Selaginella boomii (Selaginellaceae – Lycopodiophyta): A new and widely distributed spikemoss from South America

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Abstract. **Selaginella boomii** is described as a new species and compared to the similar *S. roraimensis*. The new species is widely distributed in Venezuela, Guyana, Suriname, and Brazil where it grows on granite outcrops and boulders in forests and savannas. *Selaginella boomii* is illustrated with Scanning Electron Micrographs of stem sections, leaves, and spores, and its conservation status is discussed based on IUCN Categories and Criteria. This new species is classified within subgenus *Stachygynandrum* because of its heteromorphic vegetative leaves and monomorphic sporophylls that are arranged in quadrangular strobili. Finally, a brief overview on the current number of *Selaginella* species known from South America is provided to highlight that our knowledge of the diversity of this genus in the region is far from complete.

Key Words: Boulders, granite outcrops, lycophyte, savanna.

Resumen. **Selaginella boomii** se describe como una especie nueva y se compara con la similar, *S. roraimensis*. La nueva especie está ampliamente distribuida en Venezuela, Guayana, Surinam y Brasil, donde crece sobre afloramientos rocosos de granito y rocas en áreas de bosques y de sabanas. *Selaginella boomii* es ilustrada con micrografías del Microscopio Electrónico de Barrido de secciones del tallo, de las hojas y de las esporas, mientras que su estado de conservación se discute con base a las Categorías y Criterios de IUCN. Esta nueva especie se clasifica en el subgénero *Stachygynandrum* ya que posee hojas vegetativas heteromórficas y esporofilos monomórficos que se disponen en estróbilos cuadrangulares. Finalmente, se provee una sinopsis sobre el número actual de especies de *Selaginella* que se registran en Suramérica para subrayar que nuestro conocimiento de la diversidad de éste género en dicha región es todavía incompleto.

Selaginella P. Beauv. is the largest lycophyte genus and one of the oldest seedless vascular plant lineages with fossils dating back 333–350 Myr ago (Banks, 2009). It is widely distributed through the world but is most diverse and species-rich in tropical and subtropical regions, where an estimated 600–750 species occur (Jermy, 1990; Valdespino, 1993a; Mickel et al., 2004; Valdespino et al., 2015). The genus grows under a wide range of climate, soil, and light regimes (Korall & Kenrick, 2002).

For South America, the only treatment of *Selaginella* is that of Alston et al. (1981), where 133 species, including five subspecies and one variety, are recognized. That treatment contains a key to the taxa, species synonymy, a list of collectors and collectors' numbers, and descriptions for a few newly described taxa therein. However, the previously published *S. carinata* R.M. Tryon (Tryon, 1955), which is only the third known isophyllous (subg. *Tetragonostachys* Jermy) species in South America, is overlooked. Subsequently, new species of *Selaginella* were described for the continent, including one by Steyermark and Smith (1986), thirteen by Smith (1990), three by Valdespino (1992), four by Kessler et al. (2006), two by Valdespino (see Cremers & Boudrie, 2007, and Gibby, 2007), two by Valdespino (2015), and seven by Valdespino et al. (2015). Nine of the taxa treated by Alston et al. (1981) and one of the species described by Kessler et al. (2006) from South America, as well as one included in Alston (1934) for Trinidad and Tobago, are now known

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to be conspecific with other taxa (Table I). Also, according to Valdespino (2015), *S. arroyoana* M. Kessler & A. R. Sm. is doubtfully distinct from *S. cabrerensis* Hieron. Furthermore, *S. alampeta* M. Kessler & A. R. Sm. (holotype, *Kessler et al., 10101*, UC!) is also doubtfully distinct from *S. flexuosa* Spring. Nevertheless, *S. arroyoana* and *S. alampeta* are tentatively maintained here pending further studies. In addition, there are at least five other taxa synonymized in Alston et al. (1981) that deserve to be recognized as distinct species (Valdespino, unpubl. data). Taking into account previous discussion, it can be surmised that our knowledge of *Selaginella* diversity is still incomplete, particularly in tropical regions. Nevertheless, my current work on the genus involving study of herbarium material, especially type specimens, the review of published literature, and the description herein of *Selaginella boomii* allows me to preliminarily conclude that: a) currently there are 169 native *Selaginella* taxa from South America, b) of these, 164 are presently recognized and five await to be formally reinstated, and c) that this number will likely increase as work on *Selaginella* from South America continues, as pointed out by Valdespino et al. (2015) for Brazil.

In this paper, I describe *Selaginella boomii*, a previously overlooked species that grows on granite outcrops and boulders in forests and savanna areas in Venezuela, Guyana, Suriname, and Brazil. Following Jermy's (1986, 1990) infrageneric classification *Selaginella boomii* is placed in subg. *Stachygynandrum* (P. Beauv.) Baker based on its heteromorphic vegetative leaves and quadrangular strobili consisting of monomorphic sporophylls.

Material and methods

This study is based on examination of thirty collections, including 59 herbarium specimens from BM, F, GH, K, MG, MO, NY, PMA, UC, U, US, and VEN, and samples for Scanning Electron Microscopy (SEM) taken from selected collections to document upper and lower surfaces of stems and leaves, as well as spore morphology. The SEM samples were prepared following standard techniques as described by Valdespino (1995) and viewed and photographed at different magnifications using a Zeiss Model Evo 40 SEM at 20 KV. Digitized SEM images were post-processed with Adobe Photoshop to adjust contrast, make the background black, and to be assembled in multipart figures.

The terminology used to describe vegetative and fertile leaves follows Valdespino (2015) and Valdespino et al. (2015). The measurements of leaves were made as explained in Valdespino et al. (2014). Likewise, spore measurement methods and description of their sculpturing patterns follows Valdespino (1995), Valdespino et al. (2014), and Valdespino et al. (2015), complemented by terminology found in Punt et al. (2007) and Hesse et al. (2009).

Conservation status was assessed according to the IUCN Red list Categories and Criteria version 3.1, second edition (IUCN, 2012).

Taxonomic Treatment

Selaginella boomii Valdespino, **sp. nov**. Type: Venezuela. Bolívar: Distrito Cedeño, vicinity of Panare village of Corozal, 6 km from Maniapure toward Caicara, 06°55'N,

TABLE I
CONTRIBUTION TOWARDS AN UPDATED SYNONYMY FOR *SELAGINELLA* IN SOUTH AMERICA (ONLY SYNONYMS PUBLISHED SINCE ALSTON ET AL. [1981] ARE INCLUDED HEREIN; ACCEPTED TAXA ARE IN BOLD).

Synonym	Accepted taxa	Reference
S. anisoclada Alston et al.	***S. popayanensis*** Hieron.	Mickel et al., 2004
S. arenaria Baker	***S. brevifolia*** Baker	Valdespino, 2015
S. bahiensis Spring subsp. *manauscensis* Bautista	***S. palmiformis*** Alston et al.	Valdespino et al., 2015
S. chiquitana M. Kessler et al.	***S. arroyoana*** M. Kessler & A. R. Sm.	Huaylla et al., 2010
S. cladorrizans A. Braun	***S. tenella*** (P. Beauv.) Spring	Mickel et al., 2004
S. cruegeri Jenman	***S. minima*** Spring	Mickel et al., 2004
S. duidae A. C. Smith	***S. scalariformis*** A. C. Smith	Smith, 1995
S. fragillima A. Silveira	***S. vestiens*** Baker	Valdespino et al., 2015
S. scintillata Alston	***S. roraimensis*** Baker	Smith, 1995
S. tarapotenis Baker	***S. flexuosa*** Spring	Mickel et al., 2004
S. valdepilosa Baker subsp. *tricholoma* Jermy & Rankin	***S. rhodostachya*** Baker	Smith, 1995

66°30'W, 400 m, 15 Apr 1986, *B. Boom & M. Grillo 6510* (holotype: NY; isotypes: MYF-n.v.?, PMA, VEN). (Figs. 1, 2)

Selaginella boomii is similar to *S. roraimensis* Baker because they both have a suberect to erect habit, rhizophores along proximal half of the stems, and lateral leaves that may be ascending with the basiscopic margins usually revolute. However, *S. boomii* is different because it has median leaves with long-aristate (vs. acuminate to short-aristate) apices, each arista 1/3 to 1/2 (vs. acumen or arista 1/8) the length of the lamina, which have teeth-like or prickle projections on its upper surface (vs. glabrous), the broad hyaline [in a band (2–) 4–6 cells wide] and short-ciliate margins (vs. the outer margins chlorophyllous and entire and the inner margins weekly hyaline, in a band 1 or 2 cells wide, and entire or dentate margins), the lateral leaves acute (vs. obtuse) with the acroscopic margins usually distinctly hyaline (vs. greenish), short-ciliate (vs. entire or dentate), axillary leaves lanceolate (vs. ovate to ovate-elliptic) with margins broad hyaline (vs. greenish) and short-ciliate along proximal 1/2 (vs. dentate or entire), and acute (vs. broadly acute to obtuse) apices.

Plants epipetric. *Stems* suberect to erect, stramineous or reddish, 5–20 cm long, 0.4–1.2 mm diam., exarticulate, not flagelliform or stoloniferous, 2- or 3-branched. *Rhizophores* axillary to axillary-ventral or occasionally dorsal, along proximal 1/2 of the stems, filiform to stout, 0.2–0.6 mm diam. *Leaves* heteromorphic, membranaceous. *Lateral leaves* distant, spreading to ascending, lanceolate-oblong or ovate-oblong, 1.3–2.5 × 0.5–1.2 mm; bases rounded to subcordate, acroscopic bases overlapping the stem, basiscopic bases free from the stem; acroscopic margins hyaline in a band 2–6 cells wide, the cells elongate and papillate parallel to margins, papillae in a single row over each cell lumen, short-ciliate (0.05–0.10 mm) along proximal 1/3–1/2, otherwise denticulate distally, basiscopic margins greenish, often revolute, short-ciliate (0.05–0.10 mm) along proximal 1/8–1/6, otherwise denticulate to entire; apex acute, ending in 2–4 teeth; both surfaces usually glabrous or upper surfaces sometimes with submarginal short teeth-like or prickle projections along distal and proximal regions of basiscopic margins, upper surfaces comprising obscurely (because of waxy deposit) rounded to quadrangular, sinuate-walled and papillate cells, papillae 1–4 over each cell lumen, without stomata or idioblasts or sometimes with submarginal to marginal stomata along basiscopic half, lower surfaces mostly comprising elongated, sinuate-walled cells with some straight-walled, papillate idioblasts on both sides of the midribs and at the bases, the papillae in 1 or 2 rows over each cell lumen, with stomata along midribs. *Median leaves* distant to imbricate specially near apical region of branches and main stem, ascending, ovate-deltate, 0.7–1.5 × 0.5–1.2 mm; bases truncate and glabrous or, occasionally, with 2–11 caducous short-hairs; margins greenish along proximal 1/4–1/3, broadly hyaline along apical 3/4–2/3 and more so on outer margins, in a band 2–6 cells wide, the cells elongate and papillate parallel to margins, papillae in a single row over each cell lumen, serrulate to short-ciliate (0.05 mm); apices aristate, arista 0.2–0.5 mm, tipped by 2 or 3 teeth and with teeth-like or prickle projections along its length on upper surfaces; both surfaces of laminae glabrous without idioblasts, upper surfaces comprising obscurely (because of waxy deposit) rounded to quadrangular, sinuate-walled cells, many of these papillate, papillae 1–4 over each cell lumen, with stomata along distal 2/3 of midribs, lower surfaces comprising elongated, sinuate-walled cells, without stomata. *Axillary leaves* lanceolate or lanceolate-ovate, margins broadly hyaline, otherwise similar to lateral leaves. *Strobili* terminal on branch tips, one per branch, quadrangular, 2.0–10 mm long. *Sporophylls* monomorphic, without a laminar flap, ovate, 0.6–1.2 × 0.4–0.7 mm, each with a slightly developed keel apically with teeth-like or prickle projections along midribs on upper surfaces; bases rounded; margins hyaline, dentate; apices acuminate to aristate, acumen (arista) 0.2–0.4 mm with teeth-like or prickle projections on upper surfaces; both surfaces glabrous without conspicuous idioblasts; *dorsal sporophylls* with upper surfaces green and cells as in median leaves, except for the half that overlaps the ventral sporophylls, there hyaline with elongate and papillate, slightly sinuate-walled cells, lower surfaces silvery-green and comprising elongate, sinuate-walled cells; *ventral sporophylls* with both surfaces hyaline to greenish and comprising elongate, sinuate-walled cells. *Megasporangia* in 2 ventral rows; *megaspores* deep yellow to lemon yellow, with a slightly developed equatorial flange, slightly rugulate-reticulate to rugulate-granulate with echinulate and perforate microstructure on proximal and distal faces or with

a strongly developed equatorial flange, coarsely rugulate-reticulate with spheroid to spheroid-perforate microstructure on proximal and distal faces, 200–260 μm diam. *Microsporangia* in 2 dorsal rows; *microspores* deep orange, verrucate-gemmate with striate-foveolate microstructure on proximal faces, rugulate-gemmate with psilate-foveolate microstructure on distal faces, 20–30 μm diam.

Habitat and distribution.—Exposed or shaded, moist granitic outcrops and boulders in semideciduous to dry forests and savannas at 70–1760 m; found in Venezuela, Guyana, Suriname, and Brazil.

Etymology.—This species is named after Brian Boom (1954–), a staff scientist at The New York Botanical Garden who is a recognized specialist in Neotropical Rubiaceae and collector of the type and two additional specimens of this new taxon.

Conservation status.—This species is distributed in various countries and the number of collections available over a wide distributional range makes me conclude it is not under conservation threat. Therefore, it is categorized as of Least Concern (LC), according to IUCN Criteria (2012).

Additional specimens examined. VENEZUELA. Amazonas: Atabapo, Planicie del Río Jénita, 15 km antes de la desembocadura en el Río Ocamo, 02°46'N, 64°52'W, 175 m, Feb 1990, *Fernández 7205* (NY); Atures, 0–1.5 km E of Río Coro-Coro, W of Serranía de Yutaje, 4 km N of settlement of Yutaje, 05°40'N, 66°07'30"W, 270 m, 20 Feb 1987, *Liesner & Holst 21265* (MO, UC), Río Coro-Coro, W of Serranía de Yutaje, 6–8 km N of settlement of Yutaje, 05°41'N, 66°07'30"W, 320 m, 23 Feb 1987, *Liesner & Holst 21339* (MO, UC), E slope of unnamed peak, 8 km NW of settlement of Yutaje, 4 km W of Río Coro-Coro, W of Serranía de Yutaje, 05°41'N, 66°10'W, 1500–1760 m, 4 Mar 1987, *Liesner & Holst 21643* (MO, UC); Raudales de Atures, 10 km S of Puerto Ayacucho, downstream on Río Orinoco, 05°35'N, 67°34'W, 175 m, 6 Sep 1985, *Steyermark et al. 131444* (MO, UC); road Pte. Cataniapo-Gavilán, 20–25 km SE of Puerto Ayacucho, 90 m, *Maas & Huber 5111* (NY, U, VEN), 12.5 km S of Puerto Ayacucho, 70 m, 1 Nov 1971, *Davidse 2804* (MO, UC), 20 km S of Puerto Ayacucho, 2 Nov 1971, *Davidse 2848A* (BM, MO, NY, UC), 9 km S of Puerto Ayacucho on road to Samariapo, 100 m, 28 Jun 1975, *Gentry & Berry 14471* (MO, UC), along road from Puerto Ayacucho to Sanariapo, near crossing with Río Cataniapo, ca. 05°35'N, 67°36'W, 31 Jul 1967, *Wessels Boer 1919* (U, VEN); Río Metacuni, faldas de tepuy-altiplanicie Sedukerana, 03°15'N, 64°56'W, 210–650 m, 28 Jan 1990, *Stergios & Velazco 14366* (MO, VEN). **Bolívar**: Cedeño, vicinity of Panare village of Corozal, 6 km from Maniapure toward Caicara, 06°55'N, 66°30'W, 400 m, 12 Oct 1985, *Boom & Grillo 6346* (MO, MYF-n.v.?, NY, UC), Minería El Guaniamo, 06°27'N, 65°52'W, 300 m, May 1993, *Díaz 1842* (NY, VEN); 1 km S of Quebrada La Flore, affluent of Río Ore, affluent of Río Parguaza, 06°17'N, 67°05'W, 85 m, 9 Sep 1985, *Steyermark et al. 131620* (MO, UC); km 103 road Caicara-Pto. Ayacucho, Serranía La Cerbatana, 07°00'N, 66°30'W, 100–250 m, 5 Nov 1985, *van der Werff & Holst 7764* (MO, NY, UC); Río Canaracuni, entre Canaracuni y La Boca, 04°30'N, 63°42'W, 13–26 Apr 1988, *Stergios 11952* (PORT-n.v., NY); Río Parguaza, Raudal Maraca, ca. 110 river km from mouth, 115 m, 31 Dec 1955, *Wurdack & Monachino 41059* (GH, NY, PMA, UC).

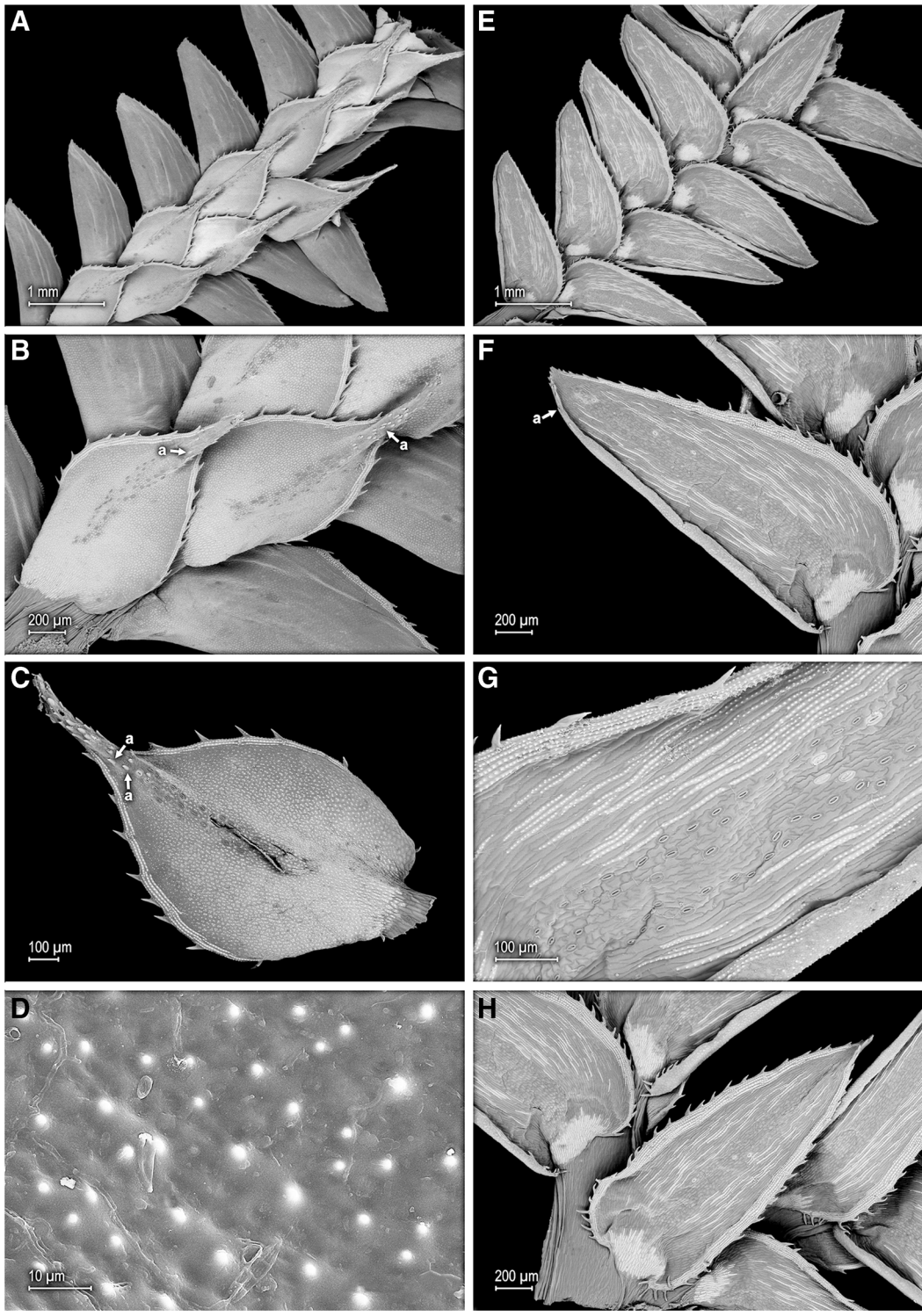
GUYANA. Upper Mazaruni River region, Karowtipu Mountain, 05°45'N, 60°35'W, 920–1080 m, 24 Apr 1987, *Boom & Gopaul 7709* (NY).

SURINAME. Mount Bakhuis between rivers [inter flum.] Kabalebo and Coppename Sinistrum [Left], track from Kabalebo-airstrip to the S (3.5–6 km), 200–450 m, 19 Dec 1964, *Florschütz & Mass 2452* (U).

BRAZIL. Amazonas: Río Negro, between Manaus and São Gabriel, Serra Curicuriari, 00°20'S, 66°50'W, 10 Jul 1979, *Poole 1948* (mixed coll., *1948b* at NY), Morro dos Seis Lagos, ca. 80 km N of São Gabriel, 00°20'N, 66°45'W, ca. 100 m, 18 Jul 1979, *Poole 2068* (NY-2 sheets), São Gabriel da Cachoeira, Mt. Morro des Seis Lagos, Lago No. 2, 00°12'N, 66°00'W, 15 Oct 1987, *Stevenson et al. 702* (NY, PMA); vicinity of Pico Rondon, Perimetral Norte Highway km 211, 3 km from km 211, lower slopes of Pico Rondon, 01°32'N, 62°48'W, 2 Feb 1984, *Prance et al. 28723* (NY). **Pará**: Serra do Cachimbo, 425 m, 14 Dec 1956, *Pires et al. 6231* (NY-2 sheets); Conceição do Araguaia, range of low hills ca. 20 km W of Redenção, nearm Córrego São João and Troncamento Santa Teresa, ca. 08°03'S, 50°10'W, 350–620 m, 9 Feb 1980, *Plowman et al. 8563* (F, GH, MG, NY, US). **Rondônia**: Ariquemes, Alto Condeias, on land of Mibrasa Tin Mine, 10°35'S, 63°35'W, 200 m, 17 May 1982, *Fife et al. 4183* (NY, UC), 128 km SW of Ariqueaes [Arequimes] at Mibrasa Mining Camp, 5 km SE of camp office, 18 May 1982, *McFarland et al. 213* (NY, US), Arequimes, Mineração Mibrasa, Sector Alto Candeias, km 128, 10°35'S, 63°35'W, SE de Arequimes, 17 May 1982, *Teixeira et al. 550* (K, NY); Porto Velho, Represa Samuel, 09°04'S, 63°15'W, *Thomas et al. 5195* (NY). **Goiás [Tocantins]**: Presidente Kennedy, road from Hwy BR–153 to Itaporã, 12 km W of Village Presidente Kennedy, Fazenda Primavera along Ribeirão Feínho, ca. 03°25'S, 48°37'W, 400–500 m, 1 Feb 1980, *Plowman et al. 8232* (NY).

Fig. 1. *Selaginella boomii*. **A**. Section of upper surface of stem. **B**. Upper surface of median leaves; note: teeth-like or prickle projections along apex (a). **C**. Upper surface of median leaf; note: teeth-like or prickle projections along apex (a). **D**. Close-up upper surface of median leaf showing bright papillae over each cell lumen. **E**. Section of lower surface of stem. **F**. Lower surface of lateral leaf; note: submarginal tooth-like or prickle projection (a). **G**. Close-up of lower surface of lateral leaf showing elongate, straight-walled, papillate cells on both sides of central stomata. **H**. Axillary leaf and basal portions of lateral leaves (lower surface view). (A–H from *Fife et al. 4183*, NY.)

Selaginella boomii is characterized by suberect to erect habit, lateral leaves with acroscopic margins plane, conspicuously hyaline on upper surfaces, in a band 2–6 cells wide, with the cells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elongate and papillate parallel to margins, and basiscopic margins strongly revolute, often with submarginal to marginal stomata and submarginal teeth-like or prickle projections, median leaves conspicuously hyaline along distal 3/4–2/3 on upper surfaces, with aristate apices that have teeth-like or prickle projections on its upper surfaces, upper surfaces of median and lateral leaves with 1–4 papillae over each cell lumen, deep yellow to lemon yellow megaspores, and axillary or axillary-ventral rhizophores. These characters may vary slightly; for example, in *Poole 1948b* (NY) the acroscopic margins of the lateral leaves tend to be revolute (vs. plane), comprising greenish (vs. hyaline) elongate cells on the upper surfaces almost without papillae (vs. papillate), and with submarginal stomata.

Additionally, in *Poole 1948b*, the proximal and distal faces of the megaspores are coarsely rugulate-reticulate and the equatorial flange is strongly developed. Both faces have spheroid to spheroid-perforate microstructure (vs. proximal and distal faces slightly rugulate-reticulate to rugulate-granulate with a slightly developed equatorial flange with echinulate and perforate microstructure in *Thomas et al. 5195*, NY).

Variations in acroscopic marginal cells and margin types may be environmentally conditioned, and could respond to factors such as light/shade and humidity growing conditions, whereas the degree of revoluteness of the acroscopic margins could be caused by the specimen drying processing technique employed. The variation observed in the sculpturing of the megaspores might be related to their degree of maturity and turgency as noted by Hesse et al. (2009) for pollen grains. An alternative, explanation is that some degree of speciation may be taking place that warrants further genetic research; however, until this is carried out, the variation described for *Poole 1948b* is, at this point, considered within the natural variation of *S. boomii*. Another variation noted consists on the presence of dorsal rhizophores in one specimen (*Fife et al. 4183*, NY), in addition to axillary and axillary-ventral ones. Dorsal rhizophores are found characteristically in articulate species of *Selaginella*; however they do sometimes occur in other taxa not related to that group such as the newly described herein.

In the past, some herbarium specimens of *Selaginella boomii* were determined as *S. cabrerensis* Hieron., a member of the *S. xiphophylla* Baker group (see Valdespino, 1993b). The latter species is found in Colombia, French Guiana, Brazil, and Bolivia. *Selaginella boomii* has also been confused with *S. roraimensis* from Venezuela and Guyana. *Selaginella boomii* differs most conspicuously from *S. cabrerensis* by its suberect to erect (vs. creeping) stems, median leaves ovate-deltate (vs. lanceolate-ovate) with each arista 1/3 to 1/2 (vs. acumen or arista at most 1/4) the length of the lamina, and the lateral leaves lanceolate-oblong and spreading to ascending and with the basiscopic margins strongly revolute (vs. ovate-oblong, tending to clasp the stem and with straight basiscopic margins). *Selaginella boomii* and *S. roraimensis* are comparable in their habit, rhizophores distribution along the stems, and orientation of lateral leaves with similar basiscopic margins, but they differ from each other by the characters discusses in the diagnosis. *Selaginella boomii* is further distinguished from *S. roraimensis* by having deep yellow to lemon-yellow (vs. light yellow) megaspores.

Fig. 2. *Selaginella boomii*. **A**. Megaspore proximal face. **B**. Close-up of megaspore proximal face surface. **C**. Megaspore distal face. **D**. Close-up of megaspore distal face surface. **E**. Microspore proximal face. **F**. Close-up of microspore proximal face surface. **G**. Microspore distal face. **H**. Close-up of microspore distal face surface. (A–H from *Thomas et al. 5195*, NY).

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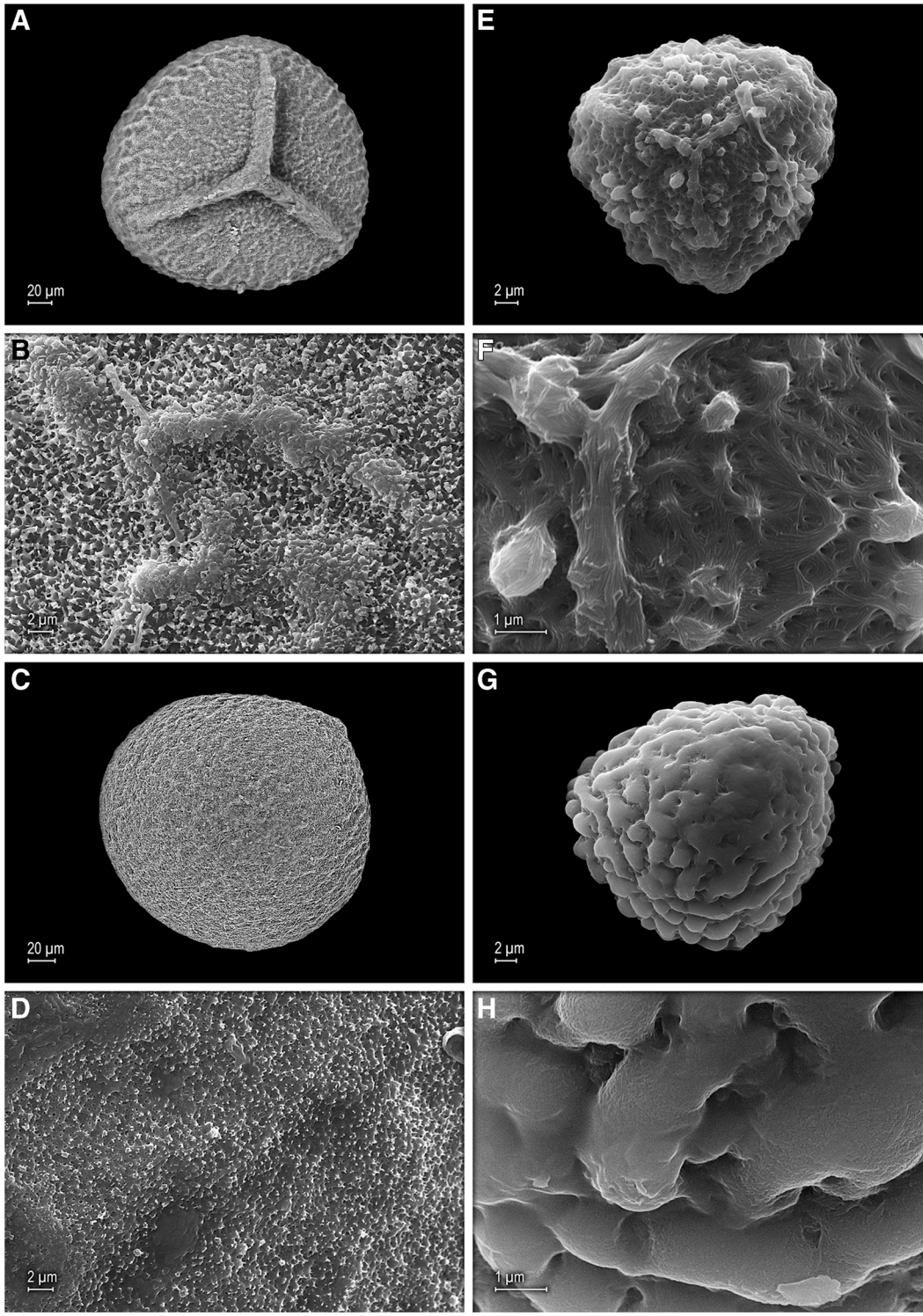
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