Liverworts (Marchantiophyta) of Ireng-ireng forest Bromo Tengger Semeru National Park, east Java Indonesia

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Abstract. The liverwort diversity of Java Island totaled 480 species and was mainly dominated by specimens from West Java. However, exploration of this plant group was still insufficient in East Java. Ireng-ireng forest, a tropical mountain forest located in the Bromo Tengger Semeru National Park (BTS National Park) east Java Indonesia, is an area with a high potency of liverworts diversity. The aim of this research was to explore the liverwort diversity originating from the Ireng-ireng forest in BTS National Park. The study investigated liverworts across the elevation gradient of tropical mountain forests in the Ireng-ireng forest. A total of 24 liverwort species were identified, belonging to 18 genera and 11 families. The family with the highest number of species in the study area was Lejeuneaceae.

1 Introduction

Liverworts are non-vascular plants classified as Marchantiophyta, one of three divisions in the bryophyte group. Marchantiophyta is unique compared to the other two divisions, hornworts (Anthocerotophyta) and mosses (Bryophyta), due to the presence of trigones and oil bodies in the cells, as well as synchronous spore maturation (desiccated at the same time just before seta elongation) [1]. Liverworts can grow in a wide range of substrates, such as on soil, rocks, tree bark, and plant leaves. Epiphytic liverworts are often found on the surface of trunks (corticolous), branches (ranicolous), and leaves (epiphyllous) [2]. The biodiversity status of liverworts in Indonesia has been overlooked compared to the vascular plants [2], [3]. Gradstein identified a total of 480 liverwort species from 3 classes, 39 families, and 107 genera in West Java [4]. Sodesrtrom et al. reported 607 liverwort and hornwort species on the island of Java, with only 61 species found in East Java [5].

Ireng-ireng forest is a tropical mountain forest located in the Bromo Tengger Semeru National Park (BTS National Park) in East Java, Indonesia. It is a hotspot for vascular epiphyte diversity, with large trees dominating and supporting the ecosystem. The forest is

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situated at an elevation between 100 to 2000 meters above sea level [6]. Our field observation in the Ireng-Ireng forest indicated a high domination of epiphytic liverworts covering the tree vegetation inside the forest. Liverwort thrives in moist habitats and plays a crucial role in the environment. A study conducted on liverwort diversity in the mountain forest of Mount Gede, West Java, reported that elevation is the primary factor contributing to species diversity [7]. Currently, reports on the diversity of Bryophytes, particularly the group of Marchantiophyta from East Java, are inadequate [1, 8].

BTS National Park is a popular international tourist destination in Indonesia due to its significant natural value. The park is managed for ecosystem protection and ecotourism activities [9]. The Ireng-Ireng forest is a highland tropical rainforest located in the Senduro resort on the east side of BTS national park. Although there were no destructive impacts recorded in the Ireng-ireng forest, the eruption activity of Mount Semeru and Mount Bromo has the potential to affect the surrounding forest. The forest fire that occurred in the Bromo area has had a significant impact on the ecology of BTS National Park and the surrounding society's economy [7]. The degradation of liverwort habitat has altered the liverwort community composition [10]. Conducting a liverwort inventory in the BTS National Park area would provide valuable diversity data to support forest conservation efforts. The aim of this research was to investigate the liverwort diversity in the Ireng-ireng forest of BTS National Park, located in East Java, Indonesia.

2 Material and Methods

2.1 Sample collection

Liverwort exploration was conducted in the Ireng-ireng forest of Bromo Tengger Semeru National Park, East Java, Indonesia. The study area covered an area of 1000 hectares and was located between 8°03'10"S 113°01'51"E to -8°00'48"S 112°57'02"E. The topography of the area is steep, with an altitude ranging from 1,102 to 2,144 meters above sea level, a temperature range of 20-23°C, humidity ranging from 74.3% to 81.6%, and a light intensity of 1733 lux. Specimen collection was conducted along the accessible areas of the left and right sides of the Ireng-ireng forest road leading to Ranu Pane. The collection included any liverworts spotted on the site, from the ground (soil, rock, dead wood, and litter), on tree bark/epiphytes (up to 2 meters high), and on leaf surfaces (epiphylls).

2.2 Identification

The specimens were identified based on morphological characters using stereo and compound microscopes. The main characteristics of liverworts include the life form (thalloid/leafy), color, leaf lobes and lobules (shape, size, margin, apex, arrangement, trigone, oil bodies), underleaves, and reproductive organs if present. Literature references for identification were the Guide to Liverworts and Hornworts of Java [4] and the Guide to the Genera of Liverworts and Hornworts of Malaysia [11]. The collected specimens have been deposited at the Herbarium Jemberiense (JR), Biology Department, Faculty of Mathematics and Sciences, Jember University.

3 Results and discussion

The present study reported a total of 24 liverwort species belonging to 18 genera and 10 families. Of the 24 species, 12 are newly reported for East Java. Leafy liverworts were the major group of liverworts observed in the study area, with a total of 19 species found on the

ground, dead trees, epiphytes on trees, and epiphyll on living leaves. Thalloid liverworts mainly covered the soil and rock surfaces in the open areas of the Ireng-ireng forest. The family Lejeuneaceae has the highest number of species, with a total of 10 species from three genera followed by Plagiochilaceae as the second-highest leafy liverwort family, with a total of four species. The list of species is presented in Table 1.

Table 1. List of species of liverworts in the Ireng-ireng forest of the Bromo Tengger Semeru National Park. A new record from East Java is indicated by an asterisk (*).

Family	**Species**
Marchantiaceae	*Dumortiera hirsuta* (Sw.) Nees
	Marchantia emarginata Reinw., Blume & Nees
	Marchantia sp.
Metzgeriaceae	*Metzgeria ciliata* Raddi *
Pallaviciaceae	*Pallavicinia* sp.
Adelanthaceae	*Denotarisia linguifolia* (De Not.) Grolle*
Frullaniaceae	*Frullania* sp.
Lejeuneaceae	*Cheilolejeunea intertexta* (Lindenb.) Steph.*
	Cheilolejeunea sp.
	Cololejeunea haskarliana (Lehm.) Schiffn.*
	Dactylophorella muricata (Gottsche) R.M. Schust.*
	Lejeunea patriciae Schäf.-Verw.*
	Lejeunea tuberculosa Steph.
	Lejeunea sp.
	Leptolejeunea foliicola Steph.*
	Mastigolejeunea sp.
	Thysananthus sp.
Lophocoleaceae	*Lophocolea muricata* (Lehm.) Nee*s
Plagiochilaceae	*Plagiochila arbuscula* (Brid. ex Lehm. & Lindenb.) Lindenb.
	Plagiochila singularis (Schiffn.) M.A.M. Renner, Schäf.-Verw. & Heinrichs*
	Plagiochila spathulifolia Mitt.*
	Plagiochila sp.
Radulaceae	*Radula javanica* Gottsche*
Porellaceae	*Porella acutifolia* (Lehm. & Lindenb.) Trevis.*

The Lejeuneaceae family can thrive in a broad range of environments, including humid tropical rainforests, shaded or semi-shaded lowlands, mountain rainforests, secondary vegetation, and even open and disturbed areas [12]. The newly reported taxa in this study reflect that the liverworts in East Java are still underexplored. We predict that a vast number

of new records are yet to be reported for the area. We were unable to identify eight taxa due to the absence of reproductive structures such as antheridia, archegonia, and bractea. Research using DNA Barcoding is expected to strengthen data on the diversity of liverworts in East Java. This molecular approach will provide objective and precise results, contributing to a better understanding of the subject [13], [14]. All specimens in this study are described and presented with corresponding figures.

Cheilolejeunea intertexta (Lindenb.) Steph.

Plant leavy. Leaf green, apex rounded, margin entire, lobes short in size 1/4 of lobules, succubus. Basal leafy appendage of innovation is an Underleaves. Underleaves bifid, size 2-3 stem wide. No trigones or minute. Oil body big (1/2 cell size). No ocelli

Fig. 1. *Cheilolejeunea intertexta*; a. ventral view; dorsal view; c. cell with oil body. Scale bars: a: 100 µm; b: 50 µm; c: 10 µm.

Cheilolejeunea sp.

Plant leavy. Leaf green, apex rounded, margin entire, lobes long in size 3/4 of lobules, succubus. Basal leafy appendage of innovation is an Underleaves. Underleaves bifid, size 2-3 stem wide. No trigones or minute. Oil body big (1/2 cell size).

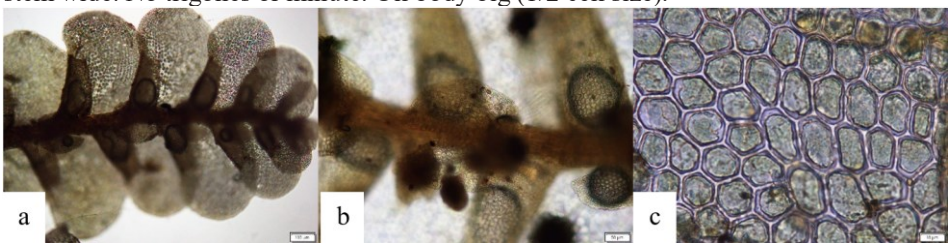

Fig. 2. *Cheilolejeunea* sp.; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 100 µm; b: 50 µm; c: 10 µm.

Cololejeunea haskarliana (Lehm.) Schiffn.

Plant leavy. Epiphyll. Size less than 1 mm. Leaf green, apex rounded, margin dentatus. Lobes long in size 3/4 of lobules, lobes without vitta, succubus. Lobules often reduced, with two teeth. No Underleaves. No trigones or minute. Oil body small (5-20 per cell).

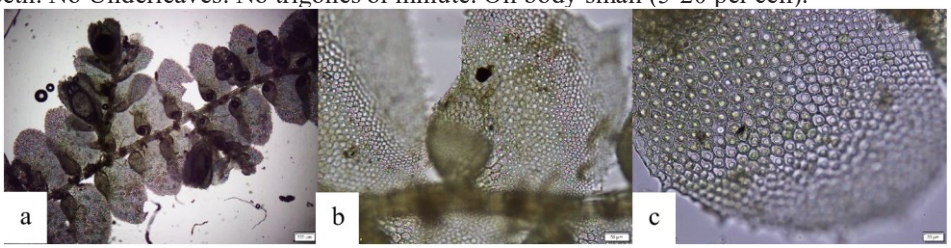

Fig. 3. *Cololejeunea haskarliana*; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 200 µm; b: 50 µm; c: 20 µm.

Dactylophorella muricata (Gottsche) R.M. Schust.

Plant leavy. Leaf green. Underleaves strongly spinose-dentate. Margin of the lobes divided into 4-5 lobes and densely spinose, the teeth in two rows. Lobule size 1/3 of lobes length.

Fig. 4. *Dactylophorella muricata*; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 100 µm; b: 20 µm; c: 10 µm.

Denotarisia linguifolia (De Not.) Grolle

Plant leavy. Leaf reddish or brown colour, margin without gemmae. Saccubus. Ventral leaves base not dilated. Vitta absent. Underleaves present. Trigone inside with dark, star-like markings.

Fig. 5. *Denotarisia linguifolia*; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 2 mm; b: 200 µm; c: 20 µm.

Dumortiera hirsuta (Sw.) Nees

Plant thalloid, dichotomously branched. Thallus more than 15 mm wide, margins irregularly incised-undulate, upper surface no pores. Gametangia produced on rounded receptacles arising from the thallus surface. On wet soil or rock.

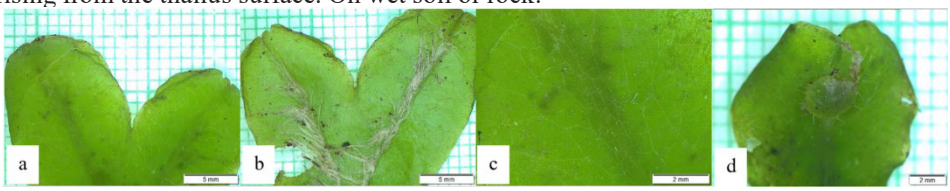

Fig 6. *Dumortiera hirsuta*; a. dorsal view; b. ventral view; c. dorsal view; d. gametangia. Scale bars: a: 5 mm; b: 5 mm; c: 1 mm; d: 2 mm a, b: 5 mm; c,d: 2 mm.

Frullania sp.

Plant leavy. Leaf green to brown, apex rounded, margin entire. Incubus. Leaves divided into lobes and lobules. Lobul almost free from the lobe. Sac-like. underleaves bifid and dentate. Rhizoid appeared from underleaves. Oil body small, finely granular.

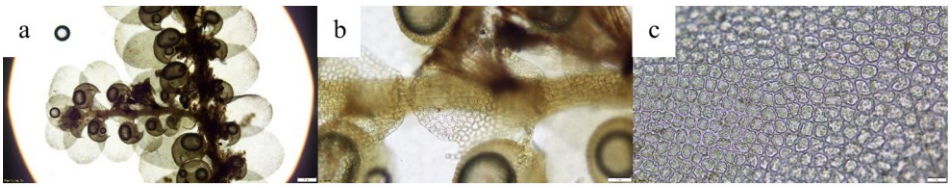

Fig 7. *Frullania* sp.; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 200 µm; b: 50 µm; c: 20 µm.

Lejeunea patriciae Schäf.-Verw.

Plant leavy. Leaf green yellow, apex rounded, margin entire, lobes size 1/3 of leaf, incubus. Keels crenulate. Underleaves bifid, size 2-3 stem wide. Marginal rhizoid present. Oil body small (less than ¼ cell). No ocelli

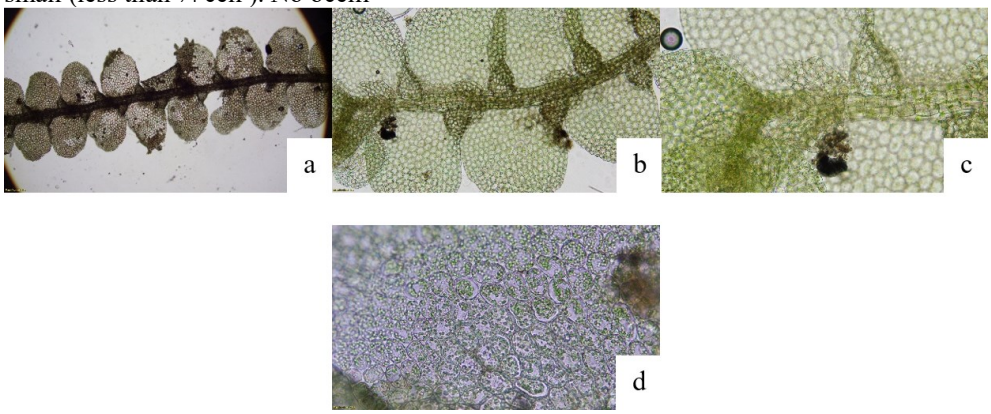

Fig. 8. *Lejeunea patriciae*; a. ventral view; b. dorsal view; c. Keels; c. Cell with oil body. Scale bars: a: 200 µm; b: 100 µm; c: 50 µm; d: 20 µm.

Lejeunea sp.

Plant leavy. Leaf green yellow, apex rounded, margin entire, lobes size 1/3 of leaf, incubus. Keels crenulate. Underleaves bifid, size 1-2 time stem wide. Marginal rhizoid present. Oil body small (less than ¼ cell). No ocelli

Fig. 9. Lejeunea; a. ventral view; dorsal view; c. cell with oil body. Scale bars: a: 200 µm; b: 50 µm; c: 20 µm.

Lejeunea tuberculosa Steph.

Plant leavy. Leaf green yellow, apex rounded, margin entire, lobes size 1/3 of leaf, incubus. Keels crenulate. Underleaves bifid, size 2-3 stem wide. Leaf cells with large trigones. Oil body small (less than ¼ cell). No ocelli

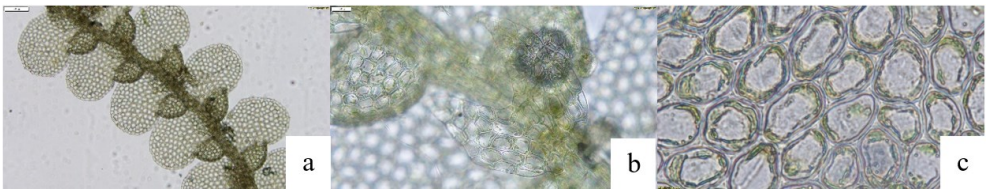

Fig. 10. *Lejeunea tuberculosa*; a. ventral view; b. *underleaf*; c. Cell with oil body. Scale bars: a: 100 µm; b: 20 µm; c: 10 µm.

Leptolejeunea foliicola Steph.

Plant leavy. Epiphyll. Size less than 1 mm. Leaf brown, apex acute, margin entire. Underleaves lobes 2 cells wide. No trigones or minute. Oil body small (5-20 per cell). Ocelli present.

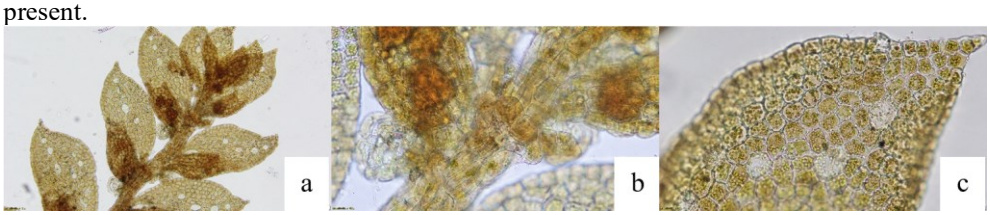

Fig. 11. *Leptolejeunea foliicola*; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 100 µm; b: 20 µm; c: 20 µm.

Lophocolea muricata (Lehm.) Nees

Plant leavy. Small size. Leaf green to brown, covered by papilla. Saccubus. Leaves not divided into lobes and lobules. No vittae. Underleaves bifid. Rhizoid colorless.

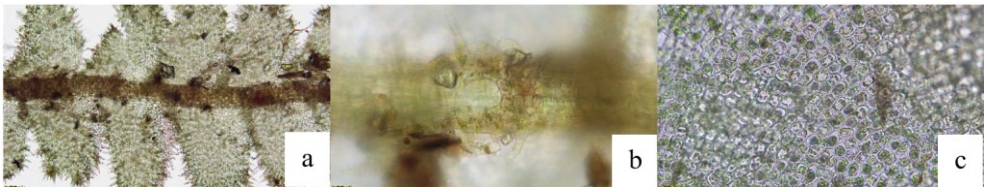

Fig. 12. *Lophocolea muricata*; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 100 µm; b: 20 µm; c: 20 µm.

Marchantia emarginata Reinw., Blume & Nees

Plant thalloid, dichotomously branched. Thallus more than 5 mm wide, margin entire, upper surface with pores, gemma cup present. Scale only along thallus midline of the ventral surface, invisible in dorsal view. Female receptacle much more deeply lobed (more than 0.5 diameter). Number of female lobe more than 6 lobes, lobes not bifid.

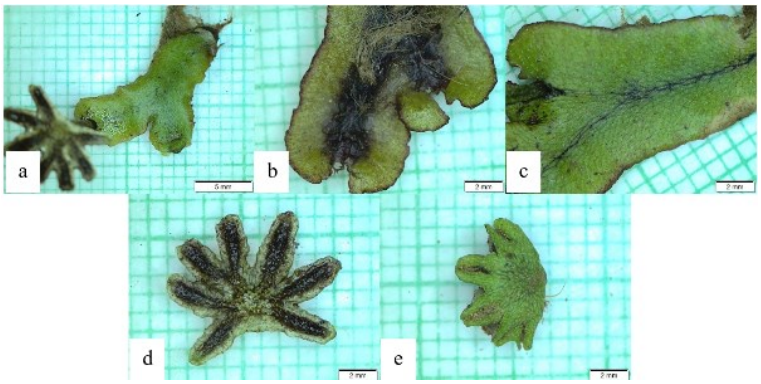

Fig. 13. *Marchantia emarginata*; a. dorsal with gemmae and female receptacle; b. Ventral with scale; c. ventral with pores; d.archegonia; e. Antheridia. Scale bars: a: 5 mm; b: 2 mm; c: 2 mm; d: 2 mm; e: 2 mm

Marchantia sp.

Plant thalloid, dichotomously branched. Thallus more than 10 mm wide, margin entire, upper surface with pores, gemma cup present. Scale only along thallus midline of the ventral surface, invisible in dorsal view. Antheridia bifid.

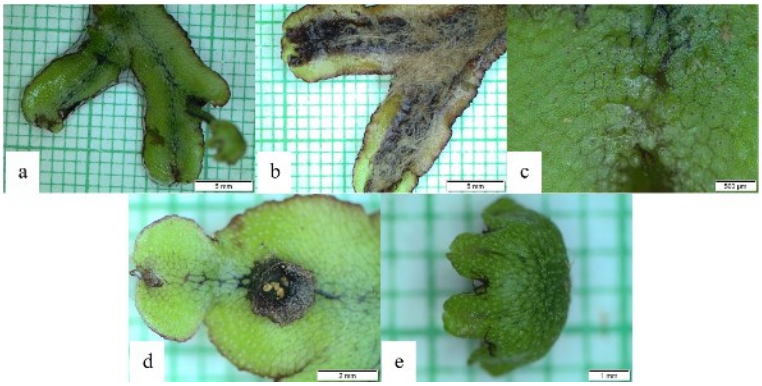

Fig. 14. *Marchantia* sp.; a. dorsal view; b. ventral view; c. pores; d. *gemma cup;* e. antheridia. Scale bars: a: 5 mm; b: 5 mm; c: 500 µm; d: 2 mm; e: 1 mm

Mastigolejeunea sp.

Plant leavy. Leaf green to black, rather flat when dry, not worm-like. Lobule with tooth. Underleaves strongly spinose-dentate. Margin entire.

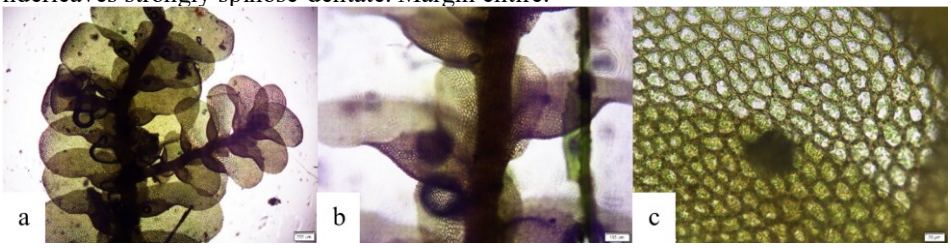

Fig. 15. *Mastigolejeunea* sp.; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 200 µm; b: 100 µm; c: 20 µm.

Metzgeria ciliata Raddi

Plants thalloid, dichotomously branched. Thallus less than 3 mm wide, with a narrow midrib, midrib colourless, thallus margin with hair. Midrib with large epidermal cells and without central strand, ventral midrib only 2 cell rows wide. Oil bodies homogenous. Rhizoid colorless. Ventral scale lacking. Epiphyte and epiphyll.

Fig. 16. *Metzgeria ciliata*; a. dorsal view; b. margin; c. cells of thallus. Scale bars: a: 200 µm; b: 50 µm; c: 20 µm.

Pallavicinia sp.

Plant thalloid, dichotomously branched. Thallus less than 6 mm wide, with a distinct, swollen midrib, margin entire. Midrib with central strand. Oil bodies finely granular. Rhizoid colorless. Ventral scale lacking. Epiphyte and epiphyll.

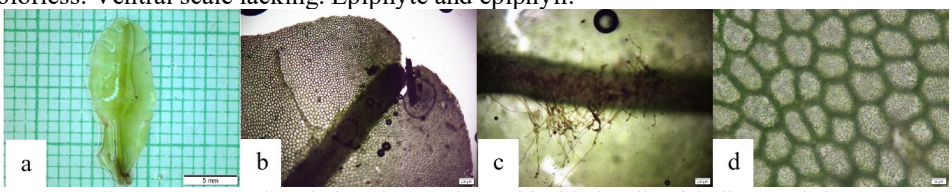

Fig. 17. *Pallavicinia sp.*; a. dorsal view; b. margin; c. rhizoid; d. cells of thallus. Scale bars: a: 5 mm; b: 200 µm; c: 200 µm; d: 20 µm

Plagiochila arbuscula (Brid. ex Lehm. & Lindenb.) Lindenb.

Plant leavy. Large size, 4-6 mm wide. Leaf bright green, more than 1 mm wide, margin dentate (7-8). Saccubus. Ventral leaves base dilated. Vitta absent. Underleaves absent. Trigone present.

Fig. 18. *Plagiochila arbuscula*; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 2 mm; b: 200 µm; c: 20 µm.

Plagiochila singularis (Schiffn.) M.A.M. Renner, Schäf.-Verw. & Heinrichs

Plant leavy. Leaf bright green, caducous, more than 1 mm wide, cell finely papillose, margin dentate (3-5). Saccubus. Ventral leaves base not dilated. Vitta absent. Underleaves absent. Trigone present.

Figure 19. *Plagiochila singularis*; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 2 mm; b: 200 µm; c: 20 µm.

Plagiochila sp.

Plant leavy. Leaf dark green, margin dentate (3-6). Saccubus. Ventral leaves base not dilated. Vitta absent. Underleaves absent. Trigone present.

Fig. 20. *Plagiochila* sp.; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 200 µm; b: 100 µm; c: 20 µm.

Plagiochila spathulifolia Mitt.

Plant leavy. Small size, 2-3 mm wide. Leaf bright green, less than 1 mm wide, margin dentate (7-8). Saccubus. Ventral leaves base not dilated. Vitta absent. Underleaves absent.

Fig. 21. *Plagiochila spathulifolia*; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 2 mm; b: 200 µm; c: 20 µm.

Porella acutifolia (Lehm. & Lindenb.) Trevis.

Plant leavy. Leaf green, apex acute-acuminate, margin entire. Incubus. Leaves divided into lobes and lobules. Incubous. No vittae. Basal margin of the lobules and underleaves crispate.

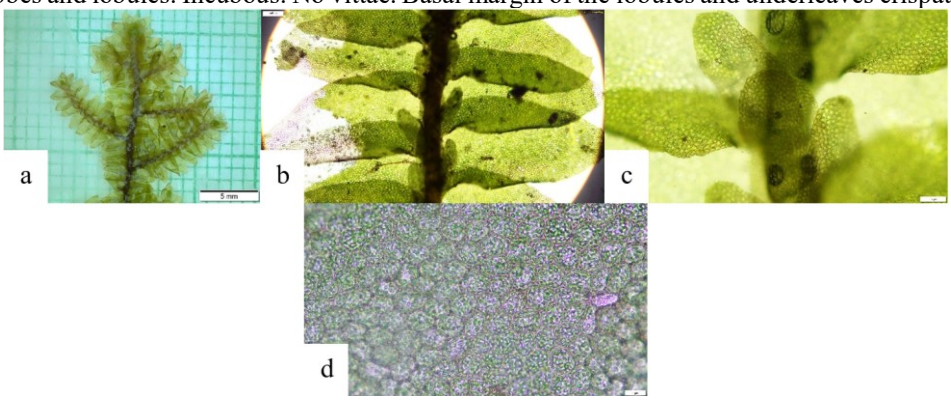

Fig. 22. *Porella acutifolia*; a. Plant; b. ventral view; c. dorsal view; d. cell with oil body. Scale bars: a: 5 mm; b: 200 µm; c: 100 µm; d: 20 µm

Radula javanica Gottsche

Plant leavy. Size less than 1 mm wide, habitat on the rock or stone. Incubus. Lobe ovate. Lobules subquadrate, about as long as wide. Trigone small, not swollen. No underleaves.

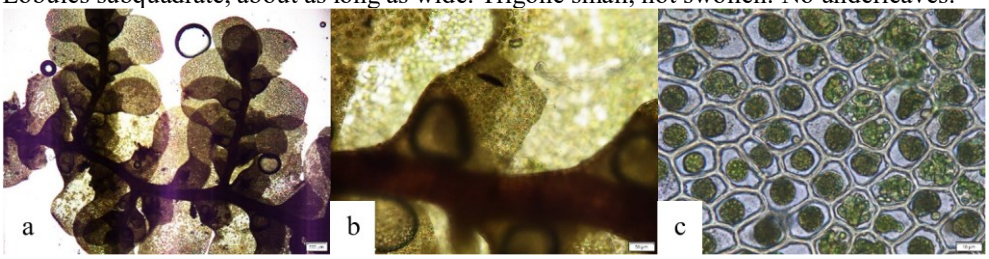

Fig. 23. *Radula javanica*; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 200 µm; b: 50 µm; c: 10 µm.

Thysananthus sp.

Plant leavy. Leaf green to brown. Margin entire. Midleaf cells isodiametric. Incubus. No vitta. Underlaves obovate and undivided. Oil bodies homogenous, more than 10 per cell.

Fig. 24. *Thysananthus* sp.; a. ventral view; b. dorsal view; c. cell with oil body. Scale bars: a: 200 µm; b: 100 µm; c: 20 µm.

4 Conclusions

The liverworts collected from the Ireng-Ireng forest of Bromo Tengger Semeru National Park were identified to belong to 18 genera and 11 families, resulting in a total of 24 species with 12 of the new record from East Java. The family Lejeuneaceae was found to be the most dominant, with 10 species from three genera.

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