

Short Communication: A new record of naturalized *Selaginella uncinata* (Desv.) Spring (Selaginellaceae) from Java, Indonesia

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ABSTRACT

Setyawan AD. 2014. A new record of naturalized *Selaginella uncinata* (Desv.) Spring (Selaginellaceae) from Java, Indonesia. *Biodiversitas* 15: 261-268. During extensive field researches on the diversity and distribution of *Selaginella* in Java, between 2007 and 2014, an alien species has been found in nature, i.e. *Selaginella uncinata*. This species is a trailing herb with small, wiry, creeping main stem, fan-shaped branches, rooting at the nodes to c.a. 100 cm long or more; leaves are dimorphic, 4-ranked, and characterized by conspicuous blue iridescent; strobili are tetragonal, up to c.a. 2 cm long. *S. uncinata* was found growing wild in the highlands with high rainfall, namely: Cibodas Botanical Garden, Cianjur, West Java and Tawang Sari, in the city district of Wonosobo, Central Java, Indonesia. Transplant experiments showed that this plant was able to grow and reproduce well in lowlands (Depok, 107 m asl.) and highlands (Wonosobo, 768 m asl.). In the experimental garden, it could compete successfully with native species of Javan selaginellas, for space, sunlight and nutrients. Therefore, we must be concerned about the invasion ability of this species.

Key words: Alien, invasive, new record, *Selaginella uncinata*, Java.

INTRODUCTION

Selaginella P. Beauv. (club moss, spike-moss) is a solely genus of fern allies belonging to the Family of Selaginellaceae Reinch., consisting of 700-750 species throughout the world in the tropical and subtropical regions (Tyron and Tyron 1982; Jermy 1990), and 25 species of Java (Setyawan 2008). This plant prefers retentive and fertile soil and moderately shaded place, requires water for fertilization, and is susceptible to drought. This genus is widespread in the shaded and moist places, especially in mountainous areas with humid climate and abundant water resources, although the distribution of each species can be limited depending on location and season.

Selaginella is a useful plant for traditional and modern medicines. Traditionally, it is used for treating wounds, postpartum, menstrual disorders and body fitness improvement (tonics). Modern biomedical research shows that this plant has potential as an anti-oxidant, anti-inflammatory, anti-cancer, anti-bacterial, etc. (Setyawan 2011a). *Selaginella* is used to treat acute infection, jaundice, hepatitis, cholecystitis, enteritis, etc. (Lei et al. 2010). It is also useful as an ornamental plant, handicraft materials, and vegetables (Winter and Jansen 2003; Setyawan 2009).

Selaginella uncinata is originated and widely distributed in southern China. It was introduced to Java many years ago.. It was never recorded in the classical literatures of *Selaginella* in Nusantara (the Malay

Archipelago), both in Java and the Lesser Sunda Islands (Alston 1935a), Sumatra (Alston 1937), Sulawesi and Maluku (Alston 1940), the Malay Peninsula (Alston, 1934), and the Philippines (Alston 1935b). Even in a recent study on flora *Selaginella* of the Malay Peninsula (Wong 1982, 2010) *S. uncinata* was not listed either.

Medicinal plants

Selaginella uncinata is one of the selaginellas species widely used in traditional Chinese medicine to treat bacterial diseases, hepatitis, infectious diseases, tumors (Ma et al. 2002), jaundice, dysentery, edema and rheumatism diseases (JNMC 1986). Phytochemical isolation of this plant has resulted in several biflavonoids, flavonoids, chromone glycosides and phenolic constituents (Ma et al. 2003; Zheng et al. 2007a, 2008). This herb contains uncinataflavone, named after the specific epithet, which have antioxidant activity (Zou et al. 2013). Amentoflavone, hinokiflavone and robustaflavone are other biflavonoids isolated from *S. uncinata* with antioxidant activity (Ma et al. 2003; Zheng et al. 2007b; Fan et al. 2009). This plant has a protective effect against anoxia due to several 3,8 -linked bioflavonoids constituents (Zheng et al. 2011), steroidal saponins (Zheng et al. 2013), and -lactone derivatives and terpenoids (Zheng et al. 2014). It also has chromone glycosides, i.e. uncinoside A and uncinoside B (Man and Takahashi 2002), which show antiviral activities against respiratory syncytial virus (RSV) and parainfluenza type 3 virus (PIV 3) (Ma et al. 2003). *S.*

uncinata has resistance to disease, drought and metal toxicity due to the high silicon content (Ma and Takahashi 2002; Ma 2004). There are many other chemical compounds isolated from this plant, but their usefulness has not been examined.

Ornamental plants

Selaginella uncinata has a very attractive appearance, especially due to the metallic blue iridescent caused by thin-film refraction (Gebeshuber 2009). This color changes with the angle of light and the local humidity levels, from blue to blue-green to emerald green. The most intense blue color tends to be indicated by the new growth particularly that lying flat on moist ground floor. Good light but full shade is necessary to bring out and maintain the color (Phair 1989). The green leaves that develop in response to more direct sunlight do not turn blue when subjected to shade, but blue leaves gradually turn green with age or exposure to more direct light (Gebeshuber 2009).

This blue appearance is caused by the way of the plant refracts light. The color phenomenon is a physical characteristic of light called thin layer refraction, similar to a shimmering rainbow on a puddle of water coated with a thin oil film. In *S. uncinata*, the leaf epidermis is coated with two bands of cells in rows that refract light from the plant. Photons of light energy, which travel in waves of different length depending on the color, are slowed down slightly when they pass through any material. The light rays that bounce back through the rows of cells are slightly slowed. Half of the light is shifted so that the peak of one stream of photons is directly opposite of the valley of another stream of photons, thus creating the iridescent blue effect (Klingaman 2010).

This China's native plant was introduced to many other countries as an ornamental plant. To date, *S. uncinata* has been introduced into the southeastern United States, Brazil, Costa Rica, Japan, Taiwan, the Philippines, India, Germany and France (e.g. Hassler and Swale 2002; GBIF 2014a; Global Mapper 2014). This species has been naturalized in Japan (Mito and Uesugi 2004; NIES 2014) and the United States (Hoshizaki and Moran 2001; Mickel 2003; IFAS 2012), but the rate of invasion is still being debated, thus it has not been stated as an invasive plant, but only a naturalized or weed plant (GCW 2007). However, some ornamental plants suppliers have stopped selling this plant.

This paper is the first report of *S. uncinata* as naturalized plant of Java and a new record for the flora of Java, as well as flora of Nusantara. The presence of *S. uncinata* in Java can be traced back from herbarium sheet, Junghuhn no. 1239, collection of the Bogor Botanical Gardens (now owned by Herbarium Bogoriense). The sheet has no collection date, but Junghuhn lived in Java in the period of 1835-1848 and 1855-1864 (Beekman 1996). Therefore, *S. uncinata* thought to have been introduced in or before those years, but has not been distributed in nature yet and not recorded in classical literature. Setyawan (2009, 2012) and Harli (2013) are the current literature indicating the presence of *S. uncinata* in Java, but without sufficient attention to the flora and naturalization. A collection of the

Royal Botanical Garden Edinburgh (RBGE) Herbarium (E) by H. Cuming no. 1996 (E00348822, 24-02-2011) stored under name of *S. uncinata* of the Philippines does not refer to this species (GBIF 2014b; RBGE Herbarium 2014). But, Pelser et al. (2011) stated that this species occurs as an escape in Luzon, the Philippines. Meanwhile, Setyawan (2009) reported the discovery of a new record of *Selaginella* from Wonosobo, Java with huge potential for land cover and ornamental plant. It can be grown in the soil surface quickly and has flagrant metallic blue color in shady conditions. This characteristic refers to *S. uncinata*, but it was mis-identified as *S. singalanensis*. Setyawan (2012) restates the presence of *S. uncinata* in Wonosobo with reference to the above specimen.

Invasiveness of selaginellas

For medical reasons and ornamental plants, *Selaginella* is introduced to many countries, including *S. plana*, *S. wildenowii*, *S. lepidophylla*, *S. martensii*, *S. biformis*, *S. moellendorffii*, *S. uncinata*, and *S. kraussiana* (Setyawan 2011b). These species have high adaptability, easy to grow, easy to maintain and reproduce rapidly, thus they are feared to be harmful to the new environment. However, at this time, it is only *S. kraussiana* which significantly threatens the new environment and harms the economy. *S. kraussiana* of mountainous African and subtropical Azores (van Leeuwen et al. 2005) has been invasive in several subtropical areas. Even, it can also be found in the cold mountainous zone of Mount Kilimanjaro, Tanzania (Hemp 2008). This introduced ornamental plant has become invasive in the United Kingdom and Ireland (Stokes et al. 2006), the United States (Stapes et al. 2004), Australia (Carr et al. 1992; Groves 2003), and New Zealand (Bannister 1984; Esler 1988; Timmins and Braithwaite 2002; West 2002). This species is a serious weed in New Zealand, though it is sensitive to intense sunshine and drought (Thetford et al. 2006).

Field research and transplant experiment

The extensive field research was carried out in more than six years, between July 2007 and January 2014, collecting more than 1450 samples of Java selaginellas from the 500s points coordinates. More than 600 herbarium sheets of Java selaginellas and 2000s sheets of other Nusantara selaginellas from the Herbarium Bogoriense (BO) have been examined. *S. uncinata* and its relatives were identified using classical bibliographies of *Selaginella* flora in Nusantara, i.e. Alston (1934, 1935a, 1935b, 1937, 1940); as well as the newer literatures of *Selaginella* from Nusantara and the surrounding areas, i.e. Andrews (1990), Tsai and Shieh (1994), Li and Tan (2005), Wong (1982, 2010), Chang et al. (2012), and Zhang et al. (2013). In the field study, *S. uncinata* was found naturalized on two locations namely: Cibodas Botanical Garden, Cianjur, West Java (1359 m asl.), and Tawang Sari, in the city district of Wonosobo, Central Java (708 m asl.). Both locations are situated in the highlands. Meanwhile, Harli (2013) showed the presence of *S. uncinata* in Cibeber, Cianjur, West Java and Bandung, West Java, not far from the botanical garden.

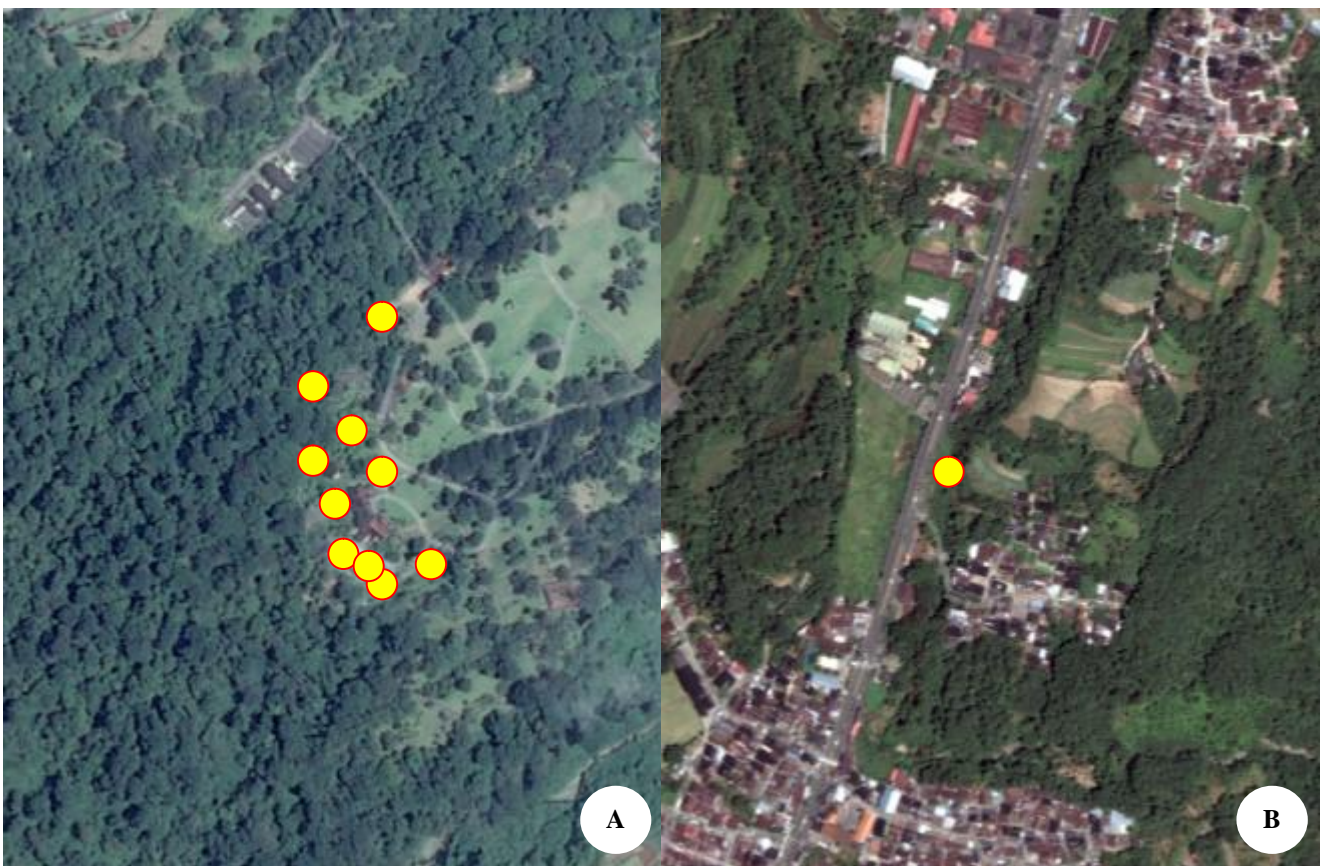
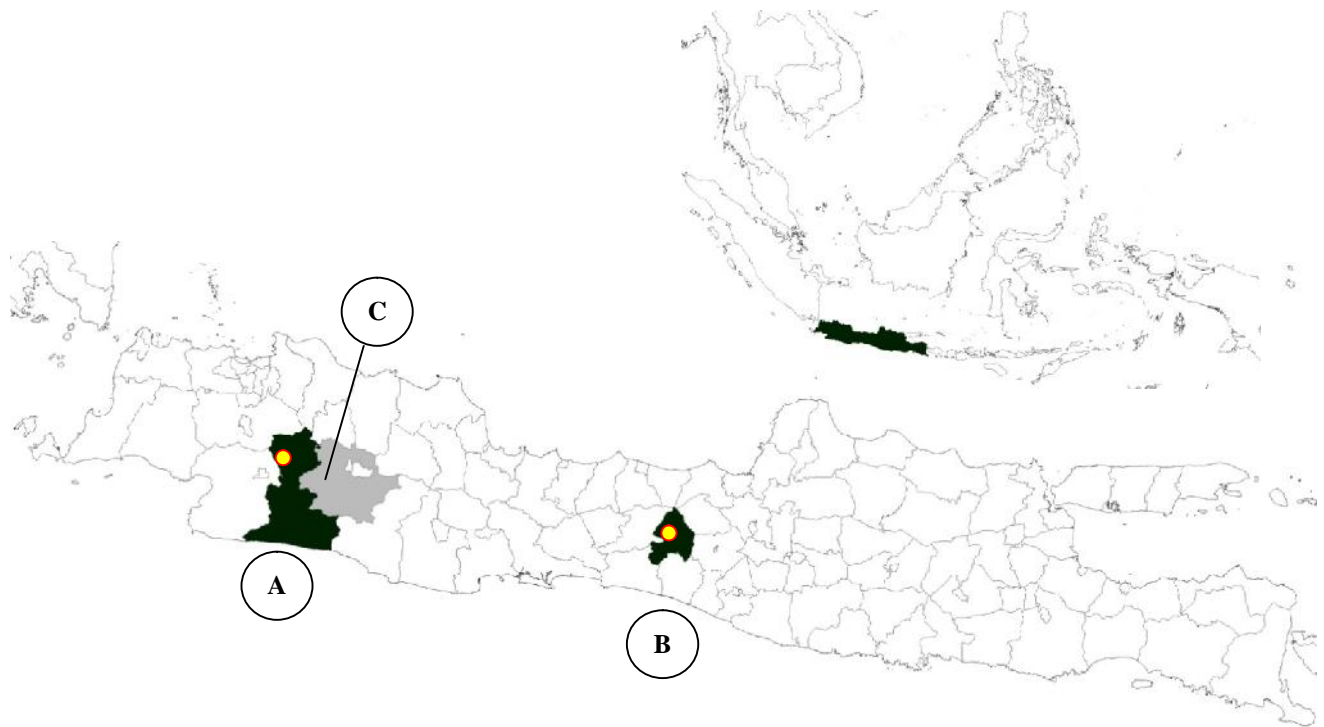


Figure 1. Site discovery of naturalized *Selaginella uncinata* in Java, Indonesia. A. Cibodas Botanical Garden, Cianjur, West Java, a recreation and plant conservation area, on the edge of primary tropical rainforest. *S. uncinata* was scattered on the forest edges, among the plant collections, on the ground floor of the greenhouse, on the banks of waterways or streams, etc., common in moist areas and slightly open. B. Tawang Sari, in the city district of Wonosobo, Central Java, a downtown that still retains agricultural land and community forests among the city's infrastructure. *S. uncinata* was only discovered once on the small river bank, below shrubs and shaded by trees. C. Harli (2013) showed the presence of *S. uncinata* in Cibeber, Cianjur, West Java and Bandung, West Java, not far from the Cibodas Botanical Garden.



Figure 2. Transplant experiment of *Selaginella uncinata* indicated that this ornamental plant is potentially invasive. A. *S. uncinata* with beautiful metallic blue iridescent, B. Growing very rapidly, overflowing from the pot and spread to the surrounding area, C. Growing as epiphytes attached to the old wall, D. Hanging from the pot to get the space and sunlight, E. Spreading, covering the ground floor and the other *Selaginella*, especially small creeping selaginellas, F. Covering small *S. rothertii*, G. Filling cracks in concrete bricks and compete with *S. meyeri*.

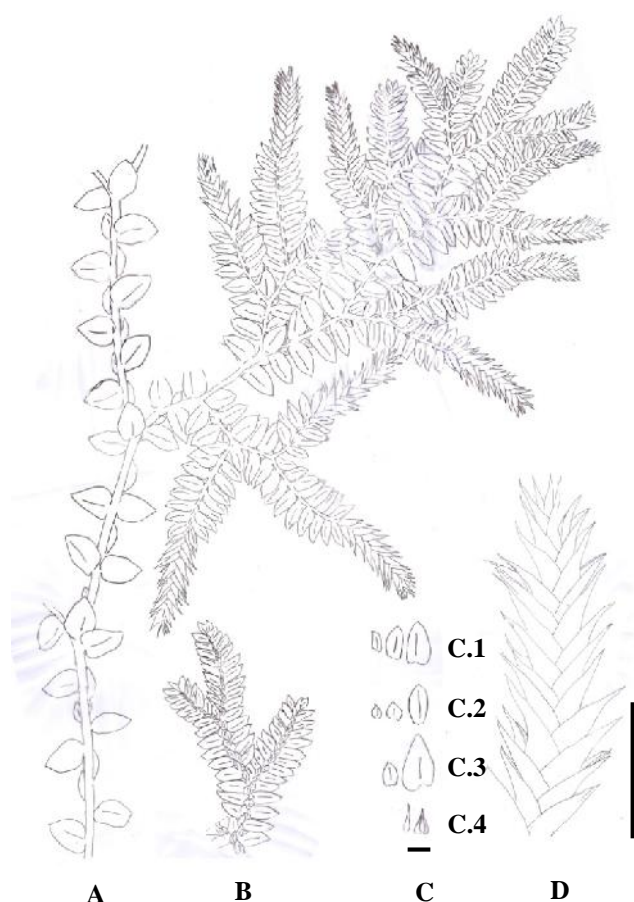


Figure 3. Schematic morphology of *Selaginella uncinata*. A. General ventral appearance, B. Dorsal tip appearance, C. Leaves morphology: C.1. Lateral leaves, C.2. Median leaves, C.3. Axillary leaves, C.4. Sporophylls, Bar = 1 cm, D. Strobilus, Bar = 1 cm.

Cibodas Botanical Garden is located at the foothills of Mount Gede-Pangrango at an altitude of 1300-1425 m asl. with an area of 84.99 hectares, the average temperature of 17.04-26.44°C, the humidity of 89.28%, and the average rainfall of 3,380 mm/year (Setiawati 2012). Cibodas Botanical Garden is a recreation and plant conservation area on the edge of primary tropical mountain rainforest. *S. uncinata* was scattered on moist shady spots of the forest edges, among the plant collections, on the ground floor of the greenhouse, on the banks of waterways or streams, etc., common in rich soil, moist areas and moderate shade. While, Tawang Sari is a downtown of Wonosobo, Central Java that still retains agricultural land and community forests among the city's infrastructure. Wonosobo district is a mountainous area, located at an altitude of 275-2250 m asl. (half is located at 500-1000 m asl.), with an area of 98,468 hectares, the average temperature of 14.3-26.5°C, the humidity of 82%, and the average rainfall of 3,400 mm/year (BPS Wonosobo 2011). *S. uncinata* was only discovered once on the small river bank, below shrubs and shaded by trees. Research on this species showed no presence in the surrounding area.

Selaginella uncinata has grown in the experimental garden soon after its discovery in nature. Garden experiment was distinguished between lowlands and

highlands, namely: Cilangkap, Depok, West Java (107 m asl.); and Kejiwan, Wonosobo, Central Java, Indonesia (768 m asl.). Transplant experiments were performed with a variety of treatments, namely: substrate (loam soil, sand, compost/manure, mixture), shade (0-60%), and water (1, 2, 3, 4 days per 4 days). *S. uncinata* has been planted in Wonosobo since four years ago (6 March 2010), and in Depok since last year (28 March 2013). It continues to grow and reproduce well now.

S. uncinata grew much better in Wonosobo highlands than the lowlands of Depok. In the moist highlands of Wonosobo, this plant grew very rapidly, overflowing from the pot and spread throughout the experimental gardens, including the garden floor, trailing in the stone wall, filling among the pots, among the erect selaginellas (*S. plana*, *S. involvens*, *S. wildenowii*, etc) and overrode the creeping selaginellas (*S. ciliaris*, *S. repanda*, *S. rothertii*). As the plant grew, the stem roots grew freely, and the plant continued to spread outwards. The growth of this plant needs supervision lest it spreads to the surrounding areas. This plant is potentially invasive and competes successfully with native species of Nusantara selaginellas. Fortunately, most of the plants will dry up, turning into warm bronze or brown and die in the extremely dry season, thus inhibiting its spread naturally. In the garden experiment, *S. uncinata* reproduced vegetatively and rarely formed strobilus. It produced root-like rhizophores along the weak stems and is easily fragmented.

In the lowlands of Depok with warmer environment, *S. uncinata* grew relatively limited, even depressed by *S. meyeri*, other creeping selaginellas. However, this plant could grow well, as long as there was enough shade, water and nutrients (compost), even if it grew among other *Selaginella* plants, such as: *S. plana*, *S. wildenowii*, etc. In both the experimental gardens, *S. uncinata* generally grew better in moist conditions, but well-drained, adequate water, humus, and shade. In Depok, direct sunlight was harmful to growth; opening or removal of paranet or shade plants in the vicinity could cause dryness and death. Meanwhile, in Wonosobo, these plants could grow in direct sunlight, although the best growth was found in the shade.

Taxonomic treatment

Selaginella uncinata (Desv. ex Poir.) Spring, Bull. Acad. Roy. Sci. Bruxelles. 10: 141. 1843.

Basionym: *Lycopodium uncinatum* Desv. ex Poir., Lamarck, Encycl. Suppl. 3: 558 (1814).

Synonym: *Lycopodioides uncinata* (Desv.) Kuntze, Rev. Gen. Pl. 1: 825 (1891); *Lycopodium aristatum* Roxb., Hort. Beng., 75 (1824) [nomen, non Hook. & Bak]; *Lycopodium caesium* Hort. ex Anon., Ann. Hort. Soc (1847): 361, descr.; *Lycopodium dilatatum* Hook. & Grev., Enum. Fil., Hook. Bot. Misc. 2: 394, no 149 (1831); *Selaginella aristata* (Roxb.) Scott; List Higher Crypt., 64 (1868); *Selaginella caesia* Hort. ex A. Br., Ind. Sem. Hort. Berol. 23 (1860); *Selaginella caesia* Kunze, Linnaea 20: 2 (1847) [nom. nud.], *Selaginella caesia* var. *violacea* Hort. ex A. Br., Ind. Sem. Hort. Berol. 23 (1860); *Selaginella eurystachya* Warb., Monsunia 1: 105, 119, no. 79 (1900).

Common name: Blue spike moss, hooked spike-moss, peacock fern, peacock moss, peacock spike moss, rainbow fern, rainbow moss (English); Chinesisches mooskraut (Germany); cui yun cao (Chinese, 翠云草, 翠雲草).

Description: This species is a perennial herb, terrestrial, wiry, pliant, creeping, fan-shaped branching, up to ca. 100 cm long or more, forming tick mats. *Stems* are long-creeping, branched from near base upward, pinnately or 3-forked branching, flat or hanging, or scandent to epiphyte on rocky wall, not articulated, terete and angulate, sulcate, glabrous with a wiry-pliant main stem, 1-1.5 mm diam., apex of main stems flagelliform, many branches; 6-8 pairs of primary leafy branches, twice pinnately branched, once or twice forked secondary branches, dense branchlets, adjacent primary branches on main stem 4-6 cm apart, 4-5 cm wide (including leaves). *Rhizophores* are axillary at intervals, mostly at main stem base near to the ground or at intervals throughout length of main stem, borne on ventral side of branches, 0.3-0.5 mm diam. *Leaves* are dimorphic, delicate, papery, iridescent, green to metallic blue-green, distinctly white-margined, margin entire, single vein, arranged in 4 lanes (2 lateral, 2 median); *lateral (ventral) leaves* are distant, ovate to oblong, asymmetrical, 2.5-4 mm long, 1.5-2 mm wide, basiscopic base with small auricle, acroscopic base overlapping stem, not enlarged; base rounded or cordate, apex acute or mucronate to obtuse, margins conspicuously transparent, entire, single vein reaching the apex, keeled; *median (dorsal) leaves* are ovate to lanceolate, asymmetrical, obviously larger on main stems than on branches, dorsal leaves on branches are approximate to imbricate, parallel to axis or overlapping at leaf apex and often reflexed, ovate, 2-3 mm long, 1-1.5 mm wide, base obtuse to auriculate, apex acute to long acuminate, margins transparent, entire, single vein; *axillary leaves* are present at branch forks, inserted at the ventral side of the stem, obviously larger on main stems than those on branches, broadly ovate or reniform, more equally sided, 3-4 mm long, 2-3 mm wide, single vein, base rounded to subcordate, apex acute to acuminate, margin transparent, entire, keeled. *Strobili* are solitary, terminal, compact, tetragonal, 0.5-2 cm long and distinctly 4-keeled.

Habitat and ecology: In Cibodas Botanical Garden, *S. uncinata* was distributed in many areas, common, grows wildly among the collection plants and at the greenhouse floors, around drains and small streams, on the forest edge; at altitude of 1359 m asl. This garden is situated in the cool highlands, on the edge of primary montane rainforest. In the experimental garden of Depok, this plant could grow and reproduced well, but it required sufficient shade, nutrients and water (moisture), because Depok is located in the warmer lowlands. It filled the gaps among pots, competed or live in co-existence with creeping *S. mayeri*. While, in Tawang Sari, Wonosobo, *S. uncinata* was only found once on the steep cliffs of the small river banks, under the bushes and shaded by trees; at altitude of 708 m asl. Creeping *Selaginella* generally is not able to grow under the bushes, but these species can do. Tawang Sari is located in the downtown of Wonosobo but still retains its farm land and community forest, among the residential, business district, road, irrigation channels, etc. In the

Wonosobo experimental garden, it could grow well, forming a thick-dense mat in moist spots on the floor and walls, hanging on the containers, filling the empty floor among the potted plants, and is very suitable as land cover in moist and shaded places. It is very easy to grow and be propagated by division of large mats or by stem cuttings. It shows attractive metallic blue-green color in the shade and will be faded in the sun exposed places. It is very suitable as ornamental plant.

Locality in nature: Cibodas Botanical Garden, Sindanglaya, Cianjur, West Java; Tawang Sari, Wonosobo, Central Java, Indonesia.

Distribution: China (common: Anhui, Chongqing, Fujian, Guangdong, Guangxi, Guizhou, Hubei, Hunan, Jiangxi, Shaanxi, Sichuan, Taiwan, Yunnan, Zhejiang), Hongkong, Macau, Vietnam. Introduced to Brazil (Rio de Janeiro), Costa Rica, India (West Bengal), Indonesia (Java: Wonosobo and Cianjur, in this research), Japan (Honshu, Kyushu, Shikoku), Paraguay, Taiwan, the United States (Florida, Georgia, Louisiana, Mississippi, Alabama, Connecticut, North Carolina), Germany (Berlin Botanical Garden) and France (Jardin Botanique du Montet, Nancy).

Specimen observed: ADS 286 (SO!) (Tawang Sari; 2010-03-06; -7.386517°, 109.895696°, 708 m asl.; Tawang Sari, Wonosobo, Central Java; cliff of a small river bank, under bushes, shaded by nearby trees); ADS 454 (SO!) and ADS 455 (SO!) (Wonosobo experimental garden, 2011-08-00; -7.347392°, 109.903347°, 768 m asl., Kejiwan, Wonosobo, Central Java; originally from Tawang Sari, Wonosobo, planted in the experimental garden at 6 March 2010; experimental garden covered by paranet or not, high rainfall, relatively humid); ADS 631 (SO!) (Cibodas Botanical Garden, 2013-03-28, -6.740285°, 107.006960°, 1359 m asl., Sindanglaya, Cipanas, Cianjur, West Java, common, grows wild in the collection garden and greenhouse floors, around drains and small streams, forest edge); ADS 1473 (SO!) (Depok experimental garden, 2014-08-13, -6.436861°, 106.864194°, 107 m asl., Cilangkap, Tapos, Depok, West Java, originally from Cibodas Botanical Garden, planted in the experimental garden at 28 March 2013; planting site is rather open, low rainfall, dry, partially exposed to direct sunlight); and Junghuhn no. 1239 (det. 1910) (BO!) Java, W. Bog., Herb. Hort. Bot. Bog.; It was redetermined by A.G.H. Alston in 1930s, but not included in the list of selaginellas from Java and the Lesser Sunda Islands (Alston 1935a), and given notes as "cultivated". There is no information about the habitat; it is likely to come from the early collection of introduced *S. uncinata* of the Bogor Botanical Gardens.

Discussion. The discovery of *S. uncinata* in the capital district of Wonosobo is a new record for Central Java. The only *S. uncinata* sheets of Herbarium Bogoriense is the collection of Junghuhn no. 1239 (det. 1910) which may be obtained from the plants collections of the Bogor Botanical Gardens. The botanical garden has brought a variety of selaginellas from outside Java and abroad, but almost all the introduced selaginellas have died and have not been naturalized. However, in the upland botanical gardens about 25 km eastward, namely the Cibodas Botanical Gardens (1350 m), this species was found either planted or

growing wild. *S. uncinata* in Wonosobo city was presumably introduced as an ornamental plant from southern China, because the Chinese have lived in the city since hundreds of years ago (Setyawan 2012). Besides, the species of Cibodas Botanic Garden can easily be grown in Depok (107 m), indicating that this species is not specific to highlands. Zhang et al. (2013) stated that *S. uncinata* can be grown below 100 to 1200 m asl. in China.

Conservation concern and future prospect

In the field study, *S. uncinata* was found naturalized in two remote highland areas, namely Cibodas Botanical Garden and Tawang Sari, Wonosobo, within 300 km. In Wonosobo, the discovery of *S. uncinata* was not followed by similar discoveries in the surrounding area. Meanwhile, in the Botanical Gardens Cibodas, the discovery of *S. uncinata* was also accompanied by similar discoveries in the surrounding area. This suggests that the plant was introduced to Cibodas Botanical Garden long before it was introduced to Wonosobo, so the naturalized area of *S. uncinata* is much broader in the botanical garden than in Wonosobo. In fact, *S. uncinata* has been naturalized in nature and it requires management effort so it will not become invasive.

On the other hand, this ornamental plant has a potential as medicinal plant. Many chemical compounds have been isolated and its usefulness has been known; the rests have not been known or have not been isolated yet. This naturalized plant is expected not only to be harmful to the environment and the economy, but also to be a blessing for the discovery of new compounds with medicinal benefits and economic value. Therefore, in-depth research is needed on the ecological and phytochemical characteristics to increase the benefits.

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