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Species diversity of *Selaginella* in Mount Lawu, Java, Indonesia

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ABSTRACT

Setyawan AD, Sutarno, Sugiyarto. 2013. Species diversity of Selaginella *in Mount Lawu, Java, Indonesia*. *Biodiversitas 14: 1-9. Selaginella* is a genus of ferns allies that lives in moist areas and requires water for fertilization; therefore it is often found in highlands. The aim of this research was to know species diversity of *Selaginella* in Mount Lawu and the vicinity areas. The research was conducted between July 2007 and November 2012 on the western and southern slopes of Mount Lawu, Central- and East-Java, Indonesia, with altitudes between 1100 and 2100 m a.s.l. The research included three sites and the vicinity areas, i.e. (i) Protected forest of Cemorosewu, (ii) Grojogansewu Natural Recreation Park, and (iii) KGPAA Mangkunagoro I (Ngargoyoso) Grand Forest Park. The research found nine selaginellas species, namely: *S. aristata, S. ciliaris, S. involvens, S. opaca, S. ornata, S. plana, S. remotifolia, S. singalanensis* and *S. zollingeriana*.

Key words: species, diversity, taxonomy, Mount Lawu, Java

INTRODUCTION

Mount Lawu, or Gunung Lawu, is a massive compound stratovolcano, straddling the border between Central Java and East Java, Indonesia (Lat: 7.625°S, Long: 111.192°E). The north side is deeply eroded and the eastern side contains parasitic crater lakes and parasitic cones. Mount Lawu has long been inactive, but still shows volcanic activity, where there is a fumarolic area on the south flank at 2,550 m. The only reported activity of Mount Lawu took place in 1885, when rumblings and light volcanic ash falls were reported (GVP 2012). Geologically, the mountain is divided into two parts, the northern part commonly known as Mount Lawu (3265 m) is the new Lawu, while the southern part known as Jobolarangan Hill (2298 m) is the ancient Lawu (Puslitbang Geologi 1992; Pratiwi 2011). Forest fires regularly occur in Mount Lawu. The latest incident was the destruction of 500 hectares of forest at the end of 2012. Large forest fires also occurred in 2002 (6284.24 ha), 2006 (1007 ha) and 2009 (1370.7 ha) (Beritasatu 25/09/2012; Tribunnews 26/09/2012).

Protected forest area in Mount Lawu is approximately 20,400 ha (Sriyanto 2003) or 24,188 ha (BLI 2004). The main area of the forest is managed by Lawu DS Forest Management Unit (consisting of North Lawu: 5354.7 ha and South Lawu: 5719.4 ha), and the rest is managed by Surakarta Forest Management Unit (*Kesatuan Pengelolaan Hutan; KPH)*. There are two nature conservation areas in the mountain, namely: Grojogansewu Natural Recreation Park (*Taman Wisata Alam; TWA*) established by the Ministry of Agriculture decree No. 264/Kpts-Um/10/1968 dated October 12, 1968 covering an area of 64.30 ha; and KGPAA Mangkunagoro I Grand Forest Park (formerly Ngargoyoso Grand Forest Park; *Taman Hutan Raya (Tahura) Ngargoyoso*) established by the Ministry of Forestry and Plantations decree No. 849/Kpts-II/1999 dated October 11, 1999 covering an area of 231.3 ha. At this time, grand forest park is proposed to be expanded to reach approximately 1000 ha, covering Karanganyar and Wonogiri, Central Java (Slamet, Office of Forestry, Central Java Province, 2012, pers. com.).

Mount Lawu has an important function for the protection of natural resources and ecosystems. This area is a buffer zone that limits the distribution of dry-type ecosystems in eastern Java and wet-type ecosystem in western Java. Mount Lawu is one of the western distribution borders of *Casuarina junghuhniana* Miq. (Pinyopusarerk and Boland 1995), and of the eastern distribution borders of *Schima wallichii* (DC.) Korth., although this later species is probably non-native in Mount Lawu (Steenis 1972). Several studies on plant diversity in Mount Lawu have been conducted, for example: fungi (Ilyas 2007), cryptogamae (Setyawan and Sugiyarto 2001), spermatophytes (Sutarno et al. 2001), epiphytic plants (Setyawan 2000), epiphytic orchids (Marsusi 2001; Yulia et al. 2011), epiphytic medicinal plants (Samsali 2008), fruit plants *Rubus* (Setyawan 1999), medicinal herb *Plantago major* (Sugiyarto et al. 2006), *Vanda tricolor* orchid (Suparno-Putri 2013), home-garden plants (Harsono 2001), plants of Cemorosewu (Khussurur 2006), etc. This region has been proposed as a national park (Setyawan and Sutarno 2000; Setyawan 2001; Sriyanto 2003; Setyawan and Dirgahayu 2005; WDPA 2010).

Selaginella is one of the genera that live in Mount Lawu. This plant lives in moist environment and requires water for fertilization. Mountainous region with humid climate and abundant water sources throughout the year is a hotspot for its diversity. Research on species diversity of *Selaginella* in Mount Lawu had never been conducted before, but there have been reports of the presence of *S. ornata* (Setyawan and Sugiyarto 2001) and *S. opaca* (Setyawan 2009). The observation on the Herbarium Bogoriense (BO) collections have found three *Selaginella* species of Mount Lawu, namely: *S. aristata*, *S. opaca*, and *S. involvens* (ADS 2012, pers. obs.).

A large number of *Selaginella* species are morphologically polymorphic and have high morphological similarity among species; Selaginella is a difficult genus to be classified (Setyawan et al. 2012). This confusion led to almost every species having more than one name, even *S. ornata* and *S. involvens*, which have high morphological variation, each having more than 25 synonyms (Kessler and Swale 2008). Nowadays, there are 700-750 recognized species around the world, while more than 200 species are found in Nusantara (Malay Archipelago), 25 species in Java (Setyawan 2008), 10 species in southern Central Java (Setyawan 2012) and eight species in Mount Merapi, Java (Setyawan et al. 2012).

Since *Selaginella* commonly grows well in humid places and requires water for fertilization, it becomes interesting for studying the biodiversity and the climate change. This study aimed to determine the diversity of *Selaginella* in Mount Lawu and the surrounding areas.

MATERIALS AND METHODS

The field work was carried out more than six years, between July 2007 and November 2012. Several surveys of *Selaginella* have been conducted in Mount Lawu and the adjacent areas, with altitude between 1100 and 2100 m a.s.l., both in the wet and dry seasons. The research sites were grouped into three divisions, namely: (i) Protected forest of Cemorosewu (1600-2100 m a.s.l.), (ii) Grojogansewu Natural Recreation Park (1100-1400 m a.s.l.), and (iii) KGPAA Mangkunagoro I (Ngargoyoso) Grand Forest Park (1100-1500 m a.s.l.). Survey sites indicating the presence of *Selaginella* was shown in Table 1 and Figure 1.

All three sites are influenced by human activities. *Selaginella* is generally found in places that are moist and shady, such as roadside cliffs, footpaths and tributries cliffs. Some species can also grow in relatively open sites, such as forest stands of pine (*Pinus merkusii*), the settlements and agricultural land. *Selaginella* rarely grows under a dense clumps of herbs or shrubs; that place does not provide space and light for growth. The southern and western slopes of Mount Lawu – where this research was conducted – has Andisol soil type (Sargiman 1990; Sarifuddin 1998; Jubaedah 2008). This clay soil type has relatively higher ability to hold water and nutrients than pyroclastic sandy soil in the northern and eastern slopes.

All *Selaginella* species were recorded and collected as herbarium specimen and living collection for the experimental garden in Kejiwan, Wonosobo, Central Java

Table 1. Study sites of *Selaginella* diversity and distribution in Mount Lawu and the adjacent areas.

Sites*	Latitude	Longitude	Altitude (m)	Species diversity
Protected forest of Cemorosewu and the vicinity (1600-2100 m)				
Cemorokandang	-7.665113°	111.181350°	1807	*S. opaca, S. remotifolia*
Cemorosewu-1	-7.656752°	111.195046°	2070	*S. opaca, S. remotifolia*
Cemorosewu-2	-7.667108°	111.191757°	1876	*S. opaca*
Cemorosewu-3	-7.670575°	111.193019°	1633	*S. opaca*
Cemorosewu-4	-7.664144°	111.197845°	1915	*S. opaca, S. remotifolia*
Cemorosewu-5	-7.666296°	111.196120°	1865	*S. remotifolia*
Jobolarangan-1	-7.668915°	111.190381°	1754	*S. opaca*
Jobolarangan-2	-7.684914°	111.182679°	1884	*S. opaca*
Jobolarangan-3	-7.670727°	111.182348°	1753	*S. opaca, S. remotifolia*
Natural Recreation Park of Grojogansewu and the vicinity (1100-1400 m)				
Blumbang-1	-7.664726°	111.155295°	1382	*S. involvens, S. opaca, S. ornata, S. remotifolia*
Blumbang-2	-7.670324°	111.158458°	1464	*S. remotifolia*
Kalisoro	-7.663311°	111.152281°	1337	*S. remotifolia*
Tawangmangu-1	-7.661767°	111.143464°	1222	*S. zollingeriana*
Tawangmangu-2	-7.660820°	111.136199°	1133	*S. zollingeriana*
Tawangmangu-3	-7.660554°	111.139010°	1150	*S. aristata, S. ciliaris, S. involvens, S. opaca, S. ornata, S. plana, S. remotifolia, S. singalanensis*
Grand Forest Park of KGPAA Mangkunagoro I (Ngargoyoso) and the vicinity (1100-1500 m)				
Kemuning	-7.597704°	111.139299°	1156	*S. remotifolia*
Nglerak	-7.608175°	111.154545°	1556	*S. remotifolia*
Tahura Ngargoyoso	-7.626599°	111.133633°	1220	*S. aristata, S. ciliaris, S. opaca, S. remotifolia, S. singalanensis, S. zollingeriana*

Note: *) Each site is the midpoint of the few locations in the surrounding

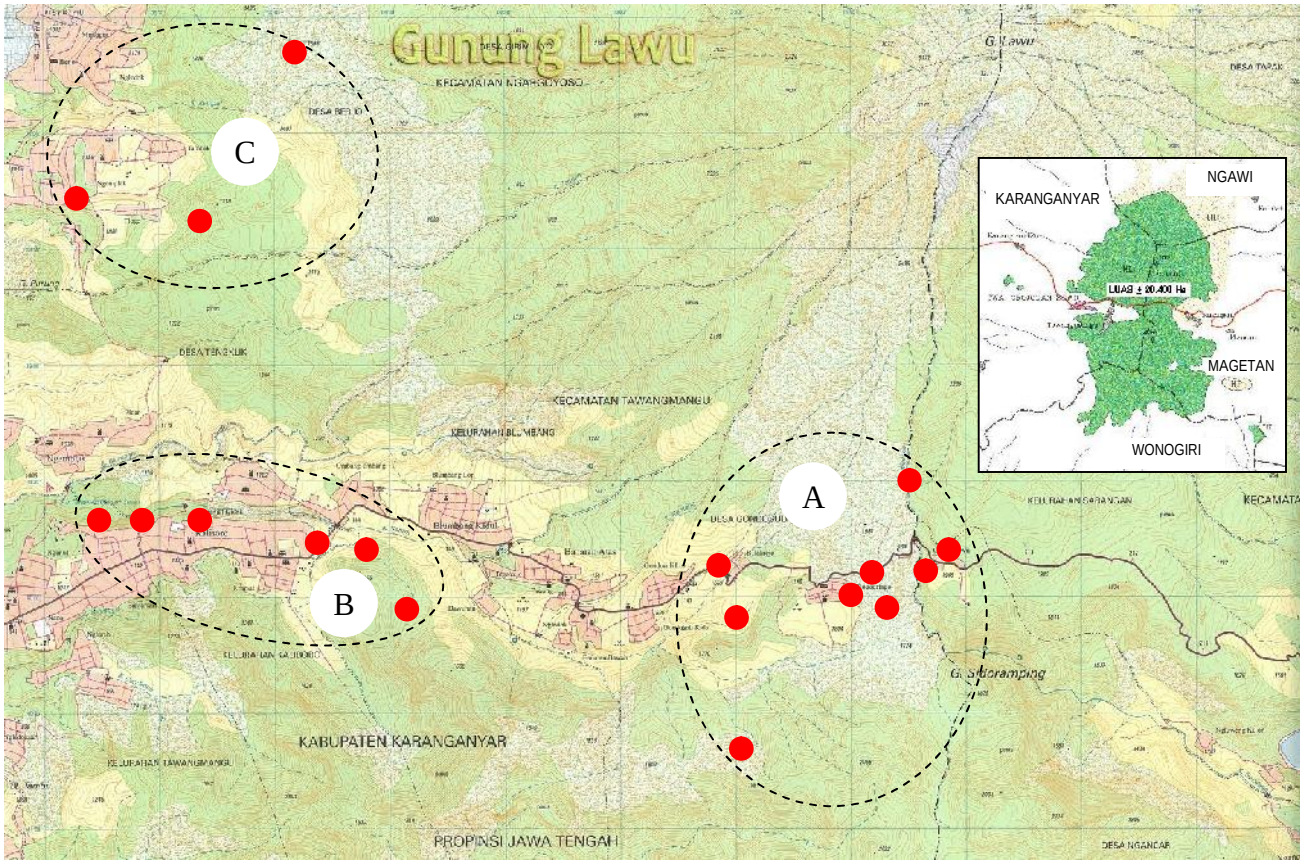

Figure 1. Study sites of *Selaginella* diversity in Mount Lawu (●): A. Cemorosewu Protected Forest and the vicinity, B. Grojogansewu Natural Recreation Park and the vicinity, C. KGPAA Mangkunagoro I (Ngargoyoso) Grand Forest Park and the vicinity. Insert: Mount Lawu Protected Forest (± 20,400 ha).

(768 m a.s.l.). A total of 56 herbarium specimens of nine species of *Selaginella* have been collected from the study site (Table 1). Each herbarium specimen was unique, distinguished by location and time of collection. Data passport collected along with the specimens were used as standard for herbaria specimen. The specimens were identified by using several literatures on selaginellas, i.e. Alderwereld van Rosenburgh (1915a,b, 1916, 1917, 1918, 1920, 1922) and Alston (1934a, 1935a,b, 1937, 1940); and were compared with the specimens collection at BO, especially the specimens that had been determined by A.G.H. Alston before; and also by using several newest references such as Wong (1982, 2010), Tsai and Shieh (1994), Li and Tan (2005), and Chang et al. (2012). In addition to direct observations, we use the literatures to guide the preparation of the description. Meanwhile, the global distribution is according to Hassler and Swale (2002).

RESULTS AND DISCUSSION

Description

Selaginella is an annual (*S. aristata*, *S. ciliaris*, *S. zollingeriana*) or perennial herb. Stems are leafy, slender, descending (*S. aristata*), creeping and rooting at intervals (*S. ciliaris*, *S. opaca*, *S. remotifolia*, *S. singalanensis*), ascending (*S. aristata*, *S. plana*), or erect, without branches on lower part, rooting near base, roll up when dry (*S. involvens*), branching dichotomously, regularly or irregularly branched. Rhizophores are present or absent (*S. involvens*), geotropic, borne on stems at branch forks, throughout (creeping ones), or confined to base (*S. ornata*). Leaves are small, simple, with a single vein (rarely veins forked), always bearing an inconspicuous ligule on the adaxial side at its base (only prominent in early development); vegetative leaves are (tropophyll) monomorphic-spirally arranged at basal main stem and dimorphic-4 lanes arranged on other parts (*S. involvens*, *S. plana*), or more often dimorphic and usually arranged in two median (ventral) and two lateral (dorsal) rows on the branches (*S. ornata*, *S. singalanensis*); median leaves are usually smaller, and in different shape from the lateral leaves; axillary leaves are single borne at the forking of each branch, being somewhat different from other leaves. *Strobilus* (clusters of imbricating sporophylls) are usually borne on the ends and sides of branches, cylindric, tetragonal (*S. involvens*, *S. opaca*, *S. remotifolia*), flattened (*S. ciliaris*) or do not in compact strobilus (*S. aristata*, sometimes). Sporophylls (fertile leaves) are monomorphic or adjacently different, slightly or highly differentiated from vegetative leaves. Sporangia are short-stalked,

solitary in an axil of sporophylls, opening by distal slits. Spores are of two types (heterosporous), megaspores tetrad (1-2-)4, large, commonly at the base of strobilus, microspores numerous (hundreds), minute; sporangia round or oval, opening by a transverse slit.

Selaginellaceae Reinch. is a family with only one genus namely *Selaginella* P. Beauv., cosmopolitan fern allies, consisting of about 700-750 species; 200s species in Nusantara, 25 species in Java, and nine species in Mount Lawu (Table 2). The results indicated that - at an altitude of 1100 to 2100 m - getting to the top, the number of collected *Selaginella* species decreased (Table 2). This suggests that the distribution of *Selaginella* is affected by altitude. A total of 9 species were found in Grojogansewu (1100-1400 m), 6 species in Ngargoyoso (1100-1500 m), and only two species in Cemorosewu (1600-2100 m). Altitude of 2100 m seems to be the upper limit of *Selaginella* distribution; therefore it is very interesting to conduct similar research at an altitude below 1100 m, and to know the distribution shift of *Selaginella* from the coastal area to the summit of Mount Lawu. Besides, a large number of species found in Grojogansewu are also allegedly associated with the local physiography. This area has a lot of high cliffs and small rivers, making it very suitable for the growth of *Selaginella*. In Java, the altitude of 1500 m may be the upper limit for the spread of *S. aristata, S. ciliaris, S. involvens, S. ornata, S. plana, S. singalanensis,* and *S. zollingeriana.* Meanwhile, the altitude of 2100 m is probably the upper limit for the spread of *S. opaca* and *S. remotifolia.*

Table 2. Species diversity and distribution of *Selaginella* in Mount Lawu and the adjacent areas.

Species	Grojogansewu (1100-1400 m)	KGPAA Mangkunagoro I (Ngargoyoso) (1100-1500 m)	Cemorosewu (1600-2100 m)	Total herbaria speciment
S. aristata	●	●		4
S. ciliaris	●	●		4
S. involvens	●			4
S. opaca	●	●	●	16
S. ornata	●			3
S. plana	●			3
S. remotifolia	●	●	●	14
S. singalanensis	●	●		4
S. zollingeriana	●	●		4
Total	9	6	2	56

Note: Each herbarium specimen was unique, distinguished by location and/or time of collection.

Key to species

1. Stem (sub-)erect, rooting at base, or bearing rhizophores 2
2. Stem shorter than 30 cm 3
3. Stem fleshy ..... *S. aristata*
3. Stem fragile ..... *S. ornata*
2. Stem longer than 30 cm 4
4. Stem hard, caulescent, easily broken .... *S. involvens*
4. Stem tough ..... *S. plana*

1. Stem creeping, rooting at intervals 5
5. Stem shorter than 15 cm 6
6. Leaves ovate to rounded ..... *S. ciliaris*
6. Leaves lanceolate ..... *S. zollingeriana*
5. Stem more than 15 cm 7
7. Stem fleshy ..... *S. opaca*
7. Not so 8
9. Leaves loosely arranged ..... *S. remotifolia*
9. Leaves imbricate ..... *S. singalanensis*

Species description

Selaginella aristata Spring; Bull. Acad. Brux. 10: 232, no. 152 (1843) (Figure 2A)

It is a small, fleshy, annual herb, prostrate to ascending, caespitose, fan-shaped; multiple branched at main stem, every branch forming dendritic stem. *Stems* are decumbent to ascending, dendritic branched, especially at the mature ones, ca. 4-20 cm long, 3-6 mm wide (including leaves). *Rhizophores* are present at basal stem, originated from the ventral side of branching stem, ca. 1 mm in diam. *Leaves* (trophophylls) are dimorphic, arranged in 4 lanes (2 lateral, 2 median), loosely arranged at the main stem but closely arranged at the branches, vein single; *lateral leaves* are lanceolate to oblong-ovate at main stem, lanceolate to falcate at branches, 1.8-3 mm long, 1-2 mm wide, base subcordate or rounded, asymmetrical, apex acute or obtuse, margin serrulate to subentire; *median leaves* are smaller than the lateral ones, lanceolate to ovate, more or less symmetrically, 1.2-2 mm long, 0.5-1 mm wide, base obtuse, apex caudate to long tail-like, apices are upward or bended back, margin serrulate, single vein reaching the apex; *axillary leaves* are lanceolate to ovate, 1.5-3 mm long, 0.5-1.5 mm wide, single vein nearly reaching the apex, base rounded, apex obtuse, margin serrulate. *Strobilus* are solitary, terminal, loosely, bisymmetrical, upper-plane sporophylls longer than lower-plane, ovate, complanate, apex acute, pointing outwards, up to 1 cm long.

Locality: Grojogansewu, Ngargoyoso

Habitat and ecology: it was found on steep cliffs, at the edge of the ditch/irigation water, and up to the stream that flows into Grojogansewu waterfall. It was also found on the cliff edge of the dirt- and cemented road to the Tahura office shaded by pine and secondary forest, only abundant in the rainy season, at altitude of 1150-1220 m a.s.l.

Distribution: Myanmar (Burma), Java, Sulawesi, Ternate, Philippines

Selaginella ciliaris (Retz.) Spring; Bull. Acad. Brux. 10: 23 (1843) (Figure 2B)

It is a small, annual herb, creeping or ascending, sometimes fan-shaped, 4-15 cm in size. *Stems* are recumbent, without a significant main stem, 4-5 mm wide (including leaves). *Rhizophores* are present at intervals but

mostly near the base, originated from the lateral side of branching stem, ca. 0.3 mm in diam. *Leaves* are dimorphic, arranged in 4 lanes (2 lateral, 2 median), vein single; *lateral leaves* are ovate-lanceolate, more or less symmetrical, 1.5-2 mm long, 0.6-1 mm wide, base rounded or subcordate, apex acuminate or acute, margin serrulate or ciliate, single vein reaching the apex, keeled, pointing outwards; *median leaves* are ovate to falcate, asymmetrical, 2-2.5 mm long, 0.6-1.5 mm wide, base rounded, apex acute, attenuate or cuspidate, margin serrulate but laciniate at basal part, pointing upwards, minutely toothed, ciliate, midrib prominent, single vein reaching or nearly reaching the apex; *axillary leaves* are lanceolate to ovate, equally sided (bisymmetrically), 1.8-2.5 mm long, 1-1.5 mm wide, single vein reaching or nearly reaching the apex, base rounded to subcordate, ciliate, apex acute, margin toothed, laciniate at basal part and serrulate at apical part. *Strobilus* are solitary or twin, terminal, flattened, complanate, up to ca. 1.5-2 cm long;

Locality: Grojogansewu, Ngargoyoso

Habitat and ecology: It was found on the steep cliff, at the edge of the irigation water, and up to the stream that flows into Grojogansewu waterfall. It was also found on the cliff edge of the cemented road to the Tahura office

shaded by pine and secondary forest, not recorded in the dry season, at altitude of 1150-1220 m a.s.l.

Distribution: India, Sri Lanka, Myanmar, S-China (Guangdong), Taiwan, Thailand, Vietnam, New Guinea, Solomons, Java, Sulawesi, Ternate, Philippines, Northern Australia, Marianas, Palau Isl., Micronesia

Selaginella involvens (Sw.) Spring; Bull. Acad. Brux. 10: 136, no. 6 (1843) (Figure 2C)

It is a robust perennial herb, erect with stoloniferous rhizome, without branches on the lower half, from a very widely creeping shallow subterranean branching rhizome to

Figure 2. Species diversity of selaginellas in Mount Lawu and the surrounding; A. *S. aristata*, B. *S. ciliaris*, C. *S. involvens*, D. *S. opaca*, E. *S. ornata*, F. *S. plana*, G. *S. remotifolia*, H. *S. singalanensis*, and I. *S. zollingeriana.*

an ascending rhizome, up to ca. 50 cm tall, 3-4 cm wide (including leaves). It has two types of *stems*: creeping (rhizome) and erect, with a significant main stem when erect; creeping stems when subterranean. Leaves are monomorphic, colorless, scales ovate ciliate, sessile, apex acute, apprised or recurved; erect branches dendritic, fan-shaped, up to more than 40-50 cm long, 1-1.5 mm in diam., with several dormant buds or leaves on lower part of main stem, monomorphic but dimorphic on much branching parts. *Rhizophores* are absent. Leaves of the basal main stem are monomorphic, ovate, clasping, nearly asymmetrical, appressed, 1-2 mm long, 1-1.8 mm wide, apex acute to attenuate, base truncate, auriculate or not, margin serrate to serrulate but lacerate with spinose at the auricule, arose and long ciliate towards apex. Leaves on the branches are dimorphic, arranged in 4 lanes (2 lateral, 2 median), vein single, reaching the apex; *lateral leaves* are lanceolate to ovate, asymmetrical, 0.8-2.5 mm long, 0.3-1.5 mm wide, ciliate near base, base oblique with auriculate, apex attenuate or acuminate, vein single always curved and pointing to abaxial side, having 2 significant grooves beside the vein, adaxial blade raised and forming two-main-vein, margin laciniate but spinose at the auricule; *median leaves* are ovate on the main stem but elliptical or laceolate to ovate on the top branch, asymmetrical, 1.5-3 mm long, 1-2.5 mm wide, base rounded to subcordate, twisting to form miniature auricle at the base, apex acute, single vein, obscure, 1-2 longitudinal groove(s) at the adaxial surface beside the vein of median leaves on the top branch, having 2-3 grooves at the abaxial surface on the top branch, 2 beside the vein and 1, less significant or absent, inside the midrib, margin entire to serrate, laciniate at most basal part of margin, concentrated spinose at the miniature-auricle base, minutely ciliate, pointing upwards; *axillary leaves* are ovate to cordate on first forked site but lanceolate to ovate at following forked site, asymmetrical, 1-2.5 mm long, 0.5-2.5 mm wide, base subcordate or cordate, apex acute or attenuate, margin serrate but laciniate at basal part, minutely ciliate. *Strobilus* are solitary, terminal, tetragonal, up to more than 2 cm long.

Locality: Grojogansewu

Habitat and ecology: It was found on the steep cliff, at the edge of the irigation water and small stream, at altitude of 1150-1382 m a.s.l.

Distribution: India, Bhutan, Nepal, Sri Lanka, Myanmar, China, Japan, Ryukyu Isl., Korea, Vietnam, Laos, Cambodia, Thailand, Java, Kalimantan, Sulawesi, Flores, Palau Isl.

Selaginella opaca Warb.; Monsunia 1: 108, 122, no. 112 (1900) (Figure 2D)

It is a fleshy herb, perennial. *Stems* are creeping to ascending, usually fertile branches alternate on long fleshy main stem, up to 80 cm long, 3-8 cm wide (including leaves). *Rhizophores* are at the branching stem, mostly near the base, originated from the dorsal side of stem at the branch site, ca. 1-1.5 mm in diam. *Leaves* on the main stem are monomorphic, oblong, asymmetrical, spaced farther apart than their width, midrib present. Leaves on the branches are dimorphic, arranged in 4 lanes (2 dorsal, 2 ventral), loosely arranged at long creeping stem but closely arranged at branches; *lateral leaves* are ovate to oblong, asymmetrical, 2-5 mm long, 2-3 mm wide, base rounded, apex acute, vein single, obscure, not reaching the apex, margin serrulate to entire or minutely ciliate at the base, pointing outwards, imbricating at the ends of branches; *median leaves* are ovate to oblong, asymmetrical, 1.5-3 mm long, 1-2 mm wide, base obliquely cordate or cordate, apex caudate, pointing upwards, imbricating at the ends of branches, vein single not reaching the apex, margin serrulate or serrate, but entire at basal part; *axillary leaves* are ovate, entire, rounded or obtuse, symmetrical, 2.5-3.5 mm long, 1.5-2.5 mm wide, apex acute, margin entire or serrulate at apical part. *Strobilus* are solitary, terminal or lateral, tetragonal, up to more than 3.5 cm long.

Locality: Grojogansewu, Ngargoyoso, Cemorosewu

Habitat and ecology: It was found on the steep cliffs and river bank above the channel irrigation and small river to Grojogansewu waterfall, on the cliff at the edge of the dirt-road and cemented road to the Tahura office shaded by pine and secondary forest, on the cliffs on the river banks near the bridge and new highway, along the footpath and the cliffs from Cemorosewu to Grojogan kembar waterfall, on the edge of several small springs near the camping ground, on the small tributaries in Jobolarangan Hills, on the cliff above the old road of Cemorokandang to Sarangan, on the trekking lane above Cemorosewu, near the field that made after forest fire. It could be found throughout the year; at altitude of 1150-2070 m a.s.l. This species is mostly found near *S. remotifolia*

Distribution: Sumatra, Java, Lombok, Ceram, New Guinea, Philippines

Selaginella ornata (Hook & Grev.) Spring; Bull. Acad. Brux. 10: 232 (1843) (Figure 2E)

It is a fragile perennial herb, greenish or brownish in general appearance. *Stems* are suberect fragile, very easily broken, 20-30 cm long, 1-3 cm wide (including leaves). *Rhizophores* are at the lower part and sometimes at branching stem, originated from the dorsal side of stem at the branch site, ca. 0.5-1 mm in diam. *Leaves* are dimorphic, arranged in 4 lanes (2 dorsal, 2 ventral), densely arranged throughout the stem and imbricating at top of branches; *lateral leaves* are oblong to falcate, denticulate to dentate, exauriculate, asymmetrical, 1.5-3 mm long, 1-1.5 mm wide, apex acuminate to acute, and prickly tip, vein single not reaching the apex, base rounded to truncate, margin entire; *median leaves* are denticulate to dentate, with arista often more than half the lamina length, asymmetrical, 1-1.5 mm long, 0.5-1 mm wide, apex acute, prickly tip, base rounded, vein single not reaching the apex, margin entire; *axillary leaves* are ovate to subcordate, exauriculate, imbricating, asymmetrical, 1-1.5 mm long, 0.5-1 mm wide, apex acute, base rounded, margin entire. *Strobilus* are solitary, terminal, bisymmetrical, upper-plane, up to more than 1 cm long.

Locality: Grojogansewu

Habitat and ecology: It was found the steep cliffs above a small irigation channel and tributary of Grojogansewu waterfall, on the cliffs on the small river banks near the

bridge and new highway; at altitude of 1150-1382 m a.s.l.

Distribution: India, Thailand, Vietnam, Cambodia, Peninsular Malaysia, Sumatra, Java, Kalimantan, Bali, Lombok, Flores, Philippines

Selaginella plana (Desv. ex Poir.) Hieron.; Nat. Pflanzenfam. 1 (4): 703 (1901) (Figure 2F)

It is a stout perennial herb. *Stems* are sub-erect with stoloniferous rhizome, without branches on the lower part, ascending from a subterranean trailing base, up to 80-100 cm long, 3-10 cm wide (including leaves); subterranean stems (rhizome) shallowly radiating. *Rhizophores* are sometimes at the branching stem, originated from the dorsal side of stem at the branch site, ca. 1-1.5 mm in diam. *Leaves* on the lower part and main stem are monomorphic, well spaced, appressed, 1.5-3 mm long, 1-2 mm wide, upper part slightly spreading, ovate, apex acuminate or acute, but rounded tip, asymmetrical, margin translucent, entire. Leaves on the branches are dimorphic, arranged in 4 lanes (2 dorsal, 2 ventral), loosely arranged at lower stem but closely arranged at branches; *lateral leaves* are oblong to ovate, asymmetrical, 2-4.5 mm long, 2-3 mm wide, apex acuminate to acute, but rounded tip, sessile, vein single, obscure, not reaching the apex, base truncate and rounded, upper base with a spur-like lobe which overlaps the stem, margin transparent, entire; *median leaves* are ovate to oblong, asymmetrical, 1.5-3 mm long, 1-2 mm wide, apex acuminate to acute, but rounded tip, sessile, vein single, obscure not reaching the apex, base truncate and rounded, margin transparent, entire; *axillary leaves* are ovate, asymmetrical, 2.5-3.5 mm long, 1.5-2.5 mm wide, apex acute, minutely ciliate, base rounded, margin entire. *Strobilus* are solitary, terminal, tetragonal, up to more than 3 cm long.

Locality: Grojogansewu

Habitat and ecology: It was found on the steep cliffs above a small irrigation channel and tributary of Grojogansewu, remaining abundant in the dry season, altitude 1150 m a.s.l.

Notes: It is originally low-lying vegetation, and 1200 m altitude in Turgo (Mt. Merapi) is probably the highest point that species can reach in Java (Setyawan et al. 2012).

Distribution: Peninsular Malaysia, Sumatra, Java, Bali, Timor, Flores, Sumbawa, Solor, Sulawesi, Maluku (Ambon, Banda, Ceram, Kei Isl., Ternate, Buru). Introduced: India, Taiwan, Philippines, Florida, Puerto Rico, Honduras, Costa Rica, Panama, Colombia, Brazil, Jamaica, Trinidad, St. Kitts, Barbados, Ecuador, British Guyana, St. Thomas, Dominica, Martinique, Tanzania.

Selaginella remotifolia Spring; Miq. Pl. Jungh. 3: 276, no. 5 (1854) (Figure 2G)

It is a wiry, perennial herb. *Stems* are creeping, usually several fertile branches alternate on long main stem, up to 100 cm long, 0.5-1 cm wide (including leaves). *Rhizophores* are at the branching stem, originated from the dorsal side of stem at the branch site, ca. 0.5 mm in diam. *Leaves* are on the main stem monomorphic, lanceolate, acuminate, asymmetrical, spaced farther apart than their width, midrib present. Leaves on the branches are dimorphic, arranged in 4 lanes (2 dorsal, 2 ventral), loosely arranged at the long creeping main stem but closely arranged at branches; *lateral leaves* are contiguous, lanceolate to ovate, asymmetrical, 1.5-3 mm long, 1-2 mm wide, apex acute to acuminate, vein single, obscure not reaching the apex, base rounded, margin serrulate but usually entire or minutely ciliate, pointing outwards; . *median leaves* are lanceolate to ovate, asymmetrical, 1.5-2.5 mm long, 0.5-1 mm wide, base obliquely cordate or cordate or cuneate, apex attenuate or caudate, leaves at ends of branches imbricating, vein single not reaching the apex, margin serrulate or serrate, but entire at abaxial medium and basal part; *axillary leaves* are ovate, entire, rounded or obtuse, symmetrical, 2-2.5 mm long, 1-1.5 mm wide, apex acute, margin entire or loosely serrulate at apical part. *Strobilus* are solitary, terminal or lateral, tetragonal, up to more than 2 cm long.

Locality: Grojogansewu, Ngargoyoso, Cemorosewu

Habitat and ecology: It was found on the steep cliffs and river bank above the channel irrigation and small river towards Grojogansewu waterfall, on the cliff at the edge of the dirt-road and cemented road to the Tahura office shaded by pine and secondary forest, among pine stand of Tahura forest, on the cliffs on the river banks near the bridge and new highway, and around the vegetable fields, along the footpath and cliffs from Cemorosewu to Grojogan Kembar waterfall, on the edge of several small springs near the camping ground, cliff above the old road of Cemorokandang to Sarangan, on the trekking lane above Cemorosewu, near the field made after forest fire. It grew throughout the year but decreased at dry season; at altitude of 1150-2070 m a.s.l.

Distribution: Myanmar, China (Guizhou, Guangxi, Yunnan), Taiwan, Japan, Ryukyu Isl., Korea, Sumatra, Java, New Guinea, Philippines

Selaginella singalanensis Hieron.; Hedwigia 50: 18, no. 12 (1910) (Figure 2H)

It is a tender, perennial herb, in humid environments, growing all year round, yellowish in general appearance. *Stems* are creeping, attached to the ground, very soft and very thin, 20-25 cm long, 1-3 cm wide (including leaves). *Rhizophores* are at branching stem, originated from the dorsal side of stem at the branch site, ca. 0.5 mm in diam. *Leaves* are dimorphic, very soft, arranged in 4 lanes (2 dorsal, 2 ventral), densely arranged at thorough stem and imbricating at top of branches; *lateral leaves* are oblong, imbricating, asymmetrical, 1.5-2.5 mm long, 0.5-1.5 mm wide, apex acute, vein single not reaching the apex, base rounded, margin entire; *median leaves* are dentate, exauriculate, asymmetrical, 0.5-1.5 mm long, 0.5 mm wide, apex acute, vein single not reaching the apex, base rounded, margin entire; *axillary leaves* are ovate, imbricating, asymmetrical, 0.5-1.5 mm long, 0.5 mm wide, apex acute, base rounded, margin entire. *Strobilus* are solitary, terminal, loosely, bisymmetrical, upper-plane, up to more than 1 cm long.

Locality: Grojogansewu,

Habitat and ecology: It was found on the steep cliffs and river bank above the channel irrigation and small river towards Grojogansewu waterfall, on the cliff at the edge of

the cemented road to the Tahura office shaded by pine and secondary forest. It generally died in the dry season, but in a moist area it could grow throughout the year; at altitude of 1150 m a.s.l.

Distribution: Sumatra, Java

Selaginella zollingeriana Spring; Miq., Fl. Jungh. 3: 278, no. 11 (1854) (Figure 2I)

It is a slender annual herb, annual, ascending, fan-shaped; multiple branched at main stem, every branch forming dendritic stem. *Stems* are ascending, dendritic branched, especially at the mature ones, ca. 5-15 cm long, 3-5 mm wide (including leaves). *Rhizophores* are only present at lower part, ca. 0.5 mm in diam. *Leaves* on the main stem are monomorphic, lanceolate, acuminate, asymmetrical, spaced farther apart than their width. Leaves on the branches are dimorphic, arranged in 4 (2 lateral, 2 median), loosely arranged at the main stem but closely arranged at the top branches, vein single; *lateral leaves* are lanceolate, asymmetrical, 1.5-2 mm long, 0.5-1.5 mm wide, apex acute, base rounded, margin entire; *median leaves* are smaller than lateral ones, lanceolate, 1-1.5 mm long, 0.5 mm wide, apex caudate to long tail-like, margin entire, single vein; *axillary leaves* are lanceolate to subcordate, ca 1-1.5 mm long, 0.5-1 mm wide, single vein nearly reaching the apex, apex acute, base rounded, margin entire. *Strobilus* are solitary, loosely, bisymmetrical, upper-plane, up to ca. 1 cm long.

Locality: Grojogansewu, Ngargoyoso,

Habitat and ecology: It was found on the cliff walls of the tomb and headstone, on the cliff at the edge of the cemented road to Tahura office shaded by pine and secondary forest, on the roadside on the plastered and dirt drainage ditch; not recorded in the dry season, at altitude of 1150-1222 m a.s.l.

Distribution: Bali, Java

CONCLUSION

Nine species of selaginellas have been found in Mount Lawu and the adjacent areas, namely: *S. aristata, S. ciliaris, S. involvens, S. opaca, S. ornata, S. plana, S. remotifolia, S. singalanensis* and *S. zollingeriana*. All species could be identified based on its vegetative-morphological characteristics.

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