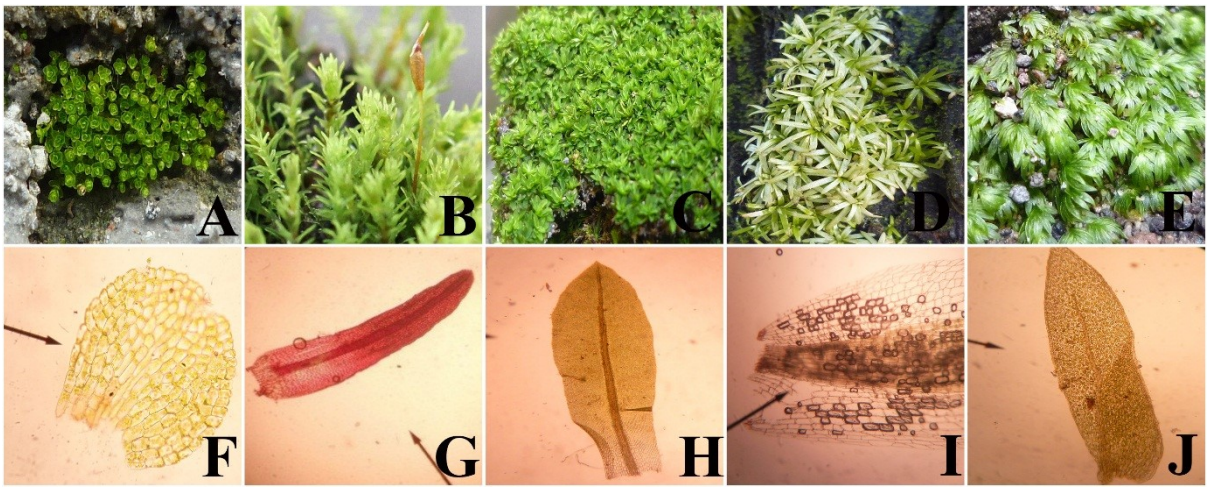


**FIGURE 3**. Morphology and anatomy of bryophyte species at Junior and Senior High Schools environment in Yogyakarta city. A and F. *Gymnostomiella vernicosa*; B and G. *Barbula javanica*; C and H. *Hyophila involuta*; D and I. *Octoblepharum albidum;* E and J. *Fissidens atroviridis*.

***Gymnostomiella vernicosa*** (Hook.) Fleisch. [6]. (Fig. 3. A and Fig. 3. F)

Plants very small, dull green, forming low, inconspicuous mats; barren shoots up to 2 cm tall but female stems much shorter, usually under 3 mm, matted with rhizoids at base; central strand lacking. Leaves of barren shoots minute, distant or imbricate, short-spatulate, usually less than 0.5 mm long but up to 0.4 mm wide distally; from narrow, hyaline, non-sheathing base expanded to broadly rounded; papillose-crenulate apices; costa thin, ending well below leaf apex; upper lamina cells quadrate-hexagonal, thin-walled; lower cells emerging into the smooth, hyaline basal cells which are up to 50 µm or more long. Dioicous; seta is yellow-brown, smooth, about 5 mm long; capsule ovoid, small, dark brown at maturity; urn 0.5 mm long; lid subulate, as long as urn; peristome lacking. Locally common on damp, shaded, usually calcareous rocks and walls. Widely distributed in tropical Asia, from India and Burma to Malesia (the Malay Peninsula to Java and the Philippines).

***Barbula javanica*** Dozy & Molk. [4, 6]. (Fig.3. B and Fig. 3. G)

Plants small, tufted, dense green to yellowish green, unbranched, stems erect up to 1 cm long, covered with erectopatent leaves, clustered near apex. Leaves erect and lightly curved when dry, about 1.5 mm long, lingulate; leaf apex rounded; leaf base broad, narrowing towards the apex, tip bluntly pointed; margins entire, plane; costa brown, ending just below tip; leaf cells pellucid and distinct; the upper lamina cells quadrate with firm, pale walls, smooth or slightly papillose, 6 µm to 8 µm, gradually larger below; basal cells rectangular, elongated, hyaline. Dioicous; seta is apical, erect, deep red below, lighter above, 8 µm to 10 µm long; capsule erect, cylindrical; peristome long, reddish, teeth spirally twisted. Locally common on wet rocks and soil but with a strong preference for calcareous habitats. Distributed in Asia (Himalaya, India, China, Indonesia, Japan, Nepal, Philippines, Taiwan, Thailand, Sri Lanka), North America, and Oceania.

***Hyophila involuta*** (Hook.) Jaeg. [6]. (Fig. 3. C and Fig. 3. H)

Plants dark green to yellowish, tufts or mats, erect up to 1.5 cm tall, simple or branched, 4 mm to 6 mm long. Leaves spreading in rosettes, erect-spreading, lingulate to spathulate, the limb typically wider than the leaf base; upper margins usually remotely and irregularly dentate; apex broadly acute to obtuse, usually with a distinct mucro; costa strong, brownish or reddish, percurrent, ending in the leaf tip; upper lamina cells quadrate; apical leaf cells mamillose; base of leaf hyaline, the colourless area relatively small and intergrading with the chlorophyllose lamina, composed of rectangular, thin-walled cells. Dioicous; frequently bear fruit; seta up to 1.5 cm long, smooth, red-brown at base, pale above; capsule cylindrical, urn 2 mm to 3 mm long; peristome absent. It has seen in a variety of habitats such as on soil, rocks, logs, walls, etc. Widely distributed from low to high altitudes, throughout Africa, Asia (China, India, Himalaya, Indonesia, Japan, Malaysia, Philippines, Sri Lanka, Taiwan, Thailand), Europe, Oceania, North and South America.

***Octoblepharum albidum*** Hedw. [6]. (Fig. 3. D and Fig. 3. I)

Plants tufted, whitish or with tinges of brown, rather glossy; stems densely foliate, simple or irregularly branched, lacking a central strand, bearing rhizoids, usually less than 2 cm tall. Leaves typically recurved-spreading from slightly sheating bases; limbs linear, of solid texture, parallel-sided then abruptly narrowed to a variously subacute, obtuse or very shortly mucronate apex, smooth; leaf composed mainly of costa which is more or less shallowly plano-convex in mid limb, with a single meshwork of chlorocysts between upper and lower layers of leucocysts, the latter is two to three cells deep; chlorocysts narrow, mainly triangular in section; hyaline lamina forming the broad wings of the sheating base, comprising thin-walled leucocysts in a single layer, without a differentiated border; lamina vanishing above leaf shoulders. Autoecious; setae 4 mm to 7 mm long, smooth; capsule ovoid; urn brown, rather glossy when ripe, 1.1 mm to 1.5 mm long, 0.5 mm to 0.6 mm wide below the middle; lid subulate; eight teethed peristome, irregular, more or less triangular teeth which are yellowish. Widespread and locally abundant in Malesia; on trees in the forest, parks, and gardens, in dense to light shade.

***Fissidens atroviridis*** Besch. [5]. (Fig. 3. E and Fig. 8 J)

Plants small, pale yellowish to dull translucent green, soft, up to 10 mm to 15 mm tall, curled when dry. Leaves rather distant, in up to 12 pairs to 16 pairs, the upper up to 2.5 mm long, 0.7 mm wide, narrowly bordered all round on the apical and dorsal lamina; leaf border thick, composed of one to two (up to three on vaginant lamina) series of prosenchymatous narrow cells, reaching or ending just below leaf tip; costa vanishing well bellow leaf apex (six or more cells); lamina cells are large, irregularly hexagonal, very thin-walled, 30 µm to 40 µm in the apical lamina, longer in the lower part of the vaginant lamina. Dioicous; archegoniate plants common, the archegonia terminal on main shoots; seta is short, about 4 mm long; capsule symmetrical. Frequent on damp, shaded soil and rocks throughout Indo-Malaya from India to New Guinea.



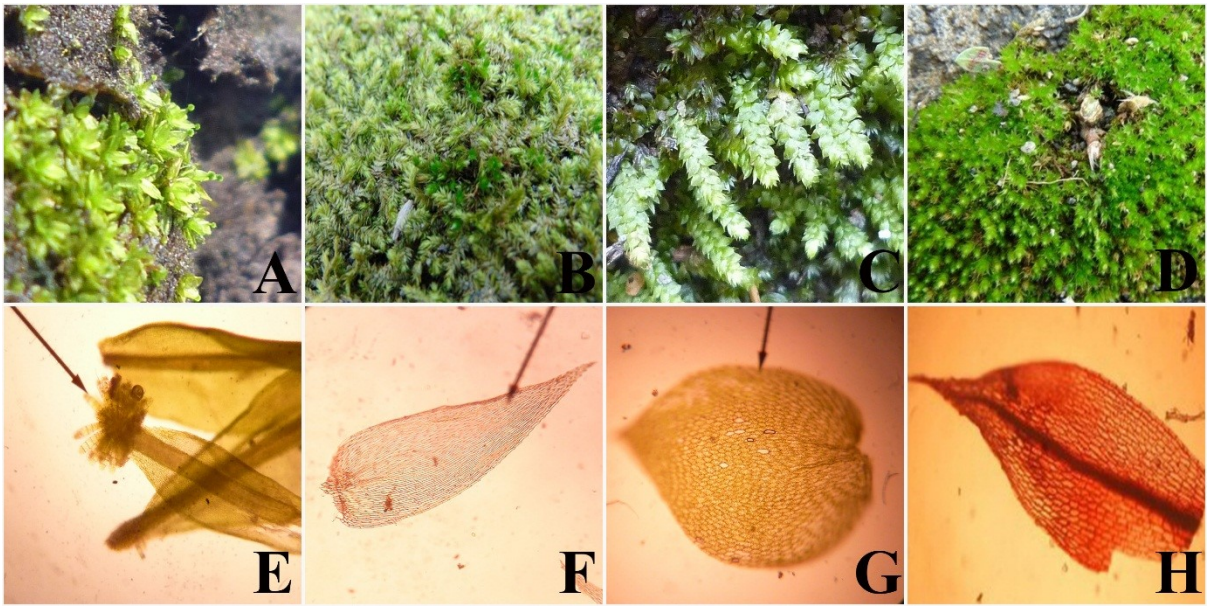


**FIGURE 4**. Morphology and anatomy of bryophyte species at Junior and Senior High Schools environment in Yogyakarta city. A&E. *Calymperes tenerum*; B&F. *Ectropothecium buitenzorgii*; C&G. *Vesicularia dubyana*; D&H. *Bryum coronatum*

***Calymperes tenerum*** C. Mull. [4, 6]. (Fig. 4. A and Fig. 4. E)

Plants very small, dull green, with low tufts or mats, seldom more than 7 mm tall; stems up to 1 cm long. Leaves erect-spreading when moist, incurved and crispate when dry, almost uniform, lingulate, 1.5 mm to 2 mm long, not or scarcely widened below base of limb, the gemmiferous ones differing only in having a more pronouncedly excurrent costa which bears gemmae all around the tip; leaf margins entire unbordered or at most with one or two marginal rows of unmodified lamina cells bistratose; apex of non-gemmiferous leaves bluntly mucronate; costa up to 60 µm wide in non-gemmiferous leaves, circular in section and showing a single series of a guide cells; costa of a gemmiferous leaves strongly excurrent and thicker, up to 100 µm, but not essentially different morphologically from that of a normal leaves; lamina cells in one layer, irregularly rounded, thin-walled in upper limb, 6 µm to 8 µm wide, lightly papillose; lamina cells bordering with short-rectangular cancellinae, occupying only about half of the width of the leaf base and consisting of four rows to seven rows of large hyaline cells. Dioicous; seta is 1.5 mm to 2 mm long; capsule cylindric, urn with 1 mm long; lid short; calyptra minutely scabrous on edges of the pleats. Distribution widespread around the coasts of tropical Asia; India, the Pacific islands to Hawaii; frequent throughout lowland Malesia, especially near the sea but ascending to 1 500 MASL; epiphytic on the tree.

***Ectropothecium buitenzorgii*** (Bel.) Jaeg. [4]. (Fig. 4. B and Fig. 4. F)

Robust-golden green or brownish glossy plants in large mats; stems elongate, regularly pinnate, branches widely spreading, slightly flattened, blunt and hooked at tips. Branch leaves falcate, ovate-lanceolate, more or less slenderly acuminate to 1.6 mm long; margins sharply serrate in the upper half and serrulate nearly to base; costa none or very short and double; cells linear or linear-rhomboidal 5 µm to 7 µm wide, subquadrate at basal angles in a small. Stem leaves slightly larger and occasionally with a larger group of hyaline alar cells. Perichaetial leaves gradually acuminate, sharply serrate. Dioicous; seta is 2.5 cm to 3.5 cm long, red; capsule pendulous, turgid, ovoid; lid convex with a short beak. Locally common on earth and tree. Distributed in Sumatra, Java, Amboina, Ceram, Celebes, and Borneo.

***Vesicularia dubyana*** (C. Mull.) Broth. [4]. (Fig. 4. C and Fig. 4. G)

Plants dull green or golden brown, in lax soft mats; stem elongate, more or less regularly pinnate, branches complanate-foliate. Leaves ovate, broadly acuminate, short-pointed, usually minutely denticulate toward apex to 1.3 mm long; cells are 6 µm to 10 µm wide and 7 to 10 times as long, narrowly rhomboidal. Perichaetial leaves slightly denticulate above. Autoicous; seta is 1.5 cm to 2 cm long; capsule ovoid, horizontal or pendulous. Distributed in Java, Banka, and Amboina; on damp rocks and earth.

***Bryum coronatum*** Schwaengr. [4, 7]. (Fig. 4. D and Fig. 4. H)

Plants dull green, in low tufts up to 1.5 cm deep, rarely over 2 cm. Leaves erect-spreading, lanceolate, slightly concave, shrivelled and erect when dry, very variable in size, generally between 1 mm to 2 mm long; margins plane; border very weakly differentiated or apparently absent, consisting at most of one row or two rows narrow and thick-walled cells; costa strong, red-brown at base, excurrent in a rather stiff arista up to 0.4 mm long; upper lamina cells rhomboid, thin-walled, 12 µm to 16 µm wide, up to 40 µm long; lower lamina cells longer, up to 80 µm. Perichaetial leaves mostly identical to branch leaves, or the innermost triangular, ending in an arista up to 0.6 mm long. Dioicous; seta is reddish, very variable in length but commonly between 2 cm to 3 cm; capsule deep red to reddish brown when ripe, short-cylindric, with a very thick apophysis rather wider than the smooth urn; peristome fully developed, with appendiculate cilia. Distributed in pantropical and subtropical; common to locally abundant throughout Malesia on a variety of mineral substrates, especially where calcareous; a common weed of disturbed areas around towns and villages, from sea-level to the alpine zone.

All of bryophytes species was found in 30 schools environment can be classified based on the similarity of traits between them. The classification system of them presented below.

**TABLE 2**. Classification of bryophyte species found in junior and senior high schools environment in Yogyakarta city.

| Class | Order | Family | Genus | Species | Habitat |
|---|---|---|---|---|---|
| Hepaticopsida | Jungermanniales | Lejeuneaceae | *Cheilolejeunea* | *Cheilolejeunea intertexta* (Lindenb.) Steph. | Tree |
| | | | *Trocholejeunea* | *Trocholejeunea sandvicensis* Schiffn. | Tree |
| | Marchantiales | Cyathodiaceae | *Cyathodium* | *Cyathodium spruceanum* Prosk. | Soil, rock surfaces |
| | | Ricciaceae | *Riccia* | *Riccia hasskarliana* Steph. | Soil, rock surfaces |

Continued on next page

**TABLE 2.** Continued

| Class | Order | Family | Genus | Species | Habitat |
|---|---|---|---|---|---|
| Bryopsida | Dicranales | Leucobryaceae | *Octoblepharum* | *Octoblepharum albidum* Hedw. | Tree |
| | Eubryales | Bryaceae | *Bryum* | *Bryum coronatum* Schwaegr. | Soil, rock surfaces |
| | Fissidentales | Fissidentaceae | *Fissidens* | *Fissidens atroviridis* Besch. | Soil, rock surfaces |
| | Hypnales | Hypnaceae | *Ectropothecium* | *Ectropothecium buitenzorgii* (Bel.) Jaeg. | Soil, rock surfaces |
| | | | *Vesicularia* | *Vesicularia dubyana* (C. Mull.) Broth. | Soil, rock surfaces |
| | Pottiales | Pottiaceae | *Barbula* | *Barbula javanica* Dozy & Molk. | Soil, rock surfaces |
| | | | *Hyophila* | *Hyophila involuta* (Hook.) Jaeg. | Soil, rock surfaces |
| | | | *Gymnostomiella* | *Gymnostomiella vernicosa* (Hook.) Fleisch. | Concrete walls |
| | | Calymperaceae | *Calymperes* | *Calymperes tenerum* C. Mull. | Tree |

Identification of bryophytes samples represented two classes, seven orders, nine families, and 13 genera of bryophytes. Among the 13 species, two species were identified as thalloid liverworts (Hepaticopsida), two species were identified as leafy liverworts (Hepaticopsida), and the other nine species were identified as mosses/musci (Bryopsida) (Table 2). Hepaticopsida species, i.e. thalloid liverworts grew on soil and rocks while leafy liverworts grew on trees. Bryopsida species, i.e. six species grew on soil and rocks, one species on concrete walls and two species grew on trees (Table 2). Thus, the results could be used for the introduction to their diversity into students and teachers to support applicative biology learning. They will be able to distinguish between bryophytes species more easily using the identification key. The identification key was made from the morphological and anatomical diagnostic characters of each bryophytes species. According to the characters from 13 bryophytes species at junior and senior high schools environment in Yogyakarta city, the identification key of them is presented below.

*The Identification Key of 13 Bryophytes Species at Junior and Senior High Schools Environment in Yogyakarta City*

1.a Gametophyte not differentiated into cauloid and filoid.....2
1.b Gametophyte differentiated into cauloid and filoid.....5
2.a Thalloid liverworts (flat thallus without leaves).....3
2.b Leafy liverworts (flat thallus with leaves).....4
3.a Thallus thick and forming rosettes.....*Riccia hasskarliana*
3.b Thallus thin and not forming rosettes.....*Cyathodium spruceanum*
4.a Leaf-lobes ovate, leaf-lobules semicircular, underleaves broadly ovate, leaf cells rhomboid.....*Trocholejeunea sandvicensis*
4.b Leaf-lobes orbicular, leaf-lobules ovate, underleaves orbicular and bifid, leaf cells polygonal.....*Cheilolejeunea intertexta*
5.a Vaginant lamina present, about ½ leaf length, costa vanishing well below leaf apex (6 or more cells).....*Fissidens atroviridis*
5.b Vaginant lamina absent.....6
6.a Leaf thick (4-8 cell-layer) and hyaline lamina forming the broad wings of the sheathing base.....*Octoblepharum albidum*
6.b Leaf thin (only one cell-layer) and without wings of hyaline lamina.....7
7.a Costa single/unicostate.....8
7.b Costa double/bicostate.....12
8.a Costa excurrent.....9
8.b Costa percurrent or less.....10
9.a Leaf margin thin with bears gemmae (all around the tip at gemmiferous ones).....*Calymperes tenerum*

9.b Leaf margin is thick without gemmae.....*Bryum coronatum*
10.a Leaf apex acute with hyaline cells at the base (rectangular, thin-walled and intergrading with chlorophyllose lamina in a small area).....*Hyophila involuta*
10.b Leaf apex obtuse without hyaline cells.....11
11.a Leaves erect-spreading, triangular lingulate; upper half lamina cells margin faintly papillose, costa thick.....*Barbula javanica*
11.b Leaves imbricate, rounded; upper lamina cells papillose; costa thin.....*Gymnostomiella vernicosa*
12.a Leaves lanceolate, acuminate at apex, lamina cells linear-rhomboid.....*Ectropothecium buitenzorgii*
12.b Leaves ovate, denticulate at apex, lamina cells rhomboid.....*Vesicularia dubyana*

Bryophyte samples from junior and senior high schools environment in Yogyakarta city had various species and were found in various locations. The number of bryophyte species within 30 junior and senior high schools environment in Yogyakarta city were shown below.

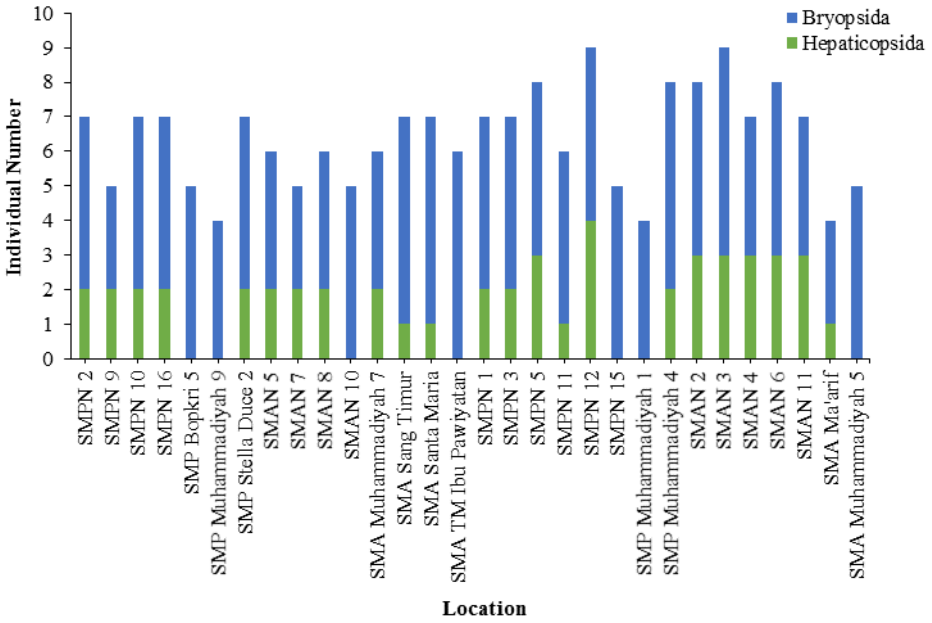


**FIGURE 5**. Comparison the number of bryophytes species at junior and senior high schools environment in Yogyakarta city.

Bryophyte species from various locations can be divided into two classes such as Hepaticopsida and Bryopsida (Fig. 5). Any bryophytes from Class Anthocerotopsida were not found because the observation and collection of bryophyte samples were done during the dry season. For instance, hornworts are easy to find during the rainy season with humid conditions. Liverworts and mosses were widely distributed because the schools were not located at a different altitude, causing homogeneous habitat. Environmental school condition is dominated by green areas with canopy, increasing humidity and air temperature that supported the growth of bryophytes. Differences in the number of bryophytes species can be affected by the condition around school environments, such as the presence of buildings, lack of humid area, and density of tree for epiphytic bryophytes. Mosses found in this study had more species than liverworts because it has complex adaptation to survive from unfavourable environmental conditions such as various life-form, branch and multicellular rhizoid, and presence of modification cell (hyalocyst, hyaline) as water storage.

## Vegetation Analysis

Bryophytes community structure were influenced by several factors such as the diversity and abundance of species, which were able to determine using Shannon-Wiener index as shown below.

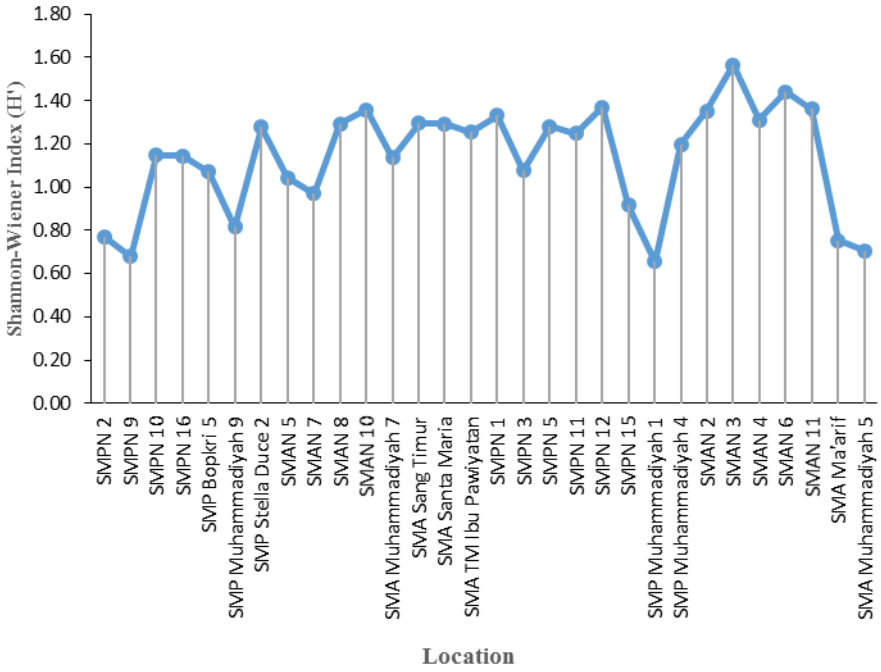


**FIGURE 6**. Comparison of Shannon-Wiener diversity index at junior and senior high schools environment in Yogyakarta city.

The value of diversity index (H') can be divided into some categories based on its range value. If the value of H' were less than 2.0302, then the species diversity level will be categorized as low [11]. The value of H' on 30 schools (Fig. 4) and H' of 13 bryophytes species (H' is 1.54) has low diversity. Species diversity level of bryophyte species community is caused by several factors, such as several species that were found in larger number than the others, environmental factors (temperature, humidity, light intensity, and altitude), and also human activity. The optimum temperature range for bryophytes is 20 °C to 30 °C [12]. The temperature range at sampling locations was 27 °C to 30 °C, which was supporting the increase of its diversity. From the observation, the humidity was ranged from 60 % to 80 %, which was able to support the bryophytes growth that needs humid condition. At the opposite, the light intensity was ranged from 50 000 lux to 90 000 lux, which was relatively higher than the optimum value of 500 lux to 1 300 lux [2]. The altitude from those locations was ranged from 80 MASL to 120 MASL, which was quite influential to the other factors. On the other hand, Yogyakarta as the capital city had many populations, on which their activity (dense buildings, less open ground, and air pollution) could have influenced the bryophytes diversity. Thus, low diversity level of bryophyte species at 30 schools in Yogyakarta city is natural.

Vegetation analysis of bryophytes species was also aimed to know about their importance values to determine species which are broadly distributed and their distribution types. The importance values of bryophytes species within 30 schools environment in Yogyakarta were shown below.

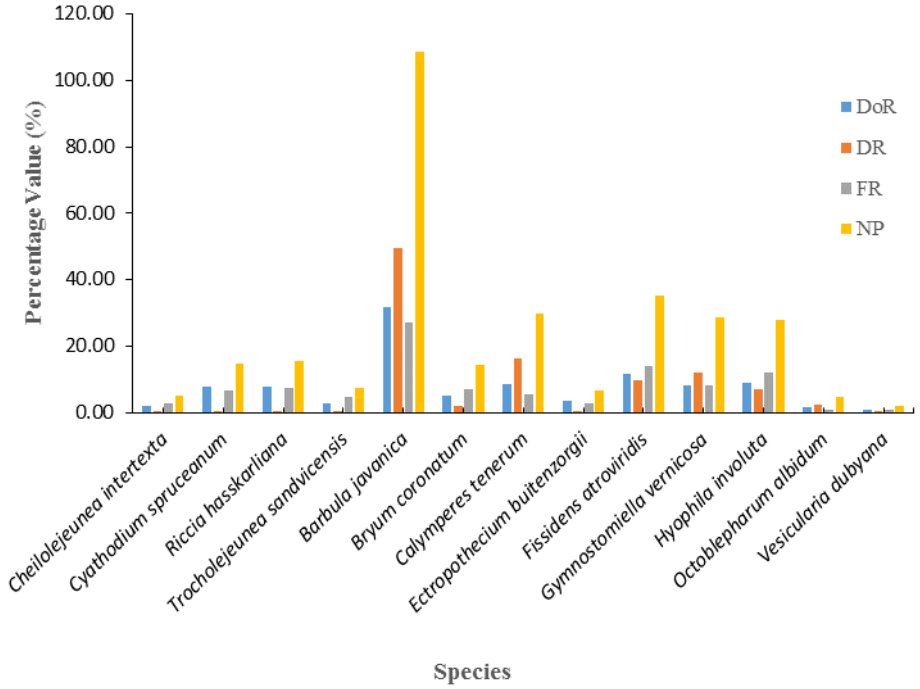


**FIGURE 7**. Comparison of the importance value of bryophytes species at junior and senior high schools environment in Yogyakarta city

If the value of relative density (DR) were less than the relative frequency (FR), the species distribution type would be categorized as random [11]. Oppositely, when DR > FR, it will be categorized as clumped. Thus, nine bryophytes species (four liverworts and five mosses) were randomly distributed and the remaining species (four mosses) had clumped distribution type. *Barbula javanica* from Class Bryopsida has the highest importance values among the other species (Fig. 7). As an acrocarpous moss, it produces many sporophytes, has long rhizoid, and grows in unlimited directions. Therefore, it is able to get nutrition more easily, penetrates on the various substrate, and its living space is greater than the other ones. That is the reason why *B. javanica* was broadly distributed. Each bryophyte species had certain morphological and anatomical characteristic that supported their distribution in the school's environment. On the other hand, bryophyte diversity and distribution are influenced by environmental conditions, adaptability, and competition between them [13]

The overall results showed that bryophyte samples collection in junior and senior high schools in Yogyakarta city consisted of various types of bryophyte species from liverworts (thalloid and leafy) to mosses and various class from Hepaticopsida to Bryopsida. They were found on the various substrate from epilithic to epiphytic, had various life-form, and some bryophyte species was broadly distributed in those areas. Thus, this research can be used to provide an introduction to the diversity of bryophytes to junior and senior high school students in Yogyakarta.

## CONCLUSION

The diversity of bryophytes at Junior and Senior High Schools environment in Yogyakarta city resulted in the total of 13 species. They were classified into two classes, Hepaticopsida and Bryopsida, which can be found on soil, rock surfaces, concrete walls, and also trees. *Barbula javanica* from Class Bryopsida had been broadly distributed at those area based on the importance values. This preliminary study should be used as a basis for introducing the diversity of bryophytes and supports the implementation of curriculum 2013, especially in applicative biology learning for junior and high school students in Yogyakarta.

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## REFERENCES


1. Kementerian Pendidikan dan Kebudayaan, "*Modul Pelatihan Implementasi Kurikulum 2013* [*Curriculum 2013 Implementation Practice Module*]," [Online] (2013), [Accessed on April, 19 2016]. [Bahasa Indonesia]
2. F. Verdoorn, *Manual of Bryology* (Martinus Nijhoff Publishers, Netherland, 1932), pp. 452–453.
3. Badan Pusat Statistik D.I. Yogyakarta, "Daerah Istimewa Yogyakarta Dalam Angka [Yogyakarta in Numbers]," [Online] www.jogjakota.bps.go.id (2012), [Accessed on April 2 2016]. [in Bahasa Indonesia]
4. E. B. Bartram, *The Philippines Journal of Science* **68**, 140 (1939).
5. A. Eddy, *A Handbook of Malesian Mosses, Vol. 1: Sphagnales to Dicranaceae* (Natural History Museum, London, 1988), pp. 86–89.
6. A. Eddy, *A Handbook of Malesian Mosses, Vol. 2: Leucobryaceae to Buxbaumiaceae* (Natural History Museum, London, 1990), pp. 31–32, 128–131, 166–167, 174, 198–199.
7. A. Eddy, *A Handbook of Malesian Mosses, Vol. 3: Splachnobryaceae to Leptostomataceae* (Natural History Museum, London, 1996), pp. 123–124.
8. S. R. Gradstein, *Guide to the Liverworts and Hornworts of Java* (Southeast Asian Regional Center for Tropical Biology, Bogor, 2011), pp 45–48.
9. M. L. So, *Mosses and Liverworts of Hong Kong Volume 1* (Hong Kong Baptist University, Hong Kong, 1995), pp 12, 15, 51, 68, 156.
10. A. E. Magurran and P. A. Henderson, *Nature* **422**, 714–716 (2003). R. Misra, *Ecology Workbook* (Oxford & IBH Publishing, New Delhi, 1968), pp. 650–663.
11. T. J. K. Dilks and M. C. F. Proctor, *J. Bryol*. **8**(3), 317–336 (1975).
12. Sun, S.-Q., Wu, Y.-H., Wang, G.-X., Zhou, J., Yu, D., Bing, H.-J., and Luo, J. *PLoS ONE*, **8**(3), e58131 (2013).