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A taxonomic revision of the genus *Selaginella* (Selaginellaceae) from Nepal

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Abstract

The present paper deals with the taxonomy of *Selaginella* from Nepal based on the examination of herbarium collections housed in major herbaria of Europe and Asia (with additional collections from virtual herbaria). A total of 25 species are recognised here, while *Selaginella trichophylla* and *S. laxistrobila* are two new records for the flora of Nepal, India (Sikkim) and Bhutan; *Selaginella monospora* var. *ciliolata* is synonymised to *S. trichophylla*; detailed descriptions, distribution and ecology and IUCN conservation status assessments (based on literature) are presented. For most of the species, illustrations of the leaves and strobili are provided for identification of the morphologically similar taxa.

Keywords

Lycophytes, Nepalese flora, new records, taxonomy

Introduction

Selaginella P. Beauv. is the largest genus of lycophytes, with more than 700 species distributed all over the world but with highest diversity in the tropics (Jermy 1986, Zhou et al. 2015, PPG I 2016, Weststrand and Korall 2016). The Himalaya is one of the diversity centers of ferns and lycophytes of the World. Alston (1945) published the first account of Indian (including Nepalese) *Selaginella* P. Beauv. Earlier Don (1824), in his "Prodromus Florae Nepalensis", described seven species in *Lycopodium* L., including species of heterosporus *Selaginella*. Thapa (2002) listed 23 species of *Selaginella*. Fraser-Jenkins et al.'s (2015) revision of Nepalese *Selaginella* also recognised 23 species.

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The purpose of our study was to revise the taxonomy of the genus *Selaginella* of Nepal, providing a taxonomic treatment with diagnostic keys by macro-morphological characters.

Material and methods

This study was based on materials deposited at the following herbaria: AAU, B, BM, E, GH, K, KATH, KUN, KYO, L, P, PE, TI and US (herbarium acronyms follow Thiers 2019). Images of type specimens of all species from Nepal and neighboring countries were studied by accessing those at E (http://data.rbge.org.uk/herb), K (http://apps.kew.org/herbcat/gotoHomePage.do), P (https://science.mnhn.fr/all/search), B (http://ww2.bgbm.org/herbarium/default.cfm), GH (https://huh.harvard.edu/collections/gray.html), US (http://collections.si.edu/search/results.htm), L (https://bioportal.naturalis.nl) and JSTOR Global Plants project database (https://plants.jstor.org). It is worth noting that part of the collections from Edinburgh Botanic Garden (E) and British Natural History Museum (BM) were borrowed and carefully examined in the Herbarium PE (Beijing). About 350 herbarium specimens, including types for most species associated with taxonomy of *Selaginella* from Nepal, and many photos of the herbarium collections from KYO and TI provided by Mr. C.R. Fraser-Jenkins, were checked.

Morphological characters, such as ventral (lateral), dorsal (median) and axillary leaves were carefully observed. The morpho-photographs of the plants were taken with a Nikon DXM 1200F camera connected to a stereomicroscope (Nikon SMZ 1000) and computer and measurement was done by D 3.10 (http://www.nikoninstruments.com).

Descriptions of the species follow the form of Zhang et al. (2013), with minor changes, and were prepared based on examined dried herbarium specimens from Nepal and neighboring countries. IUCN categories (IUCN 2001) are based on published data/assessments following Fraser-Jenkins et al. (2015).

The distribution information was gathered from herbarium specimens, and literature.

Taxonomic treatment

Key to species of *Selaginella* from Nepal

1 Sporophylls monomorphic.....**2**
– Sporophylls dimorphic.....**11**
2 Leaves dimorphic or slightly dimorphic.....**3**
– Leaves monomorphic, spirally arranged on all sides of stem and branches, linear-lanceolate..... **1. *S. indica***
3 Rhizophores restricted to base of stem, forming thick massive rootstock.....**4**
– Rhizophores at intervals throughout creeping stem and branches or in basal part..... **5**

4 Main stems branched near and above base, rosette plants, xerophytic .... **2. *S. pulvinata***

– Main stems branched from near middle part, not rosette plants, xerophytic ... . **3. *S. bryopteris***

5 Stems and branches cylindrical, often reddish, sterile leaves not obviously dimorphic, or almost monomorphic, adpressed to stems and branches **6**

– Stems and branches cylindrical, not reddish, sterile leaves dimorphic 7

6 Leaves ciliolate at margin ..... **4. *S. adunca***

– Leaves entire or slightly denticulate at margin ..... **5. *S. aitchisonii***

7 Plants with creeping subterranean rhizome and stolons **8**

– Plants with rhizophores at intervals throughout length of main stem, borne on ventral or dorsal side in axils of branches **9**

8 Plants 50–100 cm long, main stem erect, leaves ciliate at base .... **6. *S. fulcrata***

– Plants up to 16–65 cm, leaves denticulate with false vein on each side of mid-vein ..... **7. *S. involvens***

9 Rhizophores borne on ventral side in axils of branches, ventral and dorsal leaves ovate, margin dentate-serrulate ..... **8. *S. pallida***

– Rhizophores borne on dorsal side in axils of branches **10**

10 Stem articulate, ventral leaves ovate-lanceolate ..... **9. *S. remotifolia***

– Stem not articulate, ventral leaves oblong-lanceolate ..... **10. *S. semicordata***

11 Strobili cylindrical or rather lax **12**

– Strobili dorsiventrally complanate **14**

12 Strobili cylindrical, sporophylls monomorphic ..... **11. *S. helvetica***

– Strobili not cylindrical, sporophylls rather lax, often forked **13**

13 Plants to 25 cm long, ventral leaves ovate, ovate-triangular or ovate-lanceolate, margin denticulate ..... **12. *S. pallidissima***

– Plants to 6 cm high, ventral leaves ovate-triangular, margin ciliolate .... **13. *S. laxistrobila***

14 Apex of dorsal leaves mucronate or aristate, arista curved **15**

– Apex of dorsal leaves acuminate or aristate **16**

15 Apex of dorsal leaf aristate, arista curved, up to 1/2–4/5 as long as leaf, margin sparsely ciliolate; ventral leaves oblong, apex apiculate, margin ciliolate or denticulate ..... **14. *S. bisulcata***

– Apex of dorsal leaf arista, up to 1/2–3/4 as long as leaf; ventral leaves oblong or oblong-ovate, apex acute or apiculate, margin sparsely shortly ciliolate .... **15. *S. pennata***

16 Main stems tuberous at base ..... **16. *S. chrysocaulos***

– Main stems not tuberous at base **17**

17 Sporophylls at margin long ciliate ..... **17. *S. ciliaris***

– Sporophylls at margin dentate, or not long ciliate **18**

18 Plants creeping **19**

– Plants sub-erect or creeping **20**

19 Plants long creeping, ventral leaves ovate-triangular or oblong-falcate, margin denticulate; dorsal leaves ovate-lanceolate or elliptic, margin denticulate, apex acuminate or shortly aristate ..... **18. *S. monospora***
– Plants long creeping, ventral leaves ovate-triangular, margin ciliolate, dorsal leaves ovate, margin ciliolate, apex aristate ..... **19. *S. trichophylla***
20 Plants creeping..... **21**
– Plants sub-erect or ascending **22**
21 Plants ascending from decumbent base, leaves on main stems rather approximate, base of ventral leaves long ciliolate; axillary leaves ovate or ovate-lanceolate, margin shortly ciliolate..... **20. *S. repanda***
– Plants up to 10 cm, creeping, fertile stems erect, leaves on main stems and branches distant, margin denticulate in basal half, elsewhere subentire, or very ciliolate at base; axillary leaves ovate-triangular, margin ciliolate in basal half, elsewhere subentire ..... **21. *S. vaginata***
22 Plants c. 15 cm long, acroscopic base of ventral leaves dentate **23**
– Plants more 15 cm long, acroscopic base of ventral leaves dentate or dentate-ciliolate **24**
23 Apex of dorsal leaves shortly cuspidate ..... **22. *S. chrysorrhizos***
– Apes of dorsal leaves not cuspidate.....**23. *S. reticulata***
24 Ventral leaves ovate to ovate-lanceolate, acroscopic base ciliate-dentate, auriculate at base; dorsal leaves ovate, base obtuse or slightly subcordate, margin ciliolate to denticulate..... **24. *S. subdiaphana***
– Ventral leaves ovate, acroscopic base denticulate, base cordate, dorsal leaves ovate, base subcordate, margin minutely dentate.....**25. *S. tenuifolia***

***Selaginella indica* (Milde) R.M. Tryon**
Figs 1(1A–C), 9A, 12

Selaginella indica R.M. Tryon, Ann. Missouri Bot. Gard. 42: 52, f. 23, map 32. 1955; Dixit 1992; Zhang 2001; Thapa 2002; Zhang 2004; Zhang et al. 2013; Fraser-Jenkins et al. 2018.
(*Selaginella rupestris* f. *indica* Milde, Fil. Eur. Atlan.: 262. 1867, nom. nud.).
≡ *Bryodesma indicum* (R.M. Tryon) Soják, Preslia 64(2): 154. 1992. **Type.** INDIA. Khasia 5000 ft., *Hooker fil. & Thomson* (holotype: GH [00022087]; isotypes: NY [00127400]; P [00279924]; YU [000626]).
= *Selaginella emodi* Fraser-Jenk., Ferns Fern-Allies Nepal 1: 67. 2015. **Type.** NEPAL. Central Nepal, Rasuwa District, on path leading up from Dhunche to Chandanbari and Gossainkund, c. 3 km above and E. of Dhunche, N. of Trisuli Bazaar, Rasuwa District, N. of Kathmandu, rocky pathside tussocks of grasses etc. beneath cliff, 2 XII 2004. *C. R. Fraser-Jenkins 30915* (holotype: TAIF).
– *Selaginella wightii* auct. non Hieron.: Panigrahi and Dixit 1968.
– *Selaginella vardei* auct. non H. Levl.: Ching & Wu, Fl. Xizang. 1: 19, p.p. excl. figure. 1983; H.S. Kung 1988; K.H. Shing 1993.

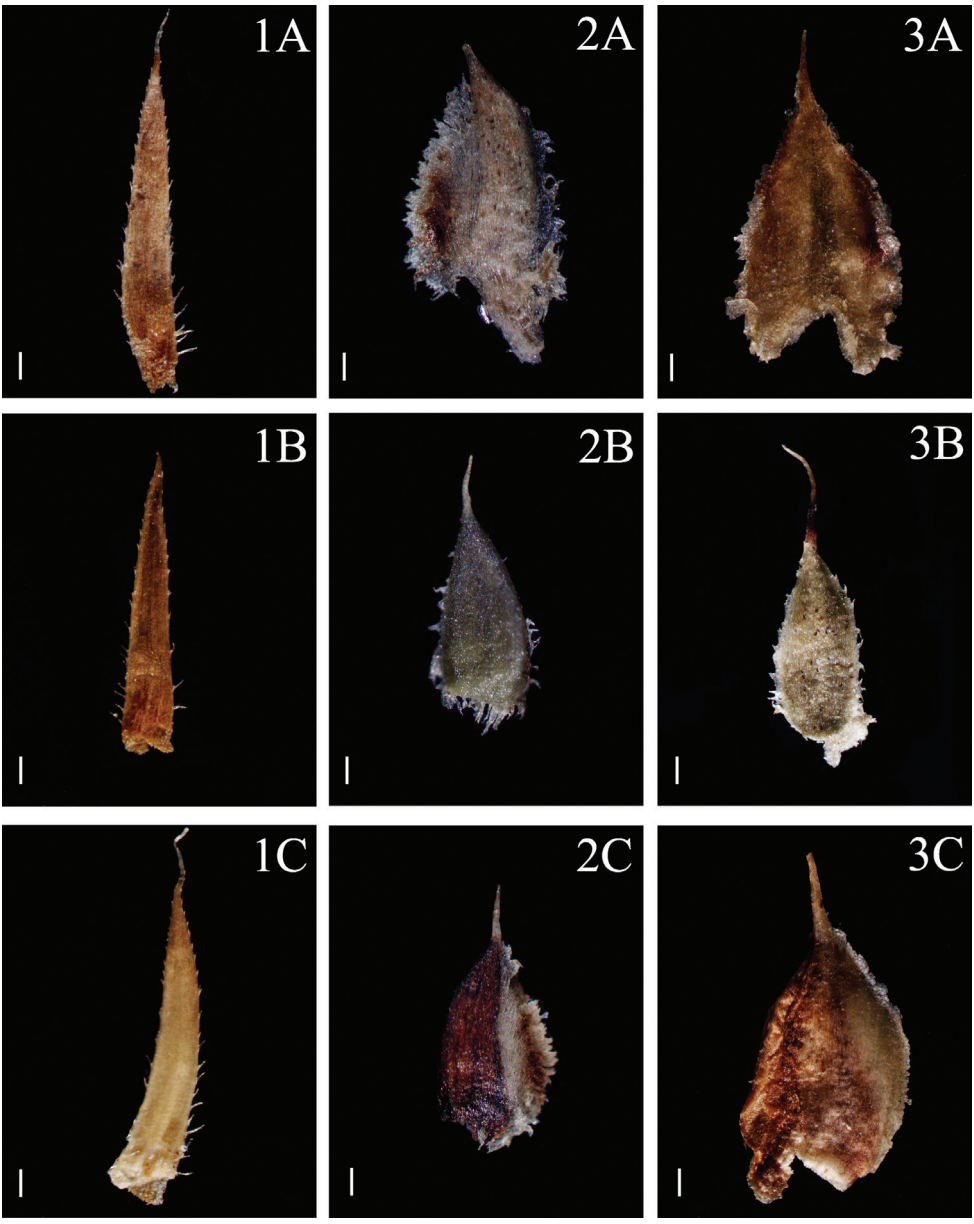

Figure 1. Morphological diversity of the leaves of Nepalese *Sealginella* species: **1A–C** *S. indica* (*Nakaike 1325*, PE) **2A–C** *S. pulvinata* (*Tabata* et al. *3520*, PE) **3A–C** *S. bryopteris* (*Tabata* et al. *11989*, PE). A – Axillary leaves, B – Dorsal leaves, C – Ventral leaves. Scale bars: 0.2 mm.

– *Selaginella longipila* auct. non Hieron; Alston 1945; Tryon 1955; Dixit 1992.

Description. Stems 5–15 cm, creeping. Rhizophores at intervals throughout the length of the creeping stem and branches, borne on dorsal side in axils of branches, densely hairy. Main stems anisotomously branched throughout, strongly dorsi-ventral in posi-

tion, glabrous. Lateral branches arranged on main stem 0.5–1 cm apart, second branches simple or forked. Leaves spirally arranged on all sides stem and branches, more or less isomorphic, long linear-lanceolate, 0.8–2.3 mm excluding seta, 0.3–0.5 mm wide, margin shortly ciliolate, apex acuminate, in apex with long apical seta c. 1/5 as long as leaves. Strobili solitary on erect branchlets, tetragonal, 5–25 × 1.5–2 mm. Sporophylls monomorphic, ovate-triangular or ovate-lanceolate, margin ciliolate, apex acuminate. Megaspores pale-orange, surface rugose; microspores deep yellow, surface rugose to reticulate.

Ecology. Epilithic, xerophytic, summer-green, in dry areas, forming clumps on moss covered rocks. Alt. 1350–2800 m.

Distribution in Nepal. W, C, E.

Nepalese threatened status: NT (Fraser-Jenkins et al. 2015).

General distribution. CHINA (Sichuan, Xizang, Yunnan), INDIA (Andhra Pradesh, Chhattisgarh, Jharkhand, Karnataka, Madhya Pradesh, Meghalaya, Odisha, Tamil Nadu, Uttarakhand, West Bengal).

Chromosome number. not available data.

Selected specimens examined:

W Nepal: DARCHULA: "Nakarigad-Khandeswori, on mossy slope in open pine forest, alt. 1650 m, 18 Jul 1984, *P.R. Shakya*, *M.K. Adhikari*, *M.N. Subedi 7882*" (KATH).

C Nepal: RASUWA: "between Lama Hotel and Sharpugaon, alt. 2600–2800 m, 3 Sep 1986, *T. Nakaike 1325*" (PE).

E Nepal: TAPLEJUNG: "Takhtem to Chautara, 1350 m, 12 May 1992, *N. Acharya 9255056*", (KATH).

***Selaginella pulvinata* (Hook. & Grev.) Maxim.**

Figs 1(2A–C), 13

Selaginella pulvinata (Hook. & Grev.)Maxim., Mém. Acad. Imp. Sci. Saint Pétersb. (Sér. 7) 9: 335. 1859; Dixit 1992; Thapa 2002; Zhang 2004; Zhang et al. 2013; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.

≡ *Lycopodium pulvinatum* Hook. & Grev., Hooker's J. Bot. Kew Gard. Misc. 2: 381. 1831.

≡ *Selaginella tamariscina* var. *pulvinata* (Hook. & Grev.) Alston, Bull. Fan Mem. Inst. Biol., Bot. 5(6): 271. 1934.

(*Selaginella pulvinata* (Hook. & Grev.) Hand.-Mazz., Symb. Sin. 6: 5. 1929, later isonym).

≡ *Lycopodioides pulvinata* (Hook. & Grev.) H.S. Kung, Fl. Sichuanica 6: 64, t. 18, f. 1–3. 1988. **Type.** INDIA. E. India, Kamoon. *Dr. Wallich* s.n. (holotype: K).

Description. Stems 2–15(–20) cm, many forming rosette at top of thick rootstock, branched from base. Main stems branched near and above base, primary branches pinnately branched, second branches 2–3 forked, stramineous or brown, main stem c. 1 mm in diam. at lower part. Axillary leaves ovate to triangular, c. 2.5 × 1 mm,

base exauriculate, margin lacerate-ciliolate, apex acute. Ventral leaves ovate, 2.9–3.2 × 1.4–1.5 mm, rotundate-cordate at base, margin lacerate, apex acuminate. Dorsal leaves ovate, 2.8–3.1 × 0.9–1.2 mm, base truncate, entire to obscurely denticulate, posterior side thickened, apex aristate. Strobili solitary, terminal, compact, tetragonal, 7–15(–20) × 1.5–2 mm. Sporophylls monomorphic, ovate, at base cordate, margin slight denticulate, apex acuminate. Megaspores white-yellow, surface verrucate; microspores yellow, surface irregularly papillate.

Ecology. Terrestrial or epilithic, xerophytic. Alt. 1800–4400 m.

Distribution in Nepal. W.

Nepalese threatened status: EN (Fraser-Jenkins et al. 2015).

General distribution. CHINA (Chongqing, S Gansu, Guangxi, Guizhou, Hebei, Henan, Liaoning, Shaanxi, Shanxi, Sichuan, Xizang), INDIA (Uttarakhand), KOREA, MONGOLIA, RUSSIA (Siberia), THAILAND, VIETNAM.

Chromosome number. not available data.

Selected specimens examined:

W Nepal: BAJHANG: "Bauligad, on open rock, rooting on crevices, alt. 1830 m, 6 Jul 1980, *P.R. Shakya*, *L.R. Sharma*, *K.R. Amatya 6328*" (KATH).

DOLPA: "between Besagad and Shahartara, 14 Sep 1976, *H. Tabata*, *K.R. Rajbhandari*, *Y. Shimizu 3520*" (PE).

***Selaginella bryopteris* (L.) Baker**

Figs 1(3A–C), 9B, 14

Selaginella bryopteris (L.) Baker, J. Bot. 22(Za): 376. 1884; Iwatsuki 1988; Dixit 1992; Thapa 2002; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.

≡ *Lycopodium bryopteris* L., Sp. Pl. 2: 1103. 1753.

≡ *Lycopodioides bryopteris* (L.) Kuntze, Revis. Gen. Pl. 1: 825. 1891. **Type.** (lectotype, designated by Mazumdar 2017). Dillenius (1741), Historia Muscorum. P. 472, t. 66, f. 11 [icon.] (fig. 1). **Epitype.** (designated by Mazumdar 2017): INDIA. Jharkhand: Deoghar, Trikut Hills, 365.76 m. 11 X 1999. *J. Mazumdar 72* (CAL).

= *Lycopodium circinale* L., in Murray, Syst. Veg. ed 13: 794. 1774.

= *Lycopodium imbricatum* Roxb., in Griff., Calc. J. Nat. Hist. 4: 475. 1844; non Forssk. 1775; Thapa 2002.

≡ *Selaginella imbricata* (Roxb.) J. Scott, J. Agr. Hort. Soc. India, n. s. 2: 260. 1868. (*Lycopodium imbricatum* Roxb., Hort. Bengal.: 75. 1814, nom. nud.).

Description. Stems 5–25 cm, suberect to erect. Rhizophores at lower and basal part stem. Main stems branched from near middle part, in basal part main stem 1.5–2.5 mm in diam. Axillary leaves slightly similar with ventral leaves, base cuneate, margin irregular, finely denticulate, 2.0–3.5 × 1.3–2.0 mm. Ventral leaves ovate, 1.5–2.0 × 1.0–1.5 mm, oblique at base, imbricate, margin denticulate, acute to acuminate at apex. Dorsal leaves ovate, 1.4–1.8 × 1.2–1.5 mm, slightly asymmetric, oblique at base,

margin entire to minutely denticulate, apex acute to acuminate. Strobili rare, solitary, terminal, compact, 3–5 × 1–2.5 mm. Sporophylls monomorphic, ovate, margin entire to minutely denticulate, apex acuminate. Megaspores dull-yellow, surface verrucate, microspore yellow, surface granulate.

Ecology. On rocks in dense forests at lower elevation. Alt. 250–1700 m.

Distribution in Nepal. W, C, E.

Nepalese threatened status: not available data.

General distribution. BHUTAN, INDIA (Assam, Darjeeling, Uttarakhand, NE, C and S India), ARABIA, N AFRICA.

Chromosome number. 2n=20 (Fabbri 1965; Jermy et al. 1967).

Selected specimens examined:

Nepal. "De la Banaoüra Khola à Balauta, alt. 400 m. 6 XI 1954. *A. Zimmernann* 2077" (KYO, photo).

W Nepal: HUMLA: "Between Danna and Sali Salla (the junction of Loti Gad and Humla Karnali River), dry rock on SW-facing slope, alt. 1740 m, 26 Sep 1983, *H. Tabata* et al. *23629*" (KYO, photo).

HUMLA, MUGU: "Between Tirthasain, Humla Dist., and Huanglu, Mugu Distr., on the trail in grassland on W-facing slope, alt. 1400 m, 5 Sep 1983, *H. Tabata* et al. *24648*" (KYO, photo).

SALYAN: "Salyana, alt. 5000 ft., dry earth bank beside track, 29 Mar 1952, *O. Polunin*, *W.R. Sykes* & *L.H.J. Williams 667*" (US, photo; KYO, photo).

C Nepal: CHITAWAN: "damp, rocky sides of small steam-gully at Lambola Khola, c. ½ km S of Beldas (Satara Kilo) village, 18 km S. of Mugling on road to Narayanghat, S. W. of Kathmandu, alt. 350 m, 20 Jan 2000, *C.R. Fraser-Jenkins 38395 (FN 4370)*" (US, photo).

E Nepal: TEHRATHUM: "en route from Iwa to Majhi, on dry slope along the river, Shorea-Shima forest, 610 m, 29 Jun 1978, *H. Tabata*, *K.R. Rajbhandari*, *Y. Shimizu 11989*" (PE).

DHANKUTA: "Dhankuta, 26°50'N, 87°20'E, alt. 400 m, 11 Oct 1971, *J.F. Dobremez* DBR NEP *1373*" (E00670572); "by River Tamur, near Suspension Bridge, alt. 1000 ft, 18 Sep 1961, *A.H. Norkett 5094*" (BM001022383).

TAPLEJUNG: "Tamur Bridge, alt. 250–300 m. 4 Sep 1977, *H. Ohashi* et al. *773141*" (TI, photo).

Selaginella adunca A. Braun ex Hieron.

Figs 2(1A–C), 15

Selaginella adunca A. Braun ex Hieron., in Engl. and Prantl, Nat. Pflanzenfam. 1(4): 674. 1901; Dixit 1992; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017. **Type.** INDIA. *Falconer 34* et *1230* p.p. (syntypes: B).

Description. Stems 10–25 cm, erect. Rhizophores restricted in basal part of stems, located on ventral side. Main stems branched from middle upward, decumbent, simple

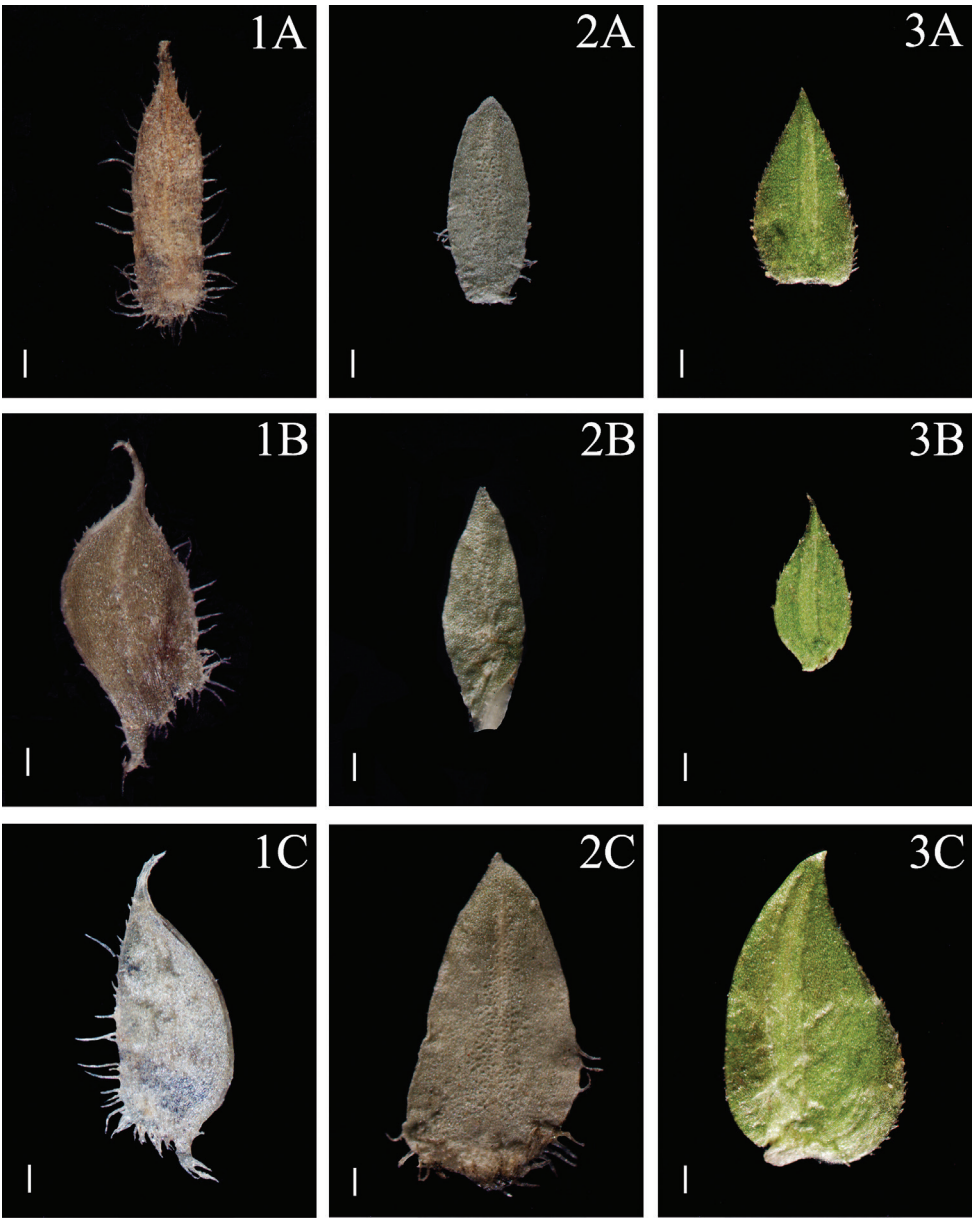

Figure 2. Morphological diversity of the leaves of Nepalese *Sealginella* species **1A–C** *S. adunca* (*Strachey* & *Winterbottom 5*, PE) **2A–C** *S. fulcrata* (*Nakaike 1923*, PE) **3A–C** *S. involvens* (*Zhang 345*, PE). A – Axillary leaves, B – Dorsal leaves, C – Ventral leaves. Scale bars: 0.2 mm.

in basal region, branches decompound, close together, flabellate, in basal part main stem 1.2–1.5 mm in diam. Main stems terete, bright and sometimes stramineous-red. Axillary leaves symmetrical, oblong, base exauriculate, margin ciliolate. Ventral leaves asymmetrical, oblong, 0.9–1.4 × 0.6–1 mm, subfalcate, acroscopic base dilated, ciliate at base, rest dentate to denticulate above, apex cuspidate. Dorsal leaves small, elliptic,

0.7–1.2 × 0.4–0.8 mm, base cuneate truncate, margin dentate, apex cuspidate. Strobili solitary, terminal, compact, tetrahedral, 3.0–5.0 × 1.0–2.2 mm, slightly wider branches. Sporophylls monomorphic, deltoid, cuspidate, margin dentate, strongly keeled. Megaspores reddish-brown, surface verrucate; microspores orange, surface verrucate

Ecology. Terrestrial or epilithic, xerophytic, on open semi-dry stony areas. Alt. 330–2500 m.

Distribution in Nepal. W.

Nepalese threatened status: NT (Fraser-Jenkins et al. 2015). Endemic NW Himalaya, rare.

General distribution. INDIA (Uttarakhand, Himachal Pradesh).

Chromosome number. not available data.

Selected specimens examined:

W Nepal: KALIKOT: "Between Kairkot and Lapha, Karnali Valley, crevices of dry cliff., alt. 4500 ft, 26 Apr 1952, *O. Polunin*, *W.R. Sykes & L.H.J. Williams 3984*" (E, photo; US, photo; KYO, photo); "Kiurithanu, Karnali River, growing on vertical rocks, alt. 4000 ft, 21 Apr 1952, *O. Polunin*, *W.R. Sykes & L.H.J. Williams 797*" (E, photo; US, photo; KYO, photo).

DOLPA: "Between Phulchangi and Chong, near Tibrikot, growing among stones on dry hot open slopes, alt. 8000 ft, 11 Nov 1952, *O. Polunin*, *W.R. Sykes & L.H.J. Williams 3323*" (AAU; E, photo; US, photo; KYO, photo).

DANG: "Between Kurpani and Ghorai, growing on damp sheltered earth banks, alt. 4000 ft, 4 Sep 1952, *O. Polunin*, *W.R. Sykes & L.H.J. Williams 1332*" (E, photo);

SURKHET: "Near Kuepani Siwalik Hills, alt. 1000 ft, 27 Oct 1952, *O. Polunin*, *W.R. Sykes & L.H.J. Williams 5920*" (E, photo).

KALIKOT: "Taelou, 28°53'N, 82°30'E, 1100 m, 22 Apr 1984, *J.F. Dobremez* DBR NEP *2689*" (E00670605); "Bodi Khola, 1700 m, 25 Apr 1974, *J.F. Dobremez* DBR NEP s.n." (E00670564).

Selaginella aitchisonii Hieron.

Selaginella aitchisonii Hieron., Nat. Pflanzenfam. 1(4): 674. 1902; Dixit 1992; Thapa 2002; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.

≡ *Selaginella sanguinolenta* f. *aitchisonii* (Hieron.) Alston, Proc. Nat. Inst. Sci. India 11(3): 215. 1945. **Type.** PAKISTAN. Kurram Valley, Shend Toi, *J.E.T. Aitchison 369* (syntype: B [20 0121871]; K, CAL); KYRGYZSTAN. Turkestan, Akburtaseh, *A. Regel 1878* (syntype: B [20 0121870]); KYRGYZSTAN. Turkestan, Musart-Thal., *A. Regel 1877* (syntype: B [20 0121869]).

Description. Stems 10–25 cm, erect, slender. Rhizophores restricted to the basal part of stems, located on ventral side. Main stems branches from near bases, lateral branches dichotomously compound. Main stems terete, reddish, in basal part main stem 1.0–1.1

mm in diam. Axillary leaves symmetrical, ovate-oblong, carinate, at base obtuse, margin hyaline, at base denticulate, in middle and upper part entire, apex acuminate. Leaves isomorphic, slightly asymmetrical, ovate-lanceolate, uniauriculate at base, obtuse, peltate, margin hyaline, denticulate at base, entire in middle and upper part, apex mucronate to acuminate. Strobili solitary, terminal, compact, tetrahedral, 6.0–10.0 × 1.0–2.0 mm, slightly wider branches. Sporophylls monomorphic, ovate, truncate at base, strongly keeled, apex mucronate to acute. Megaspores yellow, irregular verrucate. Microspores deep yellow, surface rugulose-tuberculate, with perispore on surface.

Ecology. On mossy rocks. Alt. 2200–3400 m.

Distribution in Nepal. W.

Nepalese threatened status: VU, globally threatened (Fraser-Jenkins et al. 2015).

General distribution. AFGHANISTAN, INDIA (Jammu and Kashmir), KYRGYZSTAN, PAKISTAN.

Chromosome number. not available data.

Selected specimens examined:

W Nepal: **HUMLA**: "Phal Ko Odar to Pipling, on mossy stone. 2600 m, 6 Jun 1980, *P.R. Shakya & B. Roy 5514*" (KATH).

Note. *Selaginella aitchisonii* is morphologically closely related to the widespread *S. sanguinolenta*, a species complex consists of several morphological variable forms which might be recognised as distinct species pending our molecular phylogentic analysis (data not published).

Selaginella fulcrata (Buch.-Ham. ex D. Don) Spring

Figs 2(2A–C), 9C, 16

Selaginella fulcrata (Buch.-Ham. ex D. Don) Spring, Bull. Acad. Brux. 10: 231, no.138. 1843; Iwatsuki 1988; Dixit 1992; Thapa 2002; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.

≡ *Lycopodium fulcratum* Buch.-Ham. ex D. Don, Prodr. Fl. Nepal. 17. 1824.

≡ *Lycopodioides fulcrata* (Buch.-Ham. ex D. Don) Kuntze, Revis. Gen. Pl. 1: 826. 1891. **Type.** (lectotype, designated by Fraser-Jenkins et al. 2015) NEPAL. *Lycopodium fulcratum* Ham. ex D. Don, Prod Fl. Nep. p. 17. Napaul. *Dr. Buchanan* (BM, top of sheet).

Description. Stems glabrous, 50–110 cm, erect. Main stems simple at base, branched from middle part of stem, unequally angular, drying stramineous-brown, 1.3–3.0 mm in diam. in lower part, primary branched copiously pinnate, elongate-deltoid. Axillary leaves ovate-elliptic, 1.2–1.5 × 0.5–0.7 mm, base obtuse, margin ciliate up to middle, rest entire. Ventral leaves ovate-oblong, 1.4–2 × 0.5–0.7 mm, base obtuse, acroscopic base ciliate, rest entire and revolute, basiscopic base with few cilia, apex acute. Dorsal leaves decurrent, 0.8–1.3 × 0.3–0.6 mm, unequally attenuate, subfalcate, subacute,

only older leaves ciliate at base, rest entire and younger ones entire throughout. Strobili solitary, terminal, compact, 8–12 × 1–2 mm. Sporophylls monomorphic, ovate, cordate at base, margin denticulate or entie, apex abruptly acute. Megaspores reddish-brown, surface papillate; microspore reddish-brown, surface papillate.

Ecology. On damp sheltered earth banks at lower elevation. Alt. 200–1200 m.

Distribution in Nepal. W, C, E.

Nepalese threatened status: LC (Fraser-Jenkins et al. 2015).

General distribution. INDIA (Bihar).

Chromosome number. not available data.

Selected specimens examined:

"Nepal n. 1397, Herb. Geheed, Oktbr. 1909" (B); "Nepalia, *Wallich* s.n."(K); "Mountain Nepalia, *E.J.C.* n. *125*" (E, photo); "Nepalia s.n." (E00670612, photo); "Nepalia, 1823, *Wallich 125*" (K, photo); "Nepalia, 1829, *Wallich 125*" (K, photo); "Belsot a Sogaret, 130 m, 9 Nov 1954, *A. Zimmermann 2153*" (KYO, photo).

W Nepal: DANG: "Budamar, on moist and chedy place, alt. 310 m. 29 Sep 1982, *N.P. Manandhar 8577*" (KATH); "Kwera Panii, Dang, on shady and rocky places, alt. 600 m, 10 Mar 1976, *N.P. Manandhar*, *P.M. Regmi 204*" (KATH); "Between Kurpani and Ghorai, growing on damp shelered earth banks, alt. 4000 ft, 4 Sep 1952, *O. Polunin*, *W.R. Sykes & L.H.J. Williams 1332*" (US, photo; KYO, photo; E00670606).

SURKHET: "Near Kuepani, Siwalik Hills, growing on shady banks, alt. 1000 ft, 27 Oct 1952, *O. Polunin*, *W.R. Sykes & L.H.J. Williams 5920*" (KYO, photo; US).

C Nepal: GULMI: "Gundi Khola, Kali Gandaki River, alt. 2500 ft, 13 Oct 1954. *Stainton*, *Sykes*, *L.H.J. Williams 8929*" (E, photo).

SYANGJA: "Roadbank at Galyang village, S of Waling, N of Tansen, on road between Pokhara and Butwal. 25 Sep 1997. *C.R. Fraser-Jenkins* et al. *25578* (*FN 1556*)" (US, photo).

PALPA: "Argali 833275, on moist slope strobilus green, alt. 800 m, 27 Nov 1973, *D.P. Joshi*, *M.M. Amatya 73/105a*" (KATH).

CHITAWAN: "Chitawan, Churia hills, Shorea forest undergrowth, 2000 ft., 14 Jun 1975, *Laurie 77*" (K); "North-East face of Narayani Ghat, alt. 213–360 m, 3 Jan 1977, s.n., *500*" (KATH); "Damp, rocky sides of small stream-gulley at Lambola Khola, c. ½ km S of Belbas (Satara Kilo) village, 18 km S. of Mugling on road to Narayanghat, S. W. of Kathmandu, alt. 350 m, 20 Jan 2000, *C.R. Fraser-Jenkins 28396* (*FN 4371*)" (US, photo).

MAKAWANPUR: "Forested ridges and cliffs of the Churiya Ghats, N. of Bagmati Bridge (c. 13 km E. of Chandranigarpur on main road), on path to Bagar, W. side of Baginati River, E. of Hetauda, Makawanpur District, Narayani Zone, E.C. Nepal, 21 Oct 1997. *C.R. Fraser-Jenkins* et al. *25724* (*FN 1702*)" (KATH); "Above Liot village, Basmari, c. 5 km. W of Hetauda, off Narayanghat road. Densely Sal-forested and rocky stream-gully on S. slope of first range of foothills beyond and N of the Churiya Ghats, 24 Oct 1997, *C.R. Fraser-Jenkins* et al. *25760* (*FN 1738*)" (BM001022482).

***Selaginella involvens* (Sw.) Spring**
Figs 2(3A–C), 9D, 17

*Selaginella involvens (*Sw.) Spring, Bull. Acad. Roy. Sci. Bruxelles 10(1): 136, no. 6. 1843; Iwatsuki 1975; Iwatsuki 1988; Dixit 1992; Thapa 2002; Zhang 2004; Zhang et al. 2013; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.
≡ *Lycopodium involvens* Sw., Syn. Fil. 182. 1806.
≡ *Lycopodioides involvens* (Sw.) Kuntze, Revis. Gen. Pl. 1: 826. 1891. **Type.** JAPAN. *Thunberg* in Herb. Swartz (holotype: S; isotype: B [20 0147264]).
= *Lycopodium caulescens* Wall. ex Hook. & Grev., Bot. Misc. 2: 382. 1831.
≡ *Selaginella caulescens* (Wall. ex Hook. & Grev.) Spring, Bull. Acad. Roy. Sci. Bruxelles 10(1): 137, no. 12. 1843. **Type.** NEPAL. At the River Rapty, Nepal, *Dr. Wallich 137* (holotype: K [001109362]; isotype BM?).

Description. Plants 15–45(–65) cm, with creeping subterranean rhizome and stolons; leaves on rhizome and stolons scale-like, pale yellow. Rhizophores restricted to basal part. Main stems branched from middle upward, pinnately branched, stramineous, unbranched main stem 3–20 cm tall, 1–1.5 mm in diam. in lower part, terete, not sulcate, glabrous; primary leafy branches 7–12 pairs, 2 or 3 times pinnately branched, secondary branches 1 or 2 times pinnately branched. Axillary leaves ovate to triangular, 1.1–1.6 × 0.4–1.1 mm, base exauriculate, margin denticulate in basal to middle part, to upper entire, apex acute. Ventral leaves ovate to triangular, 1.4–2.4 × 0.4–1.4 mm, basiscopic base rounded, margin entire, acroscopic base enlarged, broader, overlapping stem and branches, margin denticulate, falsely two nerved, apex subacute or apiculate. Dorsal leaves ovate-triangular or ovate-elliptic, 0.6–1.2 × 0.2–0.5 mm, slightly carinate, base cuneate, margin denticulate, apex long acuminate to shortly aristate. Strobili solitary, terminal, compact, tetragonal, 5–15 × 1–1.4 mm. Sporophylls monomorphic, ovate-triangular, margin denticulate, apex acuminate. Megaspores whitish or brown, with equatorial flange, surface with spinulose microsculptures; microspores yellowish orange, surface verrucate with blunt spines.

Ecology. Epilithic or xerophytic, in damp forests or on moss covered boulders and cliffs, evergreen or seasonally green. Alt. 650–3000 m.

Distribution in Nepal. W, C, E.

Nepalese threatened status: not available data.

General distribution. BHUTAN, CHINA (Anhui, Chongqing, Fujian, Gansu, Guangdong, Guangxi, Guizhou, Hainan, Henan, Hubei, Hunan, Jiangxi, Shaanxi, Sichuan, Taiwan, Xizang, Yunnan, Zhejiang), INDIA (N, E, C and S), JAPAN, KOREA, LAOS, MALAYSIA, MYANMAR, PHILIPPINES, SRI LANKA, THAILAND, VIETNAM.

Chromosome number. x=9 (Kuriachan 1963); 2n=18 (Jermy et al. 1967).

Selected specimens examined:

W Nepal: MUGU: "Mugu Karnali Valley, between Mangri and Lumsa, growing on wet vertical cliff face in shade, alt. 7000 ft, 26 Aug 1952, *O. Polunin*, *W.R. Sykes & L.H. Williams 3045*" (US, photo; KYO, photo).

HUMLA: "Between Ripa and Sunakhada, 29 Aug 1983, *H. Tabata* et al. *23939*" (KYO, photo); "Between Surkegad and Ripa, rock cliff facing east, alt. 1700 m, 27 Aug 1983, *H. Tabata* et al. *23757*" (KYO, photo).

BAJHANG: "Bajhang, Agara, 11 Sep 2017, *S.R. Zhang 345*" (PE no. 2525761).

C Nepal: NUWAKOT, RASUWA: "Between Betrawati, Nuwakot Dist. and Ramche, Rasuwa Distr., on the rock in the open place, alt. 1450 m, 11 Jun 1983, *H. Tabata* et al. *18029*" (KYO, photo); "Bagmati Zone, beyond Dhunche, in gorge of Trisuli River (coming down from Goissaikund), Northeast facing slopes, on mossy rocks in deep shade, alt. 1700 m, 17 Sep 1966, *D.H. Nicolson 2507*" (US).

RAMECHAP: "enroute from Those to Shibalaya, Ramechap District. Along the trail, on the rock, Pinus wallichiana zone, alt. 1750–1780 m, 2 Jun 1978, *H. Tabata*, *K.R. Rajbhandari*, *Y. Shimizu 10211*" (PE 00244240); "Jiri (1860m)–Kune (1860m)–Kattike (2000m)–Those (1740m)–Shivalaya (1800m), alt. 1740–2000 m, 27°37'N, 86°14'E –27°36'N, 86°17'E, 16 Aug 1985, *M. Suzuki*, *N. Kurosaki*, *S.K. Wu 8580885*" (TI, photo).

DOLAKHA: "Shemma-Yakuwa-Lamobagar, alt. 1100–1500 m, 1 Aug 1977. *H. Ohashi* et al. *771897*" (TI, photo); "Jire-Those, shade place, alt. 6300 ft, 23 Sep 1964. *Banerjee*, *Shrestha*, *Upadhyay 2884*" (US, photo); "Chumro, alt. 2200 m, 26 Sep 1976, *Y. Suehiro 2326*" (KYO, photo); "Près de Gongar, alt. 1280 m, 14 Sep 1956, *A. Zimmermann 1256*" (KYO, photo).

KASKI: "Tamage (1730m)–Banjan (2035m), alt. 2100 m, 28°15'22"–13'03"N, 83°49'56"–48'44"E, 9 Aug 1999, *M. Mikage* et al. *9965056*" (TI, photo); "Pokhara to Hyenda, alt. 1000–1100 m, 20 Sep 1976, *Y. Suehiro 84*" (PE); "Pokhara to Hyenda, alt. 1000–1100 m, 20 Sep 1976, *Y. Suehiro 82*" (TI, photo); "l.c. *Y. Suchiro* 83" (KYO, photo).

E Nepal: TERHATHUM: "Basantapur-Chitre, on mossy tree trunk in forest, alt. 2300–2400 m, 7 Jun 1972, *H. Kanai* et al. *725490*" (TI, photo; KYO, photo); "Kunja, 27°13'N, 87°52'E, alt. 2100 m, *J.F. Dobremez* DBR NEP *1315*" (E00754781, E00668259).

SANKHUWASABHA: "Seduwa to Kasuwa Khola, prostrate under rock, alt. 3500 ft, 6 May 1965, *Banerjee*, *Upadhyay*, *Baskola 3406*" (US, photo); "Seduwa, in shade under big rock, alt. 5500 ft, 8 Aug 1965, *Banerjee*, *Upadhyay*, *Baskola 3366*" (US, photo); "Senduwa 2100 m – Bhaluhhop 2400 m, 5 Jun 1972, *H. Kanai* et al. *725089*" (KYO, photo).

TAPLEJUNG: "Shewaden 2600 m – Mewa Khola 2100 m, on mossy rock in light shade, c. 2200 m, 29 Jun 1972, *H. Kanai* et al. *725353*" (KYO, photo); "Zongi-Iladanda, 12 Nov 1963, *H. Hara* et al." (TI, photo).

SOLUKHUMBHU: "near Namche, in shade andmoist place, alt. 8000 ft, 9 May 1965, *Banerjee* et al. *3415*" (US, photo).

ILAM: "Mai Majuwa-Mai Pokhari-Dhara Pani, 4 Dec 1963, *H. Hara* et al." (TI, photo).

***Selaginella pallida* Spring**
Figs 3(1A–C), 9E, 18

Selaginella pallida Spring, Bull. Acad. Roy. Bel. 10: 234. 1843; Iwatsuki 1988; Thapa 2002; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017; Zhang 2018.
≡ *Lycopodium pallidum* Hook. & Grev., Bot. Misc. 2: 389. 1831, nom. illeg.
≡ *Selaginella plumosa* var. *pallida* (Spring) Baker, J. Bot. 21: 145. 1883. **Type.** (lectotype, designated by Fraser-Jenkins et al. 2017) NEPAL. Nepal, [The Hon. E. Gardner for] *N. Wallich*, [c. 1817], Herb. Rudge (BM).
= *Lycopodium pallidum* Beyr. ex Gaudich., Voy. Uranie, Bot. pt. 7: 285. 1828, nom. illeg.
= *Lycopodium tenellum* D. Don, Prodr. Fl. Nepal.: 18 (1824), non (P. Beauv) Desv. ex Poir. (1814). **Type.** NEPAL. Nepalia, *Wallich* (?).
= *Selaginella nepalensis* Spring, Bull. Acad. Roy. Sci. Bruxelles 10(1): 234. 1843; Dixit 1992. **Type.** NEPAL. *Wallich* (?).
= *Selaginella bomiensis* Ching & S.K. Wu, Fl. Xizang. 1: 25. 1983. **Type.** CHINA. Xizang, Bomi (Tungmai), in rupibus, alt. 2000 m., *Y.T. Chang* et al. *881* (holotype: PE).

Description. Stems 30–50 cm, long creeping. Rhizophores at intervals throughout length of main stem, borne on ventral side in axils of branches. Main stems branched throughout, pinnately branched, 1.2–2.0 mm in diam. in lower part. Axillary leaves ovate, 1.2–1.5 × 0.6–0.8 mm, dilated at base, dentate-serrulate, margin entire or upper part subentire, apex acuminate. Ventral leaves ovate, 2.0–2.8 × 1.1–1.3 mm, basiscoic base ovate, margin slightly dentate, aroscopic base dilated at base, margin dentate-serrulate, apex acuminate. Dorsal leaves ovate, 1.6–2.1 × 1.0–1.2 mm, in base cordate, margin serrulate-denticulate, falcate, apex acuminate-aristate. Strobili solitary, terminal, compact, 5–12 × 1–2 mm. Sporophylls monomorphic, ovate, acuminate, margin denticulate, sub-pellucid, apex acuminate. Megaspores light yellow, surface verrucate; microspores red, surface smooth, with echinae.

Ecology. Forming dense mats on vertical banks in shade. Alt. 500–2200 m.

Distribution in Nepal. C, E.

Nepalese threatened status: not available data.

General distribution. BHUTAN, CHINA (Xizang). INDIA (Himachal Pradesh, Manipur, Meghalaya, Uttarakhand).

Chromosome number. x=10, 2n=c. 20 (Fraser-Jenkins and Matsumoto 2015).

Selected specimens examined:

C Nepal: NUWAKOT: "Dhunche-Singum Compa, alt. c. 2200–3000 m, 18 Oct 1979, *T. Nakaike 238*" (PE).

DHADING: "Rithey Pani (between Mugling and Pokhara), alt. c. 500 m, 27 Sep 1986, *T. Nakaike 1948*" (PE 01622281);

KASKI: "Dhampus, Pokhara, alt. 1000–1500 m, 10 Nov 1988, *T. Nakaike 3781*" (PE); Karanha, near Pokhara, alt. c. 900 m, 9 Nov 1988, *T. Nakaike 3740*" (PE); "Pokhara, alt. 900 m, 18 Jun 1967, *H. Kanai* et al. *26128*" (KYO, photo).

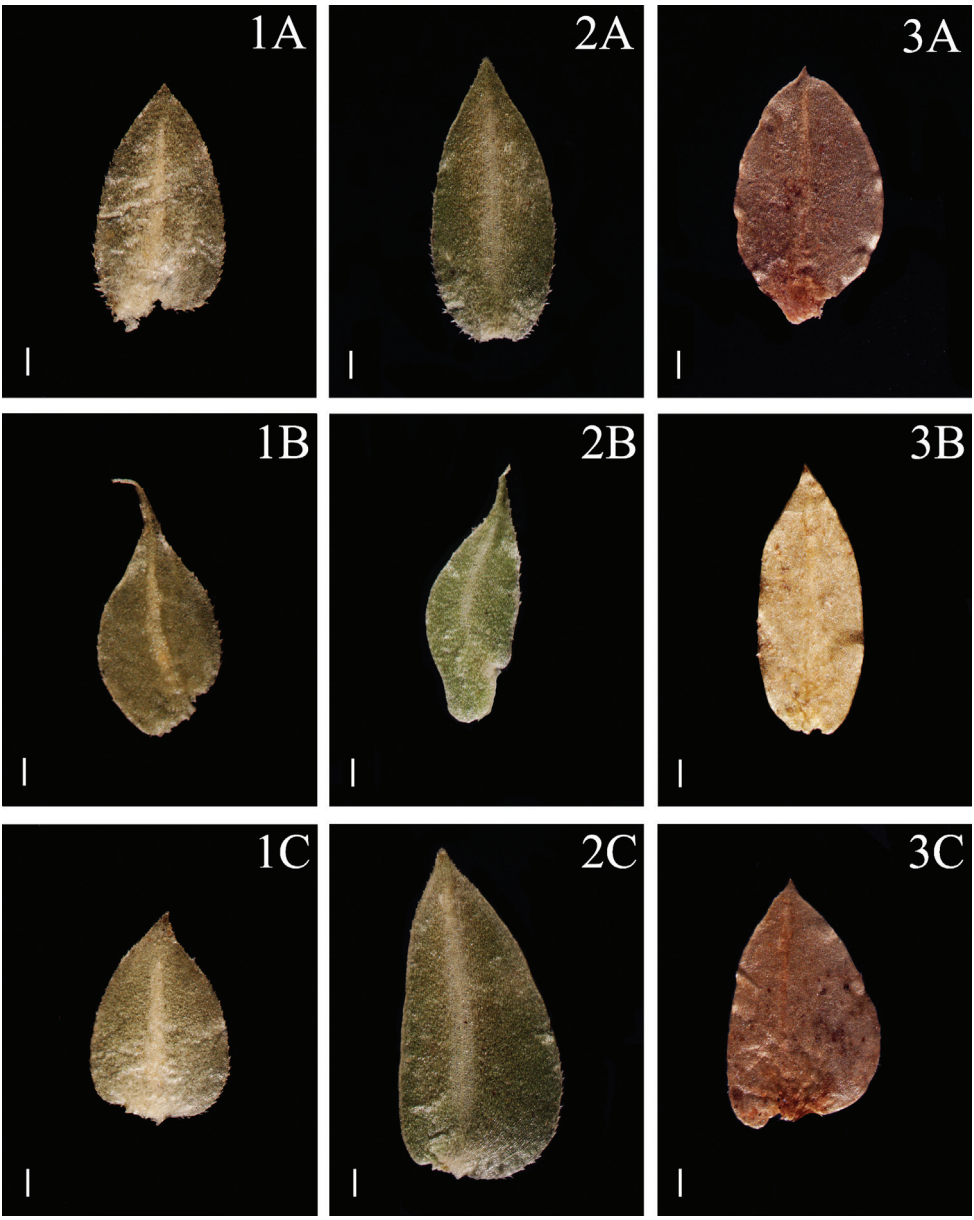

Figure 3. Morphological diversity of the leaves of Nepalese *Sealginella* species **1A–C** *S. pallida* (*Nakaike 3740*, PE) **2A–C** *S. remotifolia* (*Nakaike 3522*, PE) **3A–C** *S. semicordata* (*Jenkins* s.n., PE). A – Axillary leaves, B – Dorsal leaves, C – Ventral leaves. Scale bars: 0.2 mm.

TANAHUN: "Tanahun District, c. 6 km S of Damauli, E of Pokhara, W of Mugling and Anbu Khaireni, Rocks and forested slope below waterfall, next gorge, c. ½ km above Chowti Bara Temple gorge, 23 Mar 1997, *C.R. Fraser-Jenkins 25327* (*FN 1306*)" (US, photo).

PALPA: "Bategora, between Butwal and Pokhara, alt. c. 700 m, 9 Nov 1988, *T. Nakaike 3737*" (PE).

KATHMANDU: "Phulchoki, south of Kathmandu, on bank along path in shade, alt. c. 2200 m, alt. 2200–2700 m, 15 Jul 1972, *H. Hara*, *K. Iwatsuki* et al. *725556*" (KYO, photo); "Sundarijal-Mulkharka, alt. c. 1600 m, 4 Nov 1979. *T. Nakaike 418*" (PE); "Gokarna Ban, alt. c. 1370 m, 12 Oct 1979, *T. Nakaike 130*" (PE); "Tare Bhir, alt. c. 1400–1900 m, 4 Oct 1979, *T. Nakaike 59*" (PE); "Jamachowk, alt. c. 1500 m, 1 Oct 1986, *T. Nakaike 2169*" (PE); "Nagarjun, alt. c. 1400 m, 26 Aug 1986, *T. Nakaike 1092*" (PE); "l.c. *T. Nakaike 1124*" (PE); "l.c. *T. Nakaike* 1138" (PE); "Dakshin Kali, alt. c. 1500 m. 13 Sep 1986. *T. Nakaike 1438*" (PE); "Chandragiri, alt. 1600–2000 m, 9 Oct 1986, *T. Nakaike 2491*" (PE); "Gokarna Ban, Kathmandu, alt. c. 1350 m, 29 Oct 1988, *T. Nakaike 3587*" (PE); "first forested damp stream gully above road, 6 km N from Pharping Bazar, N of Bansbari, 1 km S of Chalankhel, NE side of Neipane Dara (hill), on W side of Bagmati River, c. 10 km S of Kathmandu on road to Dakshin Kali temple, 20 Jul 1996, *C.R. Fraser-Jenkins* et al. *24100* (*FN 78*)" (US, photo).

BHAKTAPUR: "Changu Narayan, alt. 1400–1500 m, 22 Sep 1986, *T. Nakaike 1801*" (PE); "Sankhu, alt. c. 1400 m, 24 Aug 1986, *T. Nakaike 1061*" (PE 01622270); "Nagarkot, alt. c. 1800 m, 16 Sep 1986, *T. Nakaike 1526*" (PE);

KAVREPALANCHOK: "Panauti, alt. c. 1400 m, 4 Oct 1986, *T. Nakaike 2373*" (PE).

LALITPUR: "Phulchoki, south of Kathmandu, alt. 2200–2700 m, on bank along path in shade, alt. c. 2200 m, 15 Jul 1972, *H. Hara* et al. *725556*" (TI); "Godawari (1600)–Phulchauki (2500m), alt. 1600–2500 m, 26 Jun 1967, *H. Hara* et al. s.n." (TI, photo).

RAMECHAP: "Between Bhandar and Kenja, alt. 1700–2100 m, 7 Oct 1988, *T. Nakaike 3166*, *3167*" (PE);

DOLAKHA: "between Jiri and Sivalaya, alt. 1800–2000 m, 5 Oct 1988, *T. Nakaike 3088*" (PE); "Between Sivalaya and Jiri, Dolakha, alt. 1800–2000 m, 24 Oct 1988, *T. Nakaike 3526*" (PE).

E Nepal: BHOJPUR: "en route from Phedi to Sagangma, Along Irkhua khola, subtropical semievergreen forest zone, on the mossy rock, alt. 1160 m, 27 Jun 1978, *H. Tabata* et al. *10989*" (PE); Dingla 1000 m-Doban 800 m, on rather dry bank of part in shade, alt. 800–1000 m, 2 Jul 1972, *H. Kanai* et al. *725457*" (TI, photo; KYO, photo);

SANKHUWASABHA: "Tumulingtar-Khandbari, alt. 450–1150 m, 26 Jul 1977, *H. Ohashi* et al. *771532*" (TI, photo).

PANCHTAR: "Yatkin-Akasay-Batasay, 30 Nov 1963, *H. Hara* et al." (TI).

Selaginella remotifolia **Spring**

Figs 3(2A–C), 9F, 19

Selaginella remotifolia Spring, in Miq. Pl. Jungh. 3: 276. 1854; Zhang 2004; Zhang et al. 2013; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.

≡ *Lycopodioides remotifolia* (Spring) H.S. Kung, Fl. Sichuanica 6: 65, pl. 19. 1988 **Type.** INDONESIA. Sumatrae regionem sylvaticum prov. Angkolae superioris, alt. 1–3000 ft., *F.W. Junghuhn* (holotype: L).

= *Selaginella involucrata* Warb., Monsonia 1: 113, n. 28. 1900. **Type.** INDONESIA. Java. *Forbes n. 1034* (syntype: B [20 0154220]), INDONESIA. Preanger, Mt. Tilu bei Pentalengan. *Warburg 3484* (syntype: B [20 0154212]).

= *Selaginella japonica* Miq., Ann. Mus. Bot. Lugduno-Batavi 3(6): 185. 1867. **Type.** JAPAN. Detexit Keiske in prov. Owari (syntype: L [0059796]), *Siebold* et *Textor* etiam legerunt (syntypes: L [0052424], [0052430]).

Description. Plants 15–45 cm, creeping, fertile branches erect. Rhizophores at intervals throughout length of creeping stem and branches, on dorsal side in axils of stem branches. Main stems branched above at base, 0.5–1.5 mm in diam. in lower part. Stems oval or terete, sulcate, glabrous, with single vascular bundle. Axillary leaves ovate-lanceolate or elliptic, 1.4–2.4 × 0.5–1.2 mm, base cuneate, margin slightly denticulate, apex slightly obtuse. Ventral leaves spreading, ovate-lanceolate, 1.8–3(–3.6) × 0.8–1.4(–1.7) mm, base rounded, acroscopic base not overlapping on stem and branches, margin minutely denticulate or subentire, apex acute. Dorsal leaves elliptic-lanceolate or ovate-elliptic, 1.4–2(–2.8) × 0.4–0.9(–1.2) mm, base uniauriculate, margin subentire or minutely denticulate, apex long acuminate. Strobili solitary, terminal and lateral to branches, compact, tetragonal, 3.5–6 × 1–3 mm. Sporophylls monomorphic, ovate-lanceolate, carinate, margin denticulate, apex acuminate. Megaspores gray-white, surface irregular reticulum; microspores pale yellow, surface with triangular and striped spines.

Ecology. Terrestrial, evergreen, sub-open forest banks, previously overlooked or on slopes in shade. Alt. 1800–2650 m.

Distribution in Nepal. C, E.

Nepalese threatened status: EN (Fraser-Jenkins et al. 2015).

General distribution. CHINA (Chongqing, Fujian, Guangxi, Guizhou, Hubei, Hunan, Jiangxi, Sichuan, Taiwan, Yunnan, Zhejiang), NE INDIA, INDONESIA (Sumatra), JAPAN, PHILIPPINES.

Chromosome number. Not available data.

Selected specimens examined:

C Nepal: DOLAKHA: "between Kenja and Sivalaya, Dolakha, alt. c. 2300 m, 23 Oct 1988, *T. Nakaike 3522*" (PE01722894).

KASKI: "Between Landrung and Potana, alt. 1900 m, 3 Aug 1983, *H. Tabata* et al. *19149*" (KYO, photo).

RAMECHAP: "between Sivalaya and Bhandar, alt. 1800–2500 m, 6 Oct 1988, *T. Nakaike 3137*" (PE).

E Nepal: TEHRATHUM: "Chauki (2650 m)–Tute (2480m)–Basantapur (2300m), 27°12'35"N, 87°28'01"E–27°07'00"N, 87°26'00"E, 17 Aug 1999, *K. Fujikawa* et al." (PE01722895); "Tinjure-Chauke, alt. 2700 m, 7 Aug 1972, *H. Kanai* et al. *725131*" (E00659376; KYO, photo); "Chauki (2650 m)–Tute (2480 m)–Basantapur

(2300 m), Tinjure, alt. 2800 m, 27°12'35"N, 87°28'01"E; 27°07'00"N, 87°26'00"E, 17 Aug 1999, *M. Tateno* et al. *9955140*" (KATH).

SOLUKHUMBHU: "Dorange, Junbesi, Solukhumbu, alt. c. 2500 m, 20 Oct 1988, *T. Nakaike 3472*" (PE).

ILAM: "Mai Pokhari, 27°00'N, 87°57'E, alt. 2000 m, 28 Sep 1971, *J.F. Dobremez* DBR NEP *1233*" (E00670678).

Selaginella semicordata (Wall. ex Hook. & Grev.) Spring

Figs 3(3A–C), 9G, 20

Selaginella semicordata (Wall. ex Hook. & Grev.) Spring, Fl. Bras. 1(2): 122. 1840; Dixit 1992; Thapa 2002; Singh and Panigrahi 2005; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.

≡ *Lycopodium semicordatum* Wall. ex Hook. & Grev., Bot. Misc. 2: 396. 1831.

(*Lycopodium semicordatum* Wall., Cat. n. 126, p. p. 1821, nom. nud.).

≡ *Lycopodioides semicordata* (Wall. ex Hook. & Grev.) Kuntze, Revis. Gen. Pl. 1: 827. 1891. **Type.** (lectotype, designated by Fraser-Jenkins et al. 2017) INDIA. N. E. India, Meghalaya: montes Sylhet vicinae. *M.R. S[mith]*. [*Wallich List no*.] *126.3* (E; isolectotype: K–W).

(*Selaginella burghallii* R. Sim., Priced Cat. Ferns 6: 61. 1859, nom. nud.)

Description. Stems to 150 cm, creeping, slender. Rhizophores at intervals throughout length of creeping stem and branches, on dorsal side in axils of stem branches. Stem slender, sulcate. Main stems, branched throughout, arise alternately from base of plant, branches short, pinnately, flabellate, distant located. Axillary leaves oblong-lanceolate, 2.1–2.6 × 1.3–1.8 mm, base rounded-cuneate, apex truncated; on branches, obovate, 1.3–2.0 × 0.6–0.9 mm. Ventral leaves oblong-lanceolate, 1.9–2.5 × 0.7–1.2 mm, rounded at base, acroscopic base slightly enlarged, not overlapping stem and branches, margin in apex part suberose, apex subobtuse to subacute. Dorsal leaves oblong, 1.5–1.8 × 0.5–0.7 mm, imbricate, in basal part oblique, margin entire to minutely denticulate at apex, apex shortly cuspidate. Strobili solitary, terminal, tetragonal, compact, 5.0–15 × 1.5–2.3 mm. Sporophylls monomorphic, 1.6–2 × 0.8–1 mm, ovate, keeled, margin entire, apex acute. Megaspores dark-brown, surface verrucate; microspores pale, surface exine with white, translucent wing-like perispore supported with hook-like structure.

Ecology. Terrestrial, growing in paddy field or marshland or shady areas among the grasses with abundant water content. Restricted low altitude species of wet. Alt. 100–150 m.

Distribution in Nepal. C, E.

Nepalese threatened status: EN (Fraser-Jenkins et al. 2015).

General distribution. BANGLADESH, INDIA (Assam State, Bihar, Meghalaya, Mizoram, Nagaland, Tripura, West Bengal), MYANMAR.

Chromosome number. Not available data.

Selected specimens examined:

E Nepal: JHAPA: "Range Danda, common on shady banks, alt. 100 m, 24 Jan 2003, *N. Thapa* et al. *2016*" (KATH).

Selaginella helvetica (L.) Spring

Figs 4(1A–C), 9H, 21

Selaginella helvetica (L.) Spring, Flora 21(1): 149. 1838; Zhang 2004; Zhang et al. 2013; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.
≡ *Lycopodium helveticum* L., Sp. Pl. 2: 1104. 1753.
≡ *Bernhardia helvetica* (L.) Gray, Nat. Arr. Brit. Pl. 2: 23. 1821.
≡ *Diplostachyum helveticum* (L.) P. Beauv., Prodr. Aethéogam.: 107. 1805.
≡ *Heterophyllum helveticum* (L.) Hieron. ex Börner, Fl. Deut. Volk 110, f. 29. 1912.
≡ *Lycopodioides helvetica* (L.) Kuntze, Rev. Gen. Pl. 1: 826. 1891.
≡ *Selaginella helvetica* (L.) Link, Fil. Spec. 159. 1841, later isonym.
≡ *Stachygynandrum helveticum* (L.) P. Beauv. ex J. St.-Hil., Expos. Fam. Nat. 1: 39. 1805. **Type.** (lectotype, designated by Troia and Greuter 2015) Florentiae, et in Taurero Rastadiensi, Herb. Burser XX: 46 (UPS).

Description. Stems 5–15(–25) cm, short-creeping, fertile stems erect. Rhizophores at intervals throughout length of creeping stem and branches, borne on ventral side in axils of branches.Main stems branched throughout, 0.2–0.4 mm in diam. in lower part. Stems stramineous, stem angulate, sulcate, primary leafy branches 2–5 pairs, simple, forked, or once pinnately branched, branchlets sparse, branches arranged on main stem 2–3 cm apart. Axillary leaves ovate-lanceolate or elliptic, 1.4–1.6 × 0.4–0.8 mm, base exauriculate, margin ciliolate. Ventral leaves oblong-ovate or broadly ovate, 1.6–2 × 0.8–1.2 mm, leaves on branches spreading or slightly deflexed, basiscopic margin ciliolate, acroscopic base enlarged, broader, overlapping stem and branches, margin ciliolate, apex acute or aristate, often bent upward. Dorsal leaves symmetrical or not, ovate or ovate-lanceolate, 1.2–1.6 × 0.5–0.8 mm, base obtuse, margin ciliolate, apex long acuminate or aristate, often reflexed. Fertile branches erect, 3–6 cm. Strobili solitary or forked, terminal, lax or lax in lower partion, and compact in upper part, cylindric, 12–35 × 2–4 mm. Sporophylls unlike sterile leaves or similar, margin ciliolate, apex long acuminate. Megaspores orange or yellowish orange, surface verrucate; microspores orange or orange-red, surface verrucate.

Ecology. On moss-covered cliffs, in rock crevices, on damp shaded banks in mixed forests, to mossy areas. Alt. 2300–4000 m.

Distribution in Nepal. W, C.

Nepalese threatened status: NT (Fraser-Jenkins et al. 2015).

General distribution. EUROPE, RUSSIA, JAPAN, KOREA, MONGOLIA, CHINA (S Gansu, Hebei, Heilongjiang, Jilin, Liaoning, Nei Mongol, Qinghai,

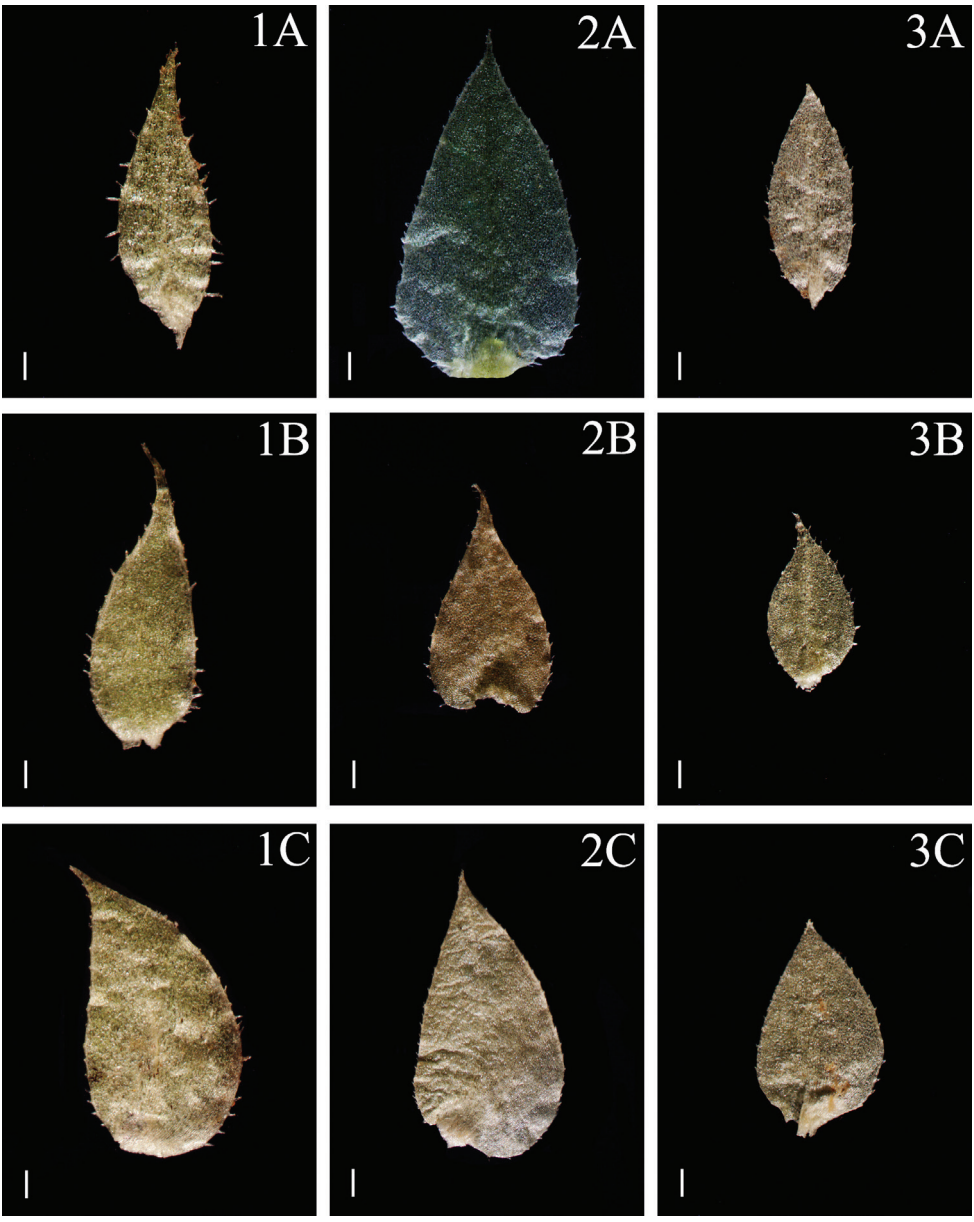

Figure 4. Morphological diversity of the leaves of Nepalese *Sealginella* species **1A–C** *S. helvetica* (*Zhang 0638*, PE) **2A–C** *S. pallidissima* (*Zhang 2746*, PE) **3A–C** *S. laxistrobila* (*Nakaike 1319*, PE). A – Axillary leaves, B – Dorsal leaves, C – Ventral leaves. Scale bars: 0.2 mm.

Shaanxi, Shandong, Sichuan, Xizang, Yunnan), INDIA (Himachal Pradesh, Uttarakhand, West Bengal).

Chromosome number. 2n=18 (Manton 1950; Jermy et al. 1967).

Selected specimens examined:

W Nepal: DOLPA: "between Rohagaon and Lulo Khola, Suli Gad, moist shady bank in mixed forest, growing among moss, alt. 10,000 ft, 15 Sep 1952, *O. Polunin*, *W.R. Sykes & L.H.J. Williams 3403*" (PE; TI, photo; E, photo; US, photo; KYO, photo).

Selaginella pallidissima Spring

Figs 4(2A–C), 9I, 22

Selaginella pallidissima Spring, Bull. Acad. Roy. Sci. Bruxelles 10: 231. 1843; Alston 1945; Iwatsuki 1975; Iwatsuki 1988; Dixit 1992; Thapa 2002; Zhang 2004; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017. **Type.** INDIA. *V. Jacquemont 2331* (holotype: P [00523060]), Himalaya, alt. 3000 m. *V. Jacquemont 2331* (isotype: K [001067411]).

– *Selaginella integerrima* sensu Strachey, Gaz. North-West Prov.: 66. 1882, non Spring, 1850.

Description. Stems 15–35 cm, creeping. Rhizophores at intervals throughout length of main stem, borne on ventral side in axils of branches. Main stems branched throughout, pinnately branched, 0.3–0.5 mm in diam. in lower part. Main stems stramineous or reddish, angulate, sulcate. Axillary leaves ovate, 2–3 × 1–1.5 mm, base subcordate, margin minutely denticulate, apex acuminate. Ventral leaves ovate or ovate-triangular, 1.8–3.2 × 1.1–1.8 mm, basiscopic base rounded, margin denticulate, acroscopic base enlarged, overlapping stem and branches, margin denticulate or ciliolate in basal portion, apex acute. Dorsal leaves ovate or ovate-lanceolate, 1.5–2.2 × 0.6–1.3 mm, base subcordate, margin minutely denticulate or ciliolate, apex acuminate. Strobili solitary or rarely paired, terminal, 6–10 × 1–2 mm. Sporophylls dimorphic, dorsal sporophylls ovate, oblique, in base subcordate, margin shortly ciliolate or denticulate, apex acute, ventral sporophylls ovate or oblong-ovate, not carinate, margin denticulate. Megaspores sulfur colored or yellowish orange, surface verrucate, microspores orange-red, surface covered with spinulose microsculpture.

Ecology. Terrestrial or epilithic, on steep, open, rather dry banks among grasses, seasonally green. Alt. 2700–3300 m.

Distribution Nepal. W, C, E.

Nepalese threatened status: LC (Fraser-Jenkins et al. 2015).

General distribution. CHINA (Sichuan, Yunnan, Xizang), INDIA (Uttar Pradesh, Himachal Pradesh).

Chromosome number. Not available data.

Selected specimens examined:

Nepal: "Manglui Banjuang, alt. 2800 m, 28 Jul 1972, *A. Maire* AMA *443*" (E00670584).

W Nepal: JUMLA: "Ghurchi Lekh, near Chautha, alt. 10,000 ft, 28 Aug 1952, *O. Polunin*, *W.R. Sykes & L.H.J. Williams 3068*" (E, photo; US, photo).

DOLPA: "Rohagaon, Suli Gad, alt. 9500 ft, 13 Sep 1952, *O. Polunin*, *W.R. Sykes & L.H.J. Williams 3364*" (E, photo; US, photo; KYO, photo); "l.c. *3365*" (KYO, photo); "Near Hurta, Bhalu Lekh, alt. 9000 ft, 5 Aug 1952, *O. Polunin*, *W.R. Sykes & L.H.J. Williams 3178*" (E; KYO, photo).

DOTI: "Dotu-Siligarhi, foliage red brown, in rocky stream bed, alt. 4500 ft, 1 Apr 1967, *N. Ecker-Racz*" (US, photo).

C Nepal: MUSTANG: "Tukucha, Kali Gandaki, alt. 10500 ft, 13 Jun 1954, *J.D.A. Stainton*, *W.R. Sykes* and *L.H.J. Williams 1110*" (E, photo).

Selaginella laxistrobila **K.H. Shing**

Figs 4(3A–C), 10A, 23

Selaginella laxistrobila K.H. Shing, Acta Phytotax. Sin. 31: 569. 1993; Zhang 2004; Zhang et al. 2013. **Type.** CHINA. Sichuan: Kanding, jieba, Sewuroug, alt. 3350 m., ad clivum australem in sylvis Quercorum, 2 Aug 1981. *S.S. Kung 6067* (holotype: PE).

Description. Stems 1–6 cm, with creeping main stems and few upright stems over a short distance. Rhizophores restricted to lower part of stem. Main stems branched from near base upward, 0.2–0.4 mm in diam. in lower part. Stems stramineous, angulate, sulcate. Axillary leaves elliptic, 1–1.8 × 0.3–0.7 mm, base exauriculate, margin slightly denticulate, apex acute, not aristate. Ventral leaves ovate-triangular, 1.8–2.3 × 0.8–1.2 mm, acroscopic base enlarged, broader, slightly overlapping stem and branches, margin ciliolate, apex acute. Dorsal leaves ovate, 1.2–1.8 × 0.6–0.8 mm, base subcordate or obtuse, margin ciliolate, apex acuminate. Sporophylls dimorphic, similar to sterile leaves in form and arrangement. Strobili solitary or forked, terminal, lax, dorsiventrally complanate, 10–20 × 3–5 mm. Ventral sporophylls ovate, margin shortly ciliolate, apex acuminate; dorsal sporophylls ovate-lanceolate, margin shortly ciliolate, apex acuminate. Megaspores orange or yellowish orange, surface verrucate; microspores orange, surface verrucate.

Ecology. Terrestrial, evergreen, under shrubs in damp places mixed forests, on rocks, soil banks. Alt. 2650–3200 m.

Distribution in Nepal. C, E.

Nepalese threatened status: not available data.

General distribution. CHINA (Sichuan, Yunnan), INDIA.

Chromosome number. Not available data.

Selected specimens examined:

C Nepal: RASUWA: "between Ghora Tabela and Lama Hotel. 2 Sep 1986, *T. Nakaike 1319*" (PE).

E Nepal: SOLUKHUMBU: "between Goem and Junbesi, Solukhumbu, alt. 2650–3200 m, 9 Oct 1988, *T. Nakaike 3256*" (PE).

***Selaginella bisulcata* Spring**
Figs 5(1A–C), 10B, 24

Selaginella bisulcata Spring, Mém. Acad. Roy. Sci. Belgique 24: 259. 1850; Iwatsuki 1975; Iwatsuki 1988; Dixit 1992; Thapa 2002; Zhang 2004; Zhang et al. 2013; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.

≡ *Lycopodioides bisulcata* (Spring) Kuntze, Revis. Gen. Pl. 2: 826. 1891, as "*bisulcatum*". **Type.** INDIA. N.E. India, Meghalaya, Khasia, *W. Griffith* (mislabelled as "Gorval", i.e. Garhwal, Uttarakhand) (holotype: K).

= *Selaginella bisulcata* var. *spinulosa* Spring, Mém. Acad. Roy. Sci. Belgique 24(2): 260. 1850. **Type.** INDIA. Assam, *Griffith* s.n. (holotype: K).

Description. Stems 20–45 cm, creeping. Rhizophores at intervals throughout stems, located on ventral side in axis branches. Main stems branched from near base upwards, in basal part main stem 1.2–1.8 mm in diam. Main stems subquadrangular, sulcate, branched throughout their length, primary leaves branches arranged 5–8 pairs. Axillary leaves elliptic, 3–4.6 × 1.1–1.6 mm, base exauriculate, margin denticulate or sparsely ciliolate. Ventral leaves asymmetrical, slightly ascending or spreading or deflexed, oblong, 3.2–5 × 1.2–2 mm, apex apiculate, in base margin entire or subentire, denticulate at apex, leaves not overlapping stem and branches, margin ciliolate or denticulate in basal and apical portions, entire in middle. Dorsal leaves asymmetrical, 1–2.4 × 0.6–1.5 mm, base obliquely cuneate, margin sparsely ciliolate, apex mucronate or aristate with arista curved, up to 1/2–4/5 as long as leaf, 0.4–0.8 mm. Strobili solitary, terminal, compact, 6–10 × 3.5–5.5 mm. Sporophylls dimorphic, ventral sporophylls ovate-lanceolate or oblong-ovate, in base dilated, margin ciliolate or lacerate-ciliolate; dorsal sporophylls oblong-lanceolate, carinate, margin ciliolate, apex acuminate or aristate, with sporophyll-pteryx incomplete and ciliolate. Megaspores white-brown, surface smooth; microspores orange, surface verrucate.

Ecology. Evergreen, often in open dry slope areas, or in a little shade in light forest. Alt. 1500–2700 m.

Distribution in Nepal. W, C, E.

Nepalese threatened status: not available data.

General distribution. BHUTAN, CHINA (Sichuan, Yunnan), INDIA (Assam State, Sikkim, Manipur, Meghalaya, Nagaland, West Bengal), INDONESIA, MYANMAR, THAILAND, VIETNAM.

Chromosome number. not available data.

Selected specimens examined:

C Nepal: NUWAKOT: "Chandragiri, near Thankot, Kathmandu, Nuwakot, c. 2000 m, 19 Nov 1986, *T. Nakaike 3855*" (PE 01622152).

KATHMANDU: "Bagmati Zone, Kathmandu Distr., Second khola from the W. side of valley, at edge of low forest, c. 150 m. above and ¼ km SE of Bhangeri, above Gagal Phedim, N.W. of Sankhu, N. E. Kathmandu, 2 Oct 2001, *C.R. Fraser-Jenkins*, *G.B. Tamang 29346* (*FN 5321*)" (US, photo); "Bhangeri, c. 1800–2100 m, 2 Oct

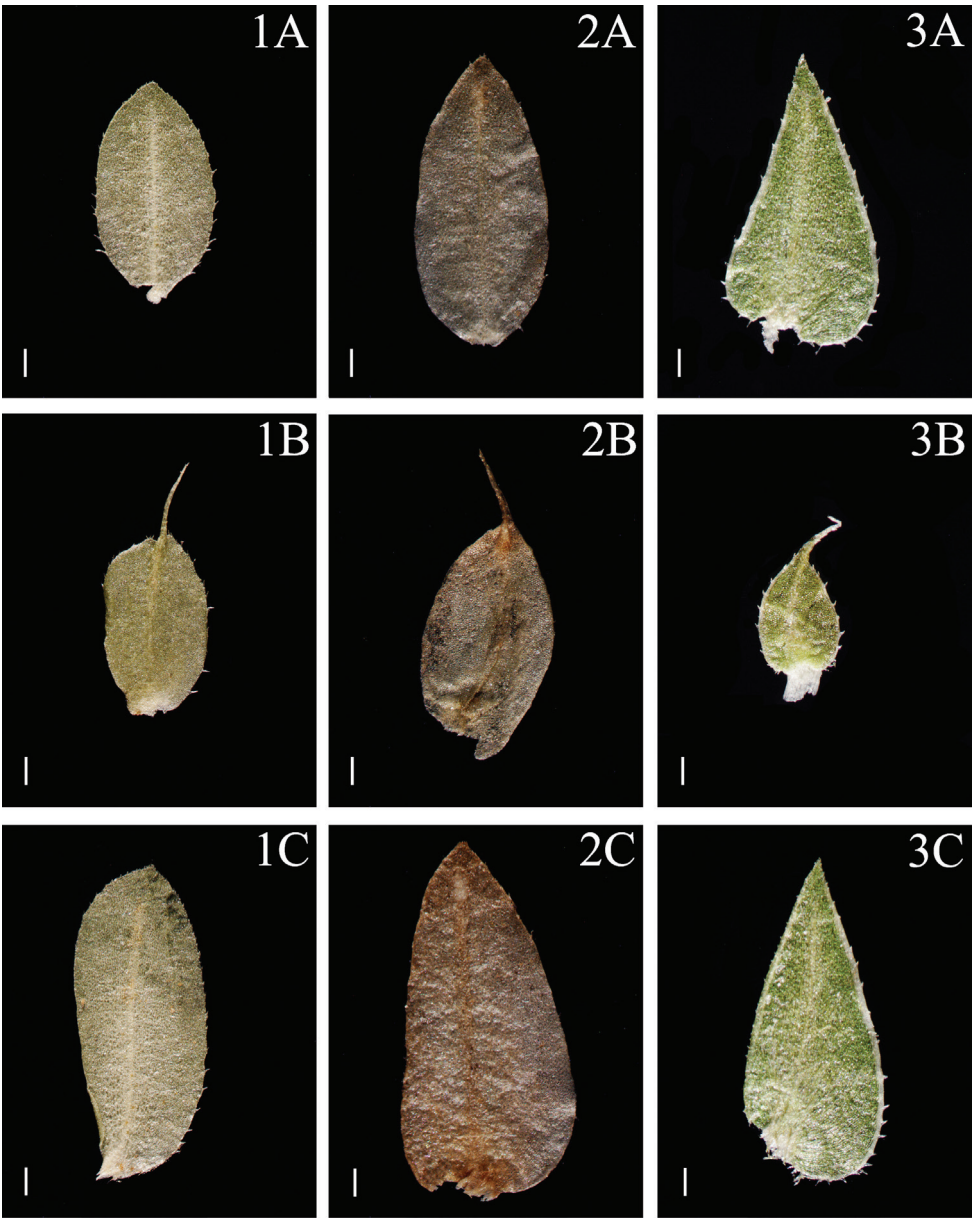

Figure 5. Morphological diversity of the leaves of Nepalese *Sealginella* species **1A–C** *S. bisulcata* (*Nakaike 3786*, PE) **2A–C** *S. pennata* (*Nakaike 3507*, PE) **3A–C** *S. chrysocaulos* (*Nakaike 1058*, PE). A – Axillary leaves, B – Dorsal leaves, C – Ventral leaves. Scale bars: 0.2 mm.

1986, *T. Nakaike 2267*" (PE 01622219); "Bhangeri, c. 1800–2100 m, 2 Oct 1986, *T. Nakaike 2306*" (PE 01622220).

KASKI: "Dhampus, Pokhara, 1000–1500 m. 10 Nov 1988, *T. Nakaike 3786*" (PE 01622148); "Panchase Lekh (Kaski Distr.), n. 834282, alt. 2350 m, 12 Dec 1973, *D.P.*

Joshi, *M.M. Amatya 73/1170*" (KATH); "Pathana (Dhampus)–Tolka, alt. 1850–2050 m, 8 Jul 1983. *H. Ohba* et al. *8330208*" (TI, photo); "Banjan (2035m)–Mt. Panchase (2500m), alt. 2120 m, 28°13'03"–15°12'N, 83°49'56"–47°54'E. 10 Sept 1999, *M. Mikage* et al. *9965087*" (TI, photo).

DOLAKHA: "Tandi, alt. 1500 m. 9 Sep 1954, *A. Zimmermann 1132*" (KYO, photo).

E Nepal: ILAM: "near Ilam, Ilam, c. 1500–2000 m, 5 Nov 1986, *T. Nakaike 3646*" (PE 01622149); "Ilam District, wooded slopes with *Cryptomeria* trees, c. ½ km W of Pashupatinagar, above main road to Ilam, ENE of Ilam, 8 Sep 2001, *C.R. Fraser-Jenkins*, *G.B. Tamang 5405*" (US, photo); "Ilam Distr.: In Oak-forest on slopes above streams, between Chitregaon and Manebhanjyang, c. 4–5 km NE of Pashupatinagar, on footpath to Manebhanjyang, near Indian border, NE of Ilam, 23 Oct 2001, *C.R. Fraser-Jenkins 29608* (*FN 5583*)" (US, photo); "Mai Pokhari, 27°00'N, 87°57'E, alt. 2000 m, 28 Sep 1971, *J.F. Dobremez* DBR NEP *1233*" (E00670678); "Mai Majuwa-Mai Pokhari-Dhara Pani, 4 Dec 1963, *H. Hara* et al." (TI, photo; KYO, photo); "Ilam, 26°57'N, 87°57'E, alt. 1450 m, 28 Sep 1971, *J.F. Dobremez* DBR NEP *1202*" (E00670573); "Ilam District, Pashupatrinagar, alt. 2300 m, 8 Oct 2001. *C.R. Fraser-Jenkins* & *G.B. Tamang 29430* (*FN 5405*)" (KATH).

TAPLEJUNG: "Dumhan, by the Tamur River, alt. 700 m, 31 Sep 1963, *G. Murata*, *M. Togashi*, *T. Tuya*" (TI, photo).

SOLUKHUMBU: "(Solukhumbu Distr.)–Janakpur Zone (Ramechhap Distr.), Namikhil (2300 m)–Chamare (1900 m)–Likhu (a bridge) (1550 m)–Bhandar (2300 m), alt. 1550–2300 m, 27°33'N, 86°23'E –27°34'N, 86°20'E, 10 Sep 1985, *H. Ohba* et al. *8581505*" (TI, photo).

Selaginella pennata (D. Don) Spring

Figs 5(2A–C), 10C, 25

Selaginella pennata (D. Don) Spring, Bull. Acad. Roy. Sci. Bruxelles 10: 232. 1843; Alston 1945; Iwatsuki 1975; Iwatsuki 1988; Dixit 1992; Thapa 2002; Zhang 2004; Zhang et al. 2013; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.

≡ *Lycopodium pennatum* D. Don, Prodr. Fl. Nepal.: 18. 1824.

≡ *Lycopodioides pennata* (D. Don) Kuntze, Revis. Gen. Pl. 1: 827. 1891. **Type.** (lectotype, designated by Alston 1945) NEPAL. «*Lycopodium pennatum* Don Prod. Fl. Nep., Napaul, *Dr. Buchanan*, type specimen of *Lycopodium pennatum* D. Don, det. A.H.G. Alston (BM).

= *Selaginella suberosa* Spring, Monogr. Lycop. 1: 253, no. 191. 1850. **Type.** INDIA. Hindustania superiori, Gorval [error for the Khasi Hills]. *Griffith* s.n. (holotype: K; isotype: P?).

Description. Stems 15–35 cm, suberect. Rhizophores long, thick, restricted to basal and lower part of main stem. Main stems branched slightly above bottom of stem, not very regularly pinnately branched. Stems terete, not sulcate or sulcate in upper

part. Axillary leaves ovate, 1.4–2.3 × 0.6–1.2 mm, base exauriculate, margin ciliolate in basal part, upward subentire, or with rarely cilia. Ventral leaves oblong or oblong-ovate, 1.6–3 × 0.7–1.4 mm, base rotundate, acroscopic base rounded, not overlapping stem and branches, margin sparsely shortly ciliolate, apex acute or apiculate. Dorsal leaves elliptic, sub-falcate, oblique, entire, margin rarely ciliolate, apex aristate with arista curved. Strobili solitary or pairs, terminal, compact, 4–10(–12) × 2.5–5 mm. Sporophylls dimorphic, dorsal sporophylls ovate-oblong, margin denticulate, apex acute, ventral sporophylls ovate, margin entire or denticulate, apex acute. Megaspores whitish, gray or dark brown, surface globose; microspores pale yellow, surface verrucate.

Ecology. Terrestrial, seasonally green, in mixed forests on rather dry mountain slopes. Alt. 500–2400 m.

Distribution Nepal. C, E.

Nepalese threatened status: not available data.

General distribution. CHINA (Yunnan), INDIA (Assam, Manipur, Meghalaya, Sikkim, West Bengal), MYANMAR, THAILAND.

Chromosome number. Not available data.

Selected specimens examined:

C Nepal: SINDHUPALCHOK: "Patibhanjyang to Talangmarang, terrestial growing on moist sandy cliff frequent, alt. 7010 to 7800 ft. (2135–2377 m), 22 Oct 1978, *V.L. Gurung*, *M. Gorkhali 78/680*" (KATH); "Manichur to Patibhanjyang, terrestial, growing on the shady moist place, common, alt. 7010–7800 ft. (2135–2377 m), 21 Oct 1978, *V.L. Gurung*, *M. Gorkhali 78/604 (a)*" (KATH).

DHADING: "Birjet, alt. 1620 m, on mossy rock. 4 Nov 1989. *N.P. Manandhar* 12962" (KATH).

RASUWA: "Mani gaon (on way to Ramche), terrestrial, grown on sandy and wetty slope by the way side abundant, alt. 1230 m, 29 Sep 1977, *Mrs. V.L. Gurung* et al. *77/600*" (KATH); "Mani gaon (on way to Ramche), terrestrial, grown on sandy and wetty slope by the way side abundant, alt. 1230 m, 29 Sep 1977, *Mrs. V.L. Gurung* et al. *77/601*" (KATH); "Rasuwa Distr.: in forest, Domen to Bompu, S. side of Langtang River, between Syabrubensi and bridge below Lama Hotel, lower Langtang Valley, alt. 1600–2200 m. 21 Aug 2001. *C.R. Fraser-Jenkins* & *G.B. Tamang* 29198 *(FN 5173)*" (US, photo).

KATHMANDU: "second Khola from the W. side of valley, at edge of low forest, c. 1500 m above and ¼ km S. E. of Bhangeri, above Gagal Phedim, N.W. of Sankhu, N. E. of Kathmandu, 2 Oct 2001, to *C.R. Fraser-Jenkins* & *G.B. Tamang 29345 (FN 5320)*" (US, photo).

LAMJUNG: "Phelingsanku, 28°13'N, 84°24'E, alt. 650 m, 25 Nov 1970, *J.F. Dobremez* DBR NEP *646*" (E00754783).

KASKI: "Dhampus, Pokhara, alt. 1000–1500 m, 10 Nov 1988, *T. Nakaike 3776*" (PE01622289); "Pokhara, on S side of Phewa Tal, c. 3–4 km. W of «Fishtail Lodge» Hotel, opposite Pokhara «Lakeside» town (Baidam). "Up forested khola at and shortly west of Anadu village. 24 Sep 1997. *C.R. Fraser-Jenkins 25566* (*FN 1544*)" (US, pho-

to); "Pokhara to Hyenda, alt. 1000–1100 m, 20 Sep 1976, *Y. Suehiro 93*, *94*" (KYO, photo); "Naudanda, alt. 1300 m, 21 Sep 1976, *Y. Suehiro 2040*" (KYO, photo).

TANAHUN: "among boulders by stream in forest on W. side of Khane khola valley, between Dumrekharka village and W. part of Chimkeshwori Darrah(mountain) S. of Khanekhola village, c. 3 km W of Anbu Khaireni, W. of Mugling on Damauli and Pokhara, 7 Oct 2000, *C.R. Fraser-Jenkins 28630* (*FN 4605*)" (US, photo).

KATHMANDU: "Jarkini, alt. 1600–1700 m. 29 Sep 1986, *T. Nakaike 2041*" (PE 01622288); **RAMECHAP**: "between Bhandar and Kenja, alt. 2100–1700 m. 7 Oct 1988, *T. Nakaike 3201*" (PE 01622286);

UDAYAPUR: "vers le col de Sukhchauri, boises exposés vers l'est, 1000 m, 7 Nov 1954, *A. Zimmermann 2100*" (KYO, photo).

E Nepal:

SANKHUWASABHA "Simbu, 27°22'N, 87°47'E, alt. 1800 m, 05 Oct 1971, *J.F. Dobremez* DBR NEP *1337*" (E00754787).

SOLUKHUMBU: "Karodo, near Kenja, Solukumbu, alt. c. 1750 m, 22 Oct 1988, *T. Nakaike 3507*" (PE);

PANCHTAR: "Ektin, 27°12'N, 87°53'E, alt. 1500 m, 2 Oct 1971, *J.F. Dobremez* DBR NEP *1300 B*" (E00670574).

MORANG: "Chisapani, on the moist place, stem red rhizome long, alt. 600 m, 26 Sep 1971, *D.P. Joshi 28*" (KATH); "Chisapani, alt. 500 m, 26°50'N, 87°55'E, 26 Sep 1971, *J.F. Dobremez* DBR NEP *1169*" (E00670671).

Selaginella chrysocaulos (Hook. & Grev.) Spring

Figs 5(3A–C), 10D, 26

Selaginella chrysocaulos (Hook. & Grev.) Spring, Bull. Acad. Roy. Sci. Bruxelles 10(1): 232, no. 141. 1843; Iwatsuki 1975; Iwatsuki 1988; Dixit 1992; Thapa 2002; Zhang 2004; Zhang et al. 2013; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.

≡ *Lycopodium chrysocaulos* Hook. & Grev., Bot. Misc. 2: 401. 1831.

≡ *Lycopodioides chrysocaulos* (Hook. & Grev.) H.S. Kung, Fl. Sichuanica 6: 78, pl. 24. 1988. **Type.** NEPAL. *N. Wallich List* n. *127* (holotype: K; isotype: E).

= *Selaginella hypnoides* Spring, Mém. Acad. Roy. Sci. Belgique 24(2): 101. 1850. **Type.** INDIA. Himalaya, *Jacquemont* n. *1041* (holotype: P [00523047]).

= *Selaginella philippina* var. *khasiensis* Baker, J. Bot. 22: 298. 1884. **Type.** INDIA. Mt. Khasia, *Griffith* s.n. (holotype: K?).

= *Selaginella rosenstockii* Hieron., Hedwigia 43: 22. 1904. **Type.** INDIA. India Orientalis: Simla in via Kangra, and Jammu and Kashmir, alt. s. m. inter 1000 et 3000 m. Jun.–Sept. 1856. *Schlagintweit* n. *13256* (syntypes: S [S–P–17948], B [200154162]); Himalaya loco accuratius non indicato, *Warburg 1005* (syntype: B [20 0154160]); Ny nee Jal, s.m. c. 3000 m., *Strachey*, *Winterbottom 9* (syntypes: B [20 0154159], [20 0154157]; Mussoorie, *Jameson* n. *582* partim (syntype: B [20 0154156]; Simla, Regio Temp., *T. Thomson* s.n. (syntype: B [20 0154158]).

Description. Stems 5–25 cm, evergreen or seasonally green, erect, with elongate tuber at base. Rhizophores restricted to base of stem or borne in lower part. Main stems branched from near base or from lower part upward, in basal part main stem 0.5–1 mm in diam. Stems stramineous, terete or subquadrangular, primary leafy branches 6–12 pairs, forked or once or twice pinnately branched, branchlets sparse. Axillary leaves asymmetrical, narrowly ovate or narrowly elliptic, 2–3 × 1–1.4 mm, base exauriculate, in base margin ciliolate, apex blunt-acute. Ventral leaves asymmetrical, ovate-lanceolate, 1.4–2 × 0.8–1.4 mm, leaves on branches slightly ascending or spreading, margin sparsely minutely denticulate or ciliolate at base, apex acute. Dorsal leaves asymmetrical, narrowly ovate, 0.6–1 × 0.3–0.5 mm, base subcordate or obliquely cordate, carinate or not carinate, in basal part margin denticulate or ciliolate, apex acuminate or aristate. Strobili solitary, terminal, compact, 3–5 × 1–1.5 mm. Sporophylls slightly or strongly dimorphic, ventral sporophylls ovate, margin denticulate; dorsal sporophylls with sporophyll-pteryx incomplete and ciliolate, margin ciliolate. Megaspores yellowish, surface verrucate; microspores orange, surface verrucate.

Ecology. On clay soil or on damp shaded banks in forest. Alt. 1400–2900 m.

Distribution in Nepal. W, C, E.

Nepalese threatened status: not available data.

General distribution. BHUTAN, CHINA (Guizhou, Sichuan, Xizang, Yunnan), INDIA (Darjeeling, Himachal Pradesh, Jharkhand, Jammu and Kashmir, Manipur, Meghalaya, Sikkim, Nagaland, Uttarakhand, West Bengal), MALAYSIA (Peninsular), MYANMAR, PAKISTAN, VIETNAM.

Chromosome number. 2n=24 (Loyal 1976; Loyal and Kumar 1984).

Selected specimens examined:

Nepal: "Ghunre, alt. 2400 m, 9 Jul 1972, *A. Maire* AMA *9*" (E00670585); "9 Jul 1972, *A. Maire*, AMA *8*" (E00754794).

W Nepal: MUGU: "Dalupata, Carpinus faginea forest, aspect N 40°W, alt. 2220 m, Incination 35° (S8301), 1 Oct 1983, *H. Tabata* et al. *20718*" (KYO, photo); "Between Toli and Rara, *Aesculus indica* forest along Khatyar Khola river, alt. 2400 m, 8 Sep 1983, *H. Tabata* et al. *24936*" (KYO, photo).

C Nepal KATHMANDU: "Chandragiri, near Thankot, Kathmandu, Nuwakot, c. 2000 m, 19 Nov 1988, *T. Nakaike 3855*" (PE 01622152), "l.c. *3856*" (PE 01593958), "l.c. *3860*" (PE 01634004); "Siwapuri, Kathmandu, Nuwakot, alt. 2500 m, 23 Nov 1988, *T. Nakaike 3877*" (PE 01593956); "Between Siwapuri and Burhanilkanth, Kathmandu, alt. 2000–2550 m, 24 Nov 1988, *T. Nakaike 3890*" (PE 01593968); "Gokarna Ban, Kathmandu, alt. 1350 m, 29 Oct 1988, *T. Nakaike 3551*" (PE 0162223).

NUWAKOT: "Nuwakot: Tare Pati-Gul Bhanjyang, alt. c. 2100–3000 m, 25 Oct 1979, *T. Nakaike 324*" (PE).

DOLAKHA: "Jarsa-jiri above Sikri, Bagmati, alt. 8000 ft, 21 Sep 1968, *Banerjee*, *S. Shrestha 2850*" (US, photo); "En route from Thore Pati, alt. 3560 m to Kutumsang, alt. 2500 m and Bhanjang, alt. 2150 m, alt. 2400 m, 9 Jun 1983, *H. Tabata* et al. *18475*" (KYO, photo); "Rolwaling Khola, Simigaon (1950m)–Sekpa (2300m)–

Kyalche (2700m), alt. 1950–2700 m, 31 Aug 1983, *H. Ohba* et al. *8331658*" (TI, photo; KYO, photo); "near Manga decorah, alt. 7500 ft, 13 Sep 1964, *M.L. Banerjee*, *T.B. Shrestha*, *A.V. Upadhyaya 2739*" (US, photo); "Khare Khola, Phedi Kharka (2100m)–Koplang (2100m)–Khanigaon (1700m), 14 Sep 1983, *M. Wakabayashi*, *M. Suzuki*, *A. Akiyama 8351514* [*862275*]" (KYO, photo); "Near Jiri, Dolakha, c. 1800 m, 25 Oct 1988, *T. Nakaike 3546*" (PE 01634006); Jiri, Dolakha, alt. 2000–2500 m, 3 Oct 1988, *T. Nakaike 3003*" (PE 01593980); "Between Sivalaya and Jiri, Dolakha, alt. 1800–2000 m, 24 Oct 1988, *T. Nakaike 3527*" (PE 01634003); "Between Jiri and Sivalaya, alt. 1800–2000 m, 5 Oct 1988, *T. Nakaike 3089*" (PE 01593984); "Bhote Kosi, vers Simigaon, alt. 1450 m, 14 Sep 1954, *A. Zimmernann 1295*" (KYO, photo).

SYANGJA: "En route from Kare to Chandrakot, alt. 1350–1400 m, 22 Sep 1976, *Y. Suehiro 322*" (KYO, photo).

SINDHUPALCHOK: "above Golu, alt. 2588 m. 27°54'23"N, 85°49'39"E, 11 Sep 2011, *M.F. Watson* et al. EKSIN *74*" (E00576125).

RASUWA: "Between Dhunche and Bharku, c. 2000 m, 29 Aug 1986, *T. Nakaike 1156*" (PE 01634001); "l.c. *1157*" (PE 01634002); "Between Lama Hotel and Sharpugaon, c. 2600–2800 m, 3 Sep 1986, *T. Nakaike 1334*" (PE 01593983), "l.c. *1333*" (PE 01593977), "l.c. *1274*" (PE 01593976)"; "Near Shabru, c. 2400 m, 6 Sep 1986, *T. Nakaike 1387*" (PE 01593998); "Between Bharku and Syabru, c. 2000–2400 m, 29 Aug 1986, *T. Nakaike 1178*" (PE 01593961).

KASKI: "en route from Kare to Chandrakot, alt. 1350–1400 m, 22 Sep 1976, *Y. Suehiro 32* (*III-1/1*)" (PE); "Between Potana and Dhumpus, on the stonehedge, alt. 1850 m, 3 Aug 1983, *H. Tabata* et al. *19164*" (KYO, photo).

KATHMANDU: "Chandragiri, alt. 1600–2000 m, 9 Oct 1986, *T. Nak*aike *2474*" (PE 01593957); "Jarkini, 1600–1700 m, 29 Sep 1986, *T. Nakaike 2005*" (PE 01593964); "Tare Bhir, alt. 1400–1900 m, 4 Oct 1979, *T. Nakaike 56*" (PE 01593970); "Bhangeri, alt. 1800–2100 m, 2 Oct 1986, *T. Nakaike 2284*" (PE 01593972); "Sankhu, alt. 1400 m, 24 Aug 1986, *T. Nakaike 1058*" (PE 01593962); "Tare Bhir, alt. c. 1400–1900 m, 4 Oct 1979, *T. Nakaike 105*" (PE 01593965); "Tare Bhir, alt. 1500–2100 m, 30 Sep 1986, *T. Nakaike 2067*" (PE 01593966); "Mulkharka, alt. c. 1700 m, 2 Oct 1986, *T. Nakaike 2329*" (PE 01634008);

LALITPUR: "Mt. Phulcoki, alt. 1800–2600 m, 17 Sep 1986, *T. Nakaike 1556*" (PE 01634005); "Bajrajogini, alt. 1600 m, 2 Oct 1986, *T. Nakaike 2194*" (PE 01593963); "Phulchoki, south of Kathmandu, on rather dry: ground in light shade, 1500 m, 15 Jun 1972, *H. Hara* et al. *852274*" (TI photo; KYO; photo).

DHADING: "Jamachok, alt. 1500–1800 m, 11 Oct 1986, *T. Nakaike 2518*" (PE 01593979); "Jamachok, alt. 1500 m, 1 Oct 1986, *T. Nakaike 2150*" (PE 01593971); "Kakani, alt. c. 2000 m, 29 Sep 1986, *T. Nakaike 1975*" (PE 01593991); "l.c. *T. Nakaike 1972*" (PE 01709395).

BHAKTAPUR: "Nagarkot, alt. c. 1800 m, 16 Sep 1986, *T. Nakaike 1533*" (PE 01593992).

MAKAWANPUR: "Daman (between Naubise and Hetauda), c. 2400 m. 23 Sep 1986. *T. Nakaike 1861*" (PE 01593973).

RAMECHAP: "Between Bhandar and Kenja, alt. 1700–2100 m. 7 Oct 1988. *T. Nakaike* 3203 (PE 01593974), "l.c. *3168*" (PE 01593999), "l.c. *3207*" (PE 01593975); "Bhandar (2300m)–Deorali (2700m)–Khasrubus (2400m)–Shivalaya (1800m), 27°34'N, 86°20'E–27°36'N, 86°17'E, 6 Aug 1985, *H. Ohba* et al. *8580836*" (TI, photo); "Between Sivalaya and Bhandar, alt. 1800–2500 m, 6 Oct 1988, *T. Nakaike 3125*" (PE 01594000).

E Nepal: DHANKUTA: "Dhankuta-Hilay-Murhay-Sinduwa, 22 Oct 1963, *M. Togashi*, *T. Tuyama s. n.*" (TI, photo).

SANKHUWASABHA: "Khandbari (1150m)–Mani Bhanjyang (1150m)–Sekaha (1450m)–Botebus (1800m), alt. 1150–1800 m, 1954, *H. Ohashi*, *H. Kanai*" (KYO, photo); "Papung-Bir Gaon, along path in light shade, alt. 1600–2000 m, 30 Jun 1972, *H. Kanai* et al. *7253393*" (KYO, photo); "Rive gauche de la Sun Kosi, en montaut a Chyaubaz, 1850 m, 7 Sep 1954, *A. Zimmermann* 1082a" (KYO, photo; PE); "Above Shinbun-Hatia Gola, alt. 1600–2100 m, 3 Aug 1977, *H. Ohashi* et al. *771973*" (TI, photo).

DHANKUTA: "Dhankuta 1300 m – Nigale 1600 m, 4 Jun 1972, *K. Kanai* et al. *725057* [*872266*, *872271*]" (KYO, photo); "Sinduwa, alt. 1100 m, 24 Oct 1963, *H. Hara* et al." (KYO, photo); "Sinduwa, 27°04'N, 87°23'E, alt. 2400 m, 1 Aug 1973, *J.F. Dobremez* DBR NEP *1763*" (E00670592), "l.c. *1750*" (E00670593).

ILAM: "Near Ilam, Ilam, alt. 1500–2000 m, 5 Nov 1988, *T. Nakaike 3671*" (PE); "Mai Pokhari, 27°00'N, 87°57'E, alt. 2000 m, *J.F. Dobremez* DBR NEP *1227*" (E00754786); "l.c. *1229*" (E00670679, E00764780); "Partia Darjeling: Phalut 3600 m – Ratho Chu 2100 m – Ramam 2400 m, along path in dense forest, c. 2100 m, 4 Aug 1972, *K. Kanai* et al. *725717*" (KYO, photo).

TAPLEJUNG: "Ghatte-Khebang, 19 Nov 1963, *H. Hara*, *H. Kanai*, *S. Kurosawa*, *G. Murata*, *M. Togashi*, *T. Tuyama*" (KYO, photo); "Shewaden (2600 m)–Mewa Khola (2100 m)–Papung (2000 m), along path in light shade, alt. c. 2200 m, *H. Kanai* et al. *725350–C*" (KYO, photo); "Taplejung, 27°21'N, 87°41'E, alt. 2000 m, 06 Oct 1971, *J.F. Dobremez* DBR NEP *1344*" (E00670571, E00754795).

TEHRATHUM: "Dor 2600 m – Tute 2300 m, Jun 1972. *H. Kanai* et al. *725494*" (KYO, photo); "Chittre, alt. 2200 m. 27°06'N, 87°25'E, 16 Aug 1972, *J.F. Dobremez* DBR NEP *1495*" (E00670575), "l.c. *1507*" (E00670576), "l.c. *1484*" (E00670577).

SOLUKHUMBU: "Between Basa and Junbesi, Solukhumbu, alt. 2600–3500 m, 16 Oct 1988, *T. Nakaike 3356*" (PE 01593989); "Between Goem and Junbesi, Solukhumbu, alt. 3200–2650 m, 9 Oct 1988, *T. Nakaike 3243*" (PE 016344007); "De Namche Bazar en direction de la Dudh Khosi (Monjo), alt. 2900 m, 17 Oct 1954, *A. Zimmermann 1735*" (KYO, photo).

OKHALDHUNGA: "Tarki a Okhaldunga, alt. 2000 m, 2 Nov 1954, *A. Zimmermann 1991*" (KYO, photo).

***Selaginella ciliaris* (Retz.) Spring**
Figs 6(1A–C), 10E, 27

Selaginella ciliaris (Retz.) Spring, Bull. Acad. Roy. Sci. Bruxelles 10(1): 231, no. 136. 1843; Alston 1945; Panigrahi and Dixit 1968; Iwatsuki 1975; Iwatsuki 1988; Dixit 1992; Thapa 2002; Zhang 2004; Zhang et al. 2013; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.
≡ *Lycopodium ciliare* Retz., Observ. Bot. 5: 32. 1789.
≡ *Lycopodioides ciliaris* (Retz.) Kuntze, Revis. Gen. Pl. 2: 826. 1891, as "*ciliare*". **Type.** SRI LANKA. E. Ceylon, *König* s.n. (holotype LD [1119541]; isotype: K).
= *Lycopodium depressum* Sw., Schrader. J. Bot. 1800(2): 119. 1801.
= *Lycopodium belangeri* Bory, Belang. Voy. Bot. 2: 12, t. 1, f. 2. 1833.
≡ *Selaginella belangeri* (Bory) Spring, Monogr. Lycop. 2: 242. no. 180. 1850.
= *Selaginella exigua* Spring, Monogr. Lycop. 2: 238. no. 175. 1850.
≡ *Lycopodioides exigua* (Spring) Kuntze, Revis. Gen. Pl. 2: 826. 1891. **Type.** MYANMAR. Peninsula indo-chinensi, Mergui, *W. Griffith*, *266* (H. Hooker) (holotype K [001067469]).

Description. Stems 2–5(–8) cm, short-creeping, fertile stem often erect. Rhizophores restricted to lower branches or to middle of main stem. Main stems branched from throughout, branches simple to compound from base of stem, 0.3–0.4 mm in diam. in lower part. Stems terete, sulcate or not sulcate, primary leafy branches 3 or 4 pairs, simple or forked or once pinnately branched. Axillary leaves ovate-obtuse or ovate, 1.2–2 × 0.7–1.1 mm, base exauriculate, margin ciliolate in basal half, upward denticulate, apex slightly acute. Ventral leaves ovate or ovate-lanceolate, 1.4–2 × 1.4–2 mm, in base obtuse, acroscopic base enlarged, broader, margin ciliolate, subentire or minutely denticulate to apex, apex acute. Dorsal leaves ovate, 1.1–1.6 × 0.5–1 mm, slightly carinate, base subcordate or obtuse, margin minutely denticulate, apex acuminate or aristate. Strobili solitary, terminal, compact, 4.5–13 × 2–4.5 mm. Sporophylls dimorphic, ventral sporophylls ovate-triangular, margin ciliolate; dorsal sporophylls ovate-oblong, minutely denticulate and ciliolate. Megaspores yellowish, surface fine reticulate; microspores orange, surface less obviously verrucate.

Ecology. On sandy and clay-slopes at the forest edge. Alt. 60–600 m.

Distribution in Nepal. W, C, E.

Nepalese threatened status: not available data.

General distribution. CHINA (Guangdong, Guangxi, Hainan, Taiwan, Yunnan), INDIA (Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bihar, Chhattisgarh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, West Bengal), MYANMAR, SRI LANKA, BANGLADESH; INDONESIA (Java), PHILIPPINES, THAILAND, VIETNAM, NEW GUINEA, AUSTRALIA.

Chromosome number. x=9; 2n=18 (Jermy et al. 1967).

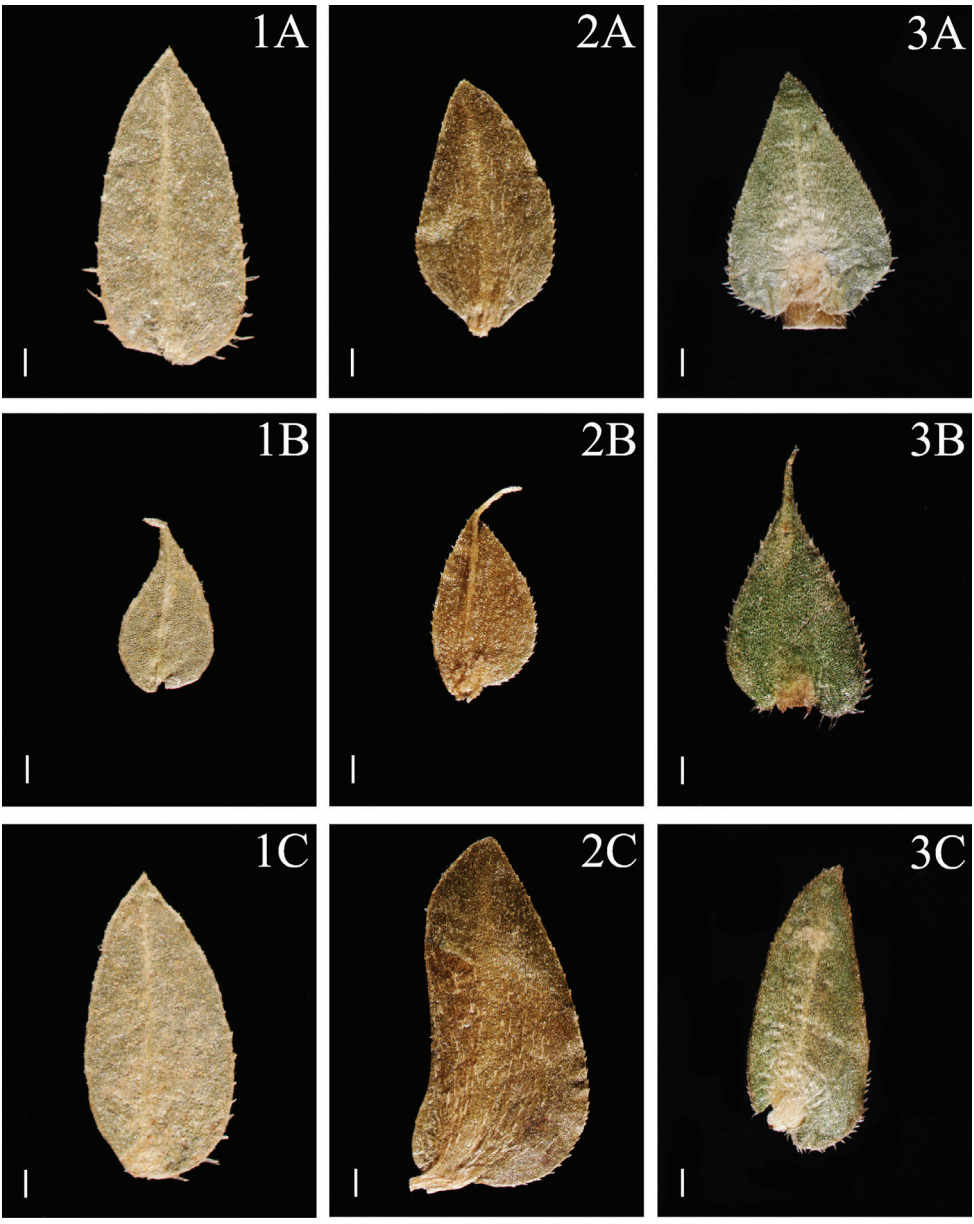

Figure 6. Morphological diversity of the leaves of Nepalese *Sealginella* species **1A–C** *S. ciliaris* (s.n. *1225*, PE) **2A–C** *S. monospora* (*Tabata* et al. *11051*, PE) **3A–C** *S. trichophylla* (*Lu* & *Zhang 27625–B*, PE). A – Axillary leaves, B – Dorsal leaves, C – Ventral leaves. Scale bars: 0.2 mm.

Selected specimens examined:

C Nepal: CHITAWAN: "Tigori (near Bharatpur), alt. c. 180 m, 26 Sep 1986, *T. Nakaike 1910*" (PE 01622170).

***Selaginella monospora* Spring**
Figs 6(2A–C), 10F, 28

Selaginella monospora Spring, Mém. Acad. Roy. Sci. Belgique. 24: 135. 1850; Alston 1945; Panigrahi and Dixit 1968; Iwatsuki 1975; Iwatsuki 1988; Dixit 1992; Thapa 2002; Zhang 2004; Singh and Panigrahi 2005; Zhang et al. 2013; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al.2017.
≡ *Lycopodium monosporum* (Spring) Hook., Bot. Misc. 9: 362. 1857.
≡ *Selaginella plumosa* var. *monospora* (Spring) Baker, J. Bot. 21: 145. 1883. **Type.** (lectotype, designated by Fraser-Jenkins et al. 2017) BHUTAN. Bootan [Khegumpa, N. of Dewangiri (Deotang)], *W. Griffith 391* Journal» [24.1.1838], Herbarium Hookerianum (K).
= *Selaginella gorvalensis* Spring, Mém. Acad. Roy. Sci. Belgique. 24: 256. 1850.
≡ *Lycopodioides gorvalensis* (Spring) Kuntze, Revis. Gen. Pl. 2: 826. 1891. **Type.** INDIA. Gorval: *Griffith* s.n., in error for Khasia (holotype: K).
= *Selaginella microclada* Baker, J. Bot. 22: 246. 1884. **Type.** INDIA. Sikkim, Chongtong, alt. 4000 ft. 22 Jul 1862. *Dr. Anderson 1404* (holotype: K [001067485]).

Description. Stems 35–85 cm, creeping. Rhizophores at intervals throughout length of main stem, borne on ventral side in axils of branches. Main stems branched throughout, pinnately branched. 1.5–2 mm in diam. in lower part. Axillary leaves ovate, narrowly ovate, or narrowly elliptic, 2–3 × 0.8–1.6 mm, base exauriculate, margin denticulate, apex acute. Ventral leaves ovate-triangular or oblong-falcate, 2.6–4.3 × 0.9–1.4 mm, basiscopic base decurrent, margin subentire or entire; acroscopic base enlarged, broader, overlapping stem and branches, margin denticulate, apex subacute. Dorsal leaves ovate-lanceolate or elliptic, 1–1.6 × 0.3– 0.7 mm, carinate or strongly carinate, base obtuse, not peltate, margin denticulate, apex acuminate or shortly aristate. Strobili solitary, terminal, compact, 3–15 × 1.9–5 mm, sporophylls isomorphic, slightly dimorphic to strongly dimorphic. Sporophylls dimorphic, ventral sporophylls ovate-lanceolate, carinate, base dilated, margin denticulate; dorsal sporophylls lanceolate, sharply carinate, margin minutely denticulate, apex acuminate. Megaspores brown, surface verrucate; microspores orange, surface verrucate.

Ecology. On moss covered rocks or on damp slopes in forests, sparse in open slopes on edge of forest. Alt. 1650–3000 m.

Distribution in Nepal. C, E.

Nepalese threatened status: not available data.

General distribution. BHUTAN, CHINA (Guangdong, Guangxi, Guizhou, Hainan, Xizang, Yunnan), INDIA (Assam, Kerala, Manipur, Meghalaya, Tamil Nadu, Sikkim, West Bengal), MYANMAR, THAILAND, VIETNAM.

Chromosome number. Not available data.

Selected specimens examined:

E Nepal: SANKHUWASABHA: "en route from Harelo to Chichila, *Castanopsis hystrix* forest, on the moist rock. alt. 1935 m, 2 Jun 1978, *H. Tabata* et al. *11051*"

(PE); "Above Shinbun-Hatia Gola, alt. 1600–2100 m, 3 Aug 1977, *H. Ohashi* et al. *771954*" (TI, photo); "Seduwa, in shade under rocks, 7 VI 1965. *Banerjee*, *Upadhyay*, *Baskola* 3322" (US, photo); "Seduwa (Kasuwa Khola) prostrate, alt. 3000 ft, 6 May 1965, *Banerjee*, *Upadhyay*, *Baskola 3374*" (US, photo).

SOLUKHUMBHU: "Near Namche, alt. 8000 ft, 9 May 1965, *Banerjee* et al. *3418*" (US, photo); "Near Namche, alt. 8000 ft, 9 May 1965, *Banerjee* et al. *3420*" (US, photo).

TAPLEJUNG: "Khebang below Siling Tzokupa, 20 Nov 1963, *H. Hara* et al." (TI, photo).

ILAM: "Densely forested, rocky stream-gully of Sudhung Khola, shortly below Sudhung khola, shortly below Sudhung, leading south below road, below Sundergaon, W. of Pashupatinagar on Ilam road, 9 Oct 2001, *C.R. Fraser-Jenkins 29549* (*FN 5494*)" (US, photo); "in Oak-forest on slopes above streams, between Chitregaon and Manebhanjyang, c. 4–5 km N.E of Pashupatinagar, on footpath to Manebhanjyang near indian border, N. E. of Ilam, 23 Oct 2001, *C.R. Fraser-Jenkins 29069* (*FN 5584*)" (US, photo).

JHAPA: "c. ½km below and S. of Kuttedara on road to Bhudabare, N. of Charali on road to Phikal and Ilam, NE of Birtamod and NW of Kakkarbhitta, forested Khola (stream-gully), 16 Aug 1998. *C.R. Fraser-Jenkins 26586* (*FN 2564*)" (US, photo).

Selaginella trichophylla **K.H. Shing**

Figs 6(3A–C), 10G, 29

Selaginella trichophylla K.H. Shing, Acta Phytotax. Sin. 31(6): 569, pl. 2. 1993; Zhang et al. 2013.

≡ *Selaginella monospora* Spring subsp. *trichophylla* (K.H. Shing) X.C. Zhang, Fl. Reipubl. Popularis Sin. 6(3): 189. 2004. **Type.** CHINA. Yunnan, Gongshan, Dulongjiang River, alt. 1450–1500 m, in sylvis frondosis, 22 VIII 1982, *Qinghai-Xizang Exped. 9451* (holotype: PE! [00452190]).

= *Selaginella monospora* var. *ciliolata* W.M. Chu, Fl. Yunnan. 20: 719. 2006, syn. nov. **Type.** CHINA. Yunnan: Jingdong Xian, Ailao Shan, Xujiaba, alt. 2450 m., under evergreen broad-leaved forest, 22 Apr 1982, *J.J. He 13352* (holotype: PYU!; isotype: PE!).

Description. Plants 20–35 cm, creeping. Rhizophores at intervals throughout length of main stem, borne on ventral side in axils of branches. Main stems pinnately branched throughout, stramineous, 1.0–1.5 mm in diam., in lower part, stem oval or terete, not sulcate, primary leafy branches 8–12 pairs, once or twice pinnately branched, branches sparse or thick, adjacent primary branches on main stem 1.5–2.5 cm apart. Axillary leaves on branches symmetrical, ovate or ovate triangular, 1.2–3.1 × 0.7–2.3 mm, base exauriculate or slightly subcordate, margin ciliolate at base, apex acute. Dorsal leaves ovate, 1.1–2.6 × 0.6–1.2 mm, slightly carinate, base obtuse or oblique subcordate, not

peltate, margin ciliolate (more densely ciliolate at base), apex aristate. Ventral leaves ovate-triangular, 1.5–3.6 × 0.9–2.1 mm, margin denticulate; basiscopic base in base with few cilia or entire, acroscopic base enlarged, broader, overlapping stem and branches, margin ciliolate, in upper part denticulate, apex acute. Strobili solitary, terminal, compact, dorsiventrally complanate, 4.0–6.5 × 1.2–2.6 mm, sporophylls dimorphic, resupinate, not white-margined; dorsal sporophylls ovate-lanceolate, carinate, margin denticulate, apex acuminate; ventral sporophylls ovate-lanceolate, carinate, margin denticulate. Megaspores whitish surface verrucate or papillate; microspores orange, surface verrucate.

Ecology. On moist cliffs, in evergreen broad-leaved forest. Alt. 1500–1600(2200) m.

Distribution in Nepal. C, E, rare, requiring additional research.

Nepalese threatened status: Data-deficient (DD) according to the IUCN (2001) criteria.

General distribution. BHUTAN ("Rukubi (2600) – Chendebi (2300) – Charikhachor (2250) – Neylong (2200), 14 Apr 1967, *H. Hara*, *H. Kanai*, *G. Murata*, *H. Ohashi*, *O. Tanaka & T. Yamazaki 4105*" (KYO); "Yuto La, between Bumthang and Trongsa, 8500 ft., Shady banks in deciduous forest. *F. Ludlow*, *G. Sherriff*, *J.H. Hicks 17023*" (KYO; L.4328981)), CHINA (Yunnan, Guangxi, Guizhou, Guandong, Hainan), INDIA (Sikkim (E Sikkim District. Above and S. of Penlang Bazaar, below and on way up to Namphung Peak of the Tinjure ridge, W. of Tashi View-Point, Across valley to the north of Gangtok. Just below crest on N. side of densely mixed-forest ridge. 29 Sep 1998. *C.R. Fraser-Jenkins 27054 (FN 3031)*" (L.4328985)), VIETNAM (Cao Bang).

Chromosome number. Not available data.

Selected specimens examined:

C Nepal: **DOLAKHA**: "Jiri, Dolakha, alt. c. 2200 m, 4 Oct 1988, *T. Nakaike 3076*" (PE).

E Nepal: **ILAM**: "Mai Majuwa-Dhara Pani, alt. 1500–1600 m, 4 Dec 1963, *H. Hara* et al." (KUN; L.3498103).

Note. We examined the type and general collections in herbaria PE, KUN and PYU for *S. trichophylla* and *S. monospora* var. *ciliolata*: the taxon described as *S. monospora* var. *ciliolata* W.M. Chu (in Chu 2006) and listed in the "Uncertain taxa" in Flora of China (Zhang et al. 2013: 66) has many similarities in morphological features with *S. trichophylla*. The only distinct feature is the spinules on the upper side of the leaves, but these are not always present and it is likely that this trait is associated with a more humid habitat.

Selaginella repanda (Desv. ex Poir.) Spring

Figs 7(1A–C), 10H, 30

Selaginella repanda (Desv. ex Poir.) Spring, in Gaudich., Voy. Bonité, Bot. 3: 329. 1846; Iwatsuki 1975; Iwatsuki 1988; Dixit 1992; Thapa 2002; Zhang 2004; Zhang et al. 2013; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.

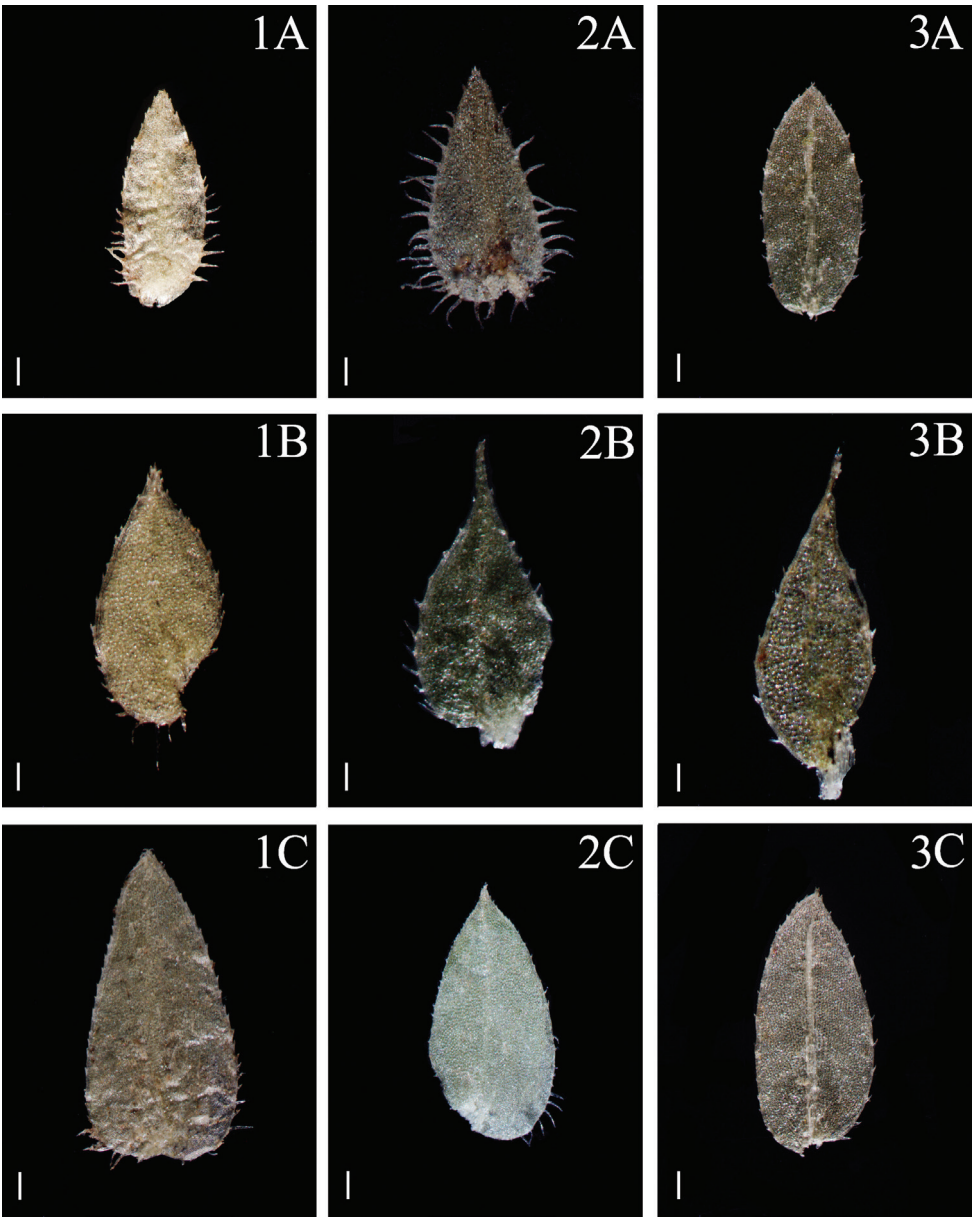

Figure 7. Morphological diversity of the leaves of Nepalese *Sealginella* species **1A–C** *S. repanda* (*Nakaike 3708*, PE) **2A–C** *S. vaginata* (*Nakaike 1102*, PE) **3A–C** *S. chrysorrhizos* (*Nakaike 3708*, PE). A – Axillary leaves, B – Dorsal leaves, C – Ventral leaves. Scale bars: 0.2 mm.

≡ *Lycopodium repandum* Desv. ex Poir., Encycl., Suppl. 3(2): 558. 1814. **Type.** PHILIPPINE. In insulis Philippinis. *Desvaux* s.n. (holotype: P).

= *Lycopodium barbatum* Kaulf., Enum. Filic.: 18. 1824.

≡ *Selaginella barbata* (Kaulf.) Spring, Bull. Acad. Roy. Sci. Bruxelles 10(1): 226. 1843. **Type.** PHILIPPINE. Isl. Manila. *Chamisso* s.n. (?).

= *Lycopodium tetragonostachyum* Wall. ex Hook. & Grev., Bot. Misc. 2: 389. no. 129. 1831.

≡ *Selaginella tetragonostachya* (Wall. ex Hook. & Grev.) Spring, Bull. Acad. Brux. 10: 234, no. 163. 1832. **Type.** BURMA. Mts. of Ava, *Wallich p. p.* (?).

= *Lycopodium tetragonostachyum* var. *major* Grev. & Hook., Bot. Misc. 2: 389. 1832. **Type.** INDIA. Rajemah Mts, of Hindustan. *Dr. Wallich*; Mongher, Dr. Hamilton; Hilly country of Madras. Dr. Wight = *S. radicata* (syntypes: E).

= *Selaginella implexa* J. Scott, J. Agri-Hort. Soc. Ind., N. S., 1(2): 262. 1868. **Type.** INDIA. Parasnath, 2000 ft., Bheerboom and Hills near Balasore (holotype C).

= *Selaginella suberecta* Baker, J. Bot. 22: 245, no. 146. 1884. **Type.** MALAYSIA. Malacca, *Griffith* s.n. (?).

Description. Stems 5–30 cm, suberect to erect. Rhizophores borne from base to upper part of main stem or restricted to creeping rhizomes and stolons, on ventral side in axils of branches. Main stem branches above base, without branching part up to 15 cm, stems oval or terete. Axillary leaves more or less similar to lateral leaves, ovate or ovate-lanceolate, 2–3 × 1–1.4 mm, base exauriculate, margin ciliolate, in upper part subdentate, apex obtuse. Ventral leaves spreading, ovate, 2.2–3 × 1–1.5 mm, subfalcate, rounded at base, basiscopic base with few cilia, acroscopic base rounded, not overlapping stem and branches, margin ciliolate in basal half, in middle and upper part dentate to denticulate, apex acute. Dorsal leaves ovate, imbricate, base cordate, in base margin ciliolate, margin in middle and upper part denticulate, apex acute to acuminate. Strobili tetragonous, submonomorphic, 3–8 × 1.5–3 mm. Sporophylls uniform, submonomorphic or sometimes dorsal sporophylls longer, ovate, margin ciliolate, apex acuminate. Megaspores yellowish orange, baculate, surface regulate or reticulate; microspores orange, surface irregular elevations.

Ecology. In the open or semi-shaded places on rocks or under shrubs on soil banks. Alt. 200–400 m.

Distribution in Nepal. C, E.

Nepalese threatened status: VU (Fraser-Jenkins et al. 2015).

General distribution. CAMBODIA, CHINA (Guangxi, Guizhou, Hainan, Taiwan, Yunnan), INDIA (Andhra Pradesh, Assam State, Bihar, Chhattisgarh, Jharkhand, Karnataka, Madhya Pradesh, Meghalaya, Maharashtra, Mizoram, Nagaland, Odisha, Rajasthan, Sikkim, Tamil Nadu, Uttarakhand, Uttar Pradesh, West Bengal), INDONESIA, LAOS, MALAYSIA, MYANMAR, PHILLIPINES, THAILAND, VIETNAM.

Chromosome number. Not available data.

Selected specimens examined:

C Nepal: MAKAWANPUR: "Suntari, W. of Hetauda, Makawanpur, alt. c. 200 m, 8 Nov 1988, *T. Nakaike 3719*" (PE); "l.c. *T. Nakaike 3708*" (PE); "l.c. *T. Nakaike 3703*" (PE); "l.c. *T. Nakaike 3715*" (PE).

***Selaginella vaginata* Spring**
Figs 7(2A–C), 10I, 31

Selaginella vaginata Spring, Mém. Acad. Roy. Sci. Belgique 24: 87. 1850; Iwatsuki 1975; Iwatsuki 1988; Dixit 1992; Thapa 2002; Zhang 2004; Zhang et al. 2013; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.

≡ *Lycopodioides vaginata* (Spring) Kuntze, Rev. Gen. Pl. 1: 827. 1891. **Type.** (lectotype, designated by Fraser-Jenkins et al. 2017) INDIA. NE India, Meghalaya, Khasiya (Khasia) [cited by Spring as "Gorval" i. e. Garhwal, Uttarakhand, in error], *W. Griffith* (K). Also cited as syntypes were Bhutan, "Bootan, W. Griffith" (K); and South India, Tamil Nadu, "Nelligheries [Nilgiris], *G.S. Perottet 642* (P [= *S. radicata*]).

= *Selaginella thomsonii* Hieron, Hedwigia 43: 38. 1904. **Type.** INDIA. India orientalis: habitat in montibus Khasia, alt. s.m. 4–6000 feet, regione temperate, *J.D. Hooker* et *T. Thomson* (holotype: K?; isotype: B [20 0176901]).

Description. Stems 3.5–10 cm, creeping, fertile stems erect. Rhizophores restricted at intervals throughout length of creeping stem and branches and to lower part of erect fertile branches, borne on ventral side in axils of branches. Main stems branched throughout, 0.2–0.4 mm in diam. in lower part. Stem stramineous, terete, sulcate or not, branches few; erect fertile stems pinnately branched throughout. Axillary leaves ovate-triangular, 1.2–2.5 × 0.5–1.5 mm, base exauriculate, margin ciliolate in basal part, subentire in middle and upper part. Ventral leaves ovate-lanceolate or oblong-falcate, 1.6–3.2 × 0.8–1.5 mm, basiscopic base rounded, margin denticulate in basal half, denticulate upward; acroscopic base endlanged, broadly overlapping stem and branches, margin ciliolate, sparsely long ciliolate at base, apex acute. Dorsal leaves ovate-lanceolate, 0.8–2.3 × 0.4–1.1 mm, imbricate, base subcordate, cuneate, or obtuse, not peltate, margin long ciliolate at base, shortly ciliolate (rarely long ciliolate) upward, apex acuminate or aristate. Strobili solitary or in pairs, terminal, 10–15(–40) × 2–3.5 mm. Sporophylls dimorphic or slightly dimorphic, dorsal sporophylls ovate-lanceolate, margin ciliolate or denticulate, apex acuminate; ventral sporophylls ovate-lanceolate, margin denticulate or ciliolate, apex acuminate. Megaspores yellowish, surface verrucate; microspores orange, surface verrucate and rugate.

Ecology. Terrestrial or epilithic, forming a carpet on vertical banks and rocks evergreen or seasonally green. Alt. 500–2900 m.

Distribution in Nepal. W, C, E.

Nepalese threatened status: not available data.

General distribution. BANGLADESH, BHUTAN, CAMBODIA, CHINA (Beijing, Chongqing, S Gansu, Guangxi, Guizhou, Henan, Shaanxi, Sichuan, Xizang, Yunnan), INDIA (Assam State, Chhattisgarh, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Madhya Pradesh, Manipur, Meghalaya, Nagaland, Odisha, Sikkim, Tripura, Uttarakhand, West Bengal), LAOS, MYANMAR, PAKISTAN, THAILAND, VIETNAM.

Chromosome number. Not available data.

Selected specimens examined:

C Nepal: KASKI: "Mahendra Cave, Pokhara, alt. c. 700 m, 11 Nov 1988, *T. Nakaike 3829*" (PE).

MAKAWANPUR: "[Pisulin] Fishling, near Mugling, Gorkha, alt. c. 300 m, 12 Nov 1988, *T. Nakaike 3830*" (PE).

PALPA/SYANGJA: "Angahora, between Butwal and Pokhara, alt. c. 650 m, 9 Nov 1988, *T. Nakaike 3732*" (PE); "Bategora, between Butwal and Pokhara, alt. c. 700 m, 9 Nov 1988, *T. Nakaike 3736*" (PE).

RAMECHAP: "between Bhandar and Kenja, alt. 2100–1700 m, 7 Oct 1988, *T. Nakaike 3160*" (PE).

KATHMANDU: "near Tribhuwan Airport, alt. c. 1300 m, 15 Sep 1986, *T. Nakaike 1506*" (PE); "Nagarjun, alt. c. 1400 m, 26 Aug 1986, *T. Nakaike 1102*" (PE); "Swayambhunath, alt. c. 1400 m, 7 Oct 1986, *T. Nakaike 2429*" (PE).

CHITAWAN: "Muglin [Mugling] (between Kathmandu and Pokhara), alt. c. 280 m, 26 Sep 1986, *T. Nakaike 1929*" (PE).

E Nepal: SOLUKHUMBU: "near Junbesi, Solukhumbu, alt. c. 2900 m, 20 Oct 1988, *T. Nakaike 3453*" (PE); "Karodo, near Kenja, Solukumbu, alt. c. 1750 m, 22 Oct 1988, *T. Nakaike* 3505" (PE); "Karodo, near Kenja, Solukumbu, alt. c. 1750 m, 22 Oct 1988, *T. Nakaike 3495*" (PE).

TAPLEJUNG: "Shewaden (2600 m)–Mewa Khola (2100 m)–Papung (2000 m), along path in light shade, alt. c. 2200 m, 26 Jun 1972, *H. Kanai* et al. *725351*" (TI, photo; KYO, photo); "Ghatte-Khebang, 19 Nov 1963, *H. Hara* et al." (TI, photo); "Bharomdin-Tharpu, 25 Nov 1963, *H. Hara* et al." (KYO, photo); "Selap-Zongi-Walunchung Gola, 10 Nov 1963, *H. Kanai* et al. s.n." (KYO, photo); "Ghatte-Khebang, 19 Nov 1963, *H. Hara* et al."(KYO, photo).

SANKHUWASABHA: "Papung-Bir Gaon, along path in light shade, alt. 1600–2000 m, 30 Jun 1972, *H. Kanai* et al. *7253393*" (TI); "Papung (2000 m)–Bir Gaon (1600 m)–Sangrati Pati (1050 m), alt. 1300 m, 26 Aug 1977, *H. Ohashi* et al. *772767*" (TI, photo); "Papung 2000 m-Bir Gaon 1600 m, 30 Jun 1972, *H. Kanai* et al. *725393* [*873274*]" (KYO, photo).

ILAM: "Mai Majuwa-Mai Pokhari-Dhara Pani, 4 Dec 1963, *H. Hara* et al." (KYO, photo); "Bilbatay Bhanjang-Tinjuray-Hati Sar, 27 Oct 1963, *H. Hara* et al. s.n." (KYO, photo);

BHOJPUR: "Birgaon 1600 m-Suju Khola 1400 m-Dingla 1000 m, 1 Jul 1972, *H. Kanai* et al. *725426*" (KYO, photo); "Dingla 1000 m-Doban 800 m, on muddy rock along path in shade, 2 Jul 1972, *H. Kanai* et al. *725456*" (KYO, photo); "Birgaon-Dingla, alt. 1600–1000 m, 01 Jul 1972, *K. Ohashi* et al. *725426*" (E00670675).

DHANKUTA: "Teku Nala 800 m-Tamur Bridge 300 m, 9 Jul 1972, *H. Kanai* et al. *725511*" (KYO, photo); "Dhankuta, 26°50'N, 87°20'E, alt. 400 m, 11 Oct 1971, *J.F. Dobremez* DBR NEP *1370*" (E00670683).

SUNSARI: "Dharan, 26°49'N, 87°18'E, alt. 600 m, 13 Aug 1972, *J.F. Dobremez* DBR NEP *1442*" (E00670587).

***Selaginella chrysorrhizos* Spring**
Figs 7(3A–C), 11A, 32

Selaginella chrysorrhizos Spring, Monogr. Lycop. 2: 251, no. 189. 1850, p. p.; Iwatsuki 1975; Dixit 1992; Thapa 2002; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.
Type. (lectotype, designated by Fraser-Jenkins et al. 2017) Assam, *Griffith 141* (K).
= *Selaginella panchghaniana* R.D. Dixit, Bull. Bot. Surv. India 25(1–4): 226, t. 1, f. 3. 1985; Dixit 1992. **Type.** INDIA. Maharashtra-Mahabaleshwar: Panchghani, 7 Nov 1966, *Panigrahi 11739* (holotype: BSA).

Description. Stems 8–12 cm, evergreen or seasonally green, suberect. Rhizophores restricted to base of stem. Main stems branched from near base or from lower part upward, in basal part main stem 0.5–1.1 mm in diam. Stems glabrous, glossy yellow, sulcate, primary leafy branches 5–8 pairs, forked or once or twice pinnately branched. Axillary leaves ovate-oblong, 1.0–2.0 × 0.5–0.8 in base slightly cuneate, margin denticulate, apex obtuse. Ventral leaves ovate-oblong, 0.6–0.8 × 1–2 mm, ascending, acroscopic base ovate-oblong, slightly dilated, imbricate, distantly rotundate at the base, margin denticulate, basiscopic base, entire, except apices, apex obtuse. Dorsal leaves ovate, 1.8–2 × 0.5–0.8 mm, subfalcate, margin denticulate, apex shortly cuspidate. Strobili solitary, terminal, compact, 3–7 × 1.5–2 mm. Sporophylls dimorphic, ventral sporophylls ovate, aristate, margin ciliate; dorsal sporophylls oblong, obtuse, margin ciliate-dentate. Megaspores dark-brown, surface verrucate; microspores pale-brown, surface verrucate.

Ecology. On banks and on large stones. Alt. 200–2000 m.

Distribution in Nepal. W, C, E.

Nepalese threatened status: not available data.

General distribution. BANGLADESH, BHUTAN, INDIA (Assam, Kerala, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Sikkim, West Bengal), LAOS, MYANMAR, THAILAND, VIETNAM.

Chromosome number. Not available data.

Selected specimens examined:

C Nepal: KASKI: "Bhoot Bridge, between Butwal and Pokhara, alt. c. 300 m, 9 Nov 1988, *T. Nakaike 3723*" (PE).

MAKAWANPUR: "Pisulin [Fishling], near Muglin, Gorkha [Makawanpur District], alt. c. 300 m, 12 Nov 1988, *T. Nakaike 3831*" (PE).

E Nepal: SOLUKHUMBHU: "between Junbesi and Rachowa, Solukumbu, alt. 2600–3400 m, 12 Dec 1988, *T. Nakaike 3304*" (PE).

SANKHUWASABHA: Simbu, 27°22'N, 87°47'E, alt. 1800 m, 5 Dec 1971, *J.F. Dobremez* DBR NEP *1335*" (E00754784); "Sunaturi, W. of Hetauda, Makawanpur, alt. c. 200 m, 8 Nov 1988, *T. Nakaike 3702*" (PE); " l.c. *3698*" (PE); "l.c. *3720*" (PE); "l.c. *3706*" (PE); "Simbu, 27°22'N, 87°47'E, alt. 2000 m, 5 Dec 1971, *J.F. Dobremez* DBR NEP *1333*" (E00670601, E00754800); "Simbu, 27°22'N, 87°47'E, alt. 1800 m, 5 Oct 1971, *J.F. Dobremez* DBR NEP *1335*" (E00670602).

***Selaginella reticulata* (Hook. & Grev.) Spring**
Figs 8(1A–C), 11B, 33

Selaginella reticulata (Hook. & Grev.) Spring, Bull. Acad. Roy. Sci. Bruxelles 10(1): 233. 1843; Alston 1945; Dixit 1992; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017.

≡ *Lycopodium reticulatum* Hook. & Grev., Bot. Misc. 2: 402. 1831. **Type.** MYANMAR. Mt. Ava. *Dr. Wallich* s.n. (holotype: K [001067446]).

= *S. nudicaulis* Spring, Monogr. Lyc. II: 235. 1850.

= *S. rajasthanensis* Gena, Bhardwaja & A.K. Yadav, Amer. Fern J. 69(4): 119. 1979. **Type.** INDIA. Kundakhon, Shahabad, Kota, Rajasthan, growing on an isolated moist rock, Sep 1977, *C.B. Gena*, *A.K. Yadav* (holotype: PUN (PYN 2610); isotypes: Pteridophyte Biology Lab. Govt. College, Ajmer, India (N° PBL/77/S1-6/28/671); B; BM [001038102]; CAL; K [001067491]; LWF; NY; US [00134391]).

= *Selaginella jainii* R.D. Dixit, Bull. Bot. Surv. India 25(4-Jan): 225, f. 2 A–H. 1985. **Type.** INDIA. Madhya Pradesh, Bilaspur: Siang, 22 Feb 1972, *Panigrahi 16838 A*, *Plant number-2* (holotype: CAL); Madhya Pradesh, Bilaspur: Siang, 22 Feb 1972, *Panigrahi 16838 B* (isotype: BSA).

= *Selaginella panigrahii* R.D. Dixit, Bull. Bot. Surv. India 25(4-Jan): 226, f. 4. A–H. 1985; Dixit 1992. **Type.** INDIA. Madhya Pradesh, Bastar-Kutumsar: Kanger valley, 19 Fed 1963, *Panigrahi 1119* (holotype: CAL; isotype: BSA).

= *S. nairii* R.D. Dixit, Bull. Bot. Surv. India 26(2-Jan): 106. 1985; Dixit 1992. **Type.** INDIA. Orissa, Jeypore, c. 850 m., 17 Sep 1970, *Nair 40637*" (holotype: CAL); INDIA. Orissa, Jeypore, c. 850 m., 17 Sep 1970, *Nair 40637A* (isotype: CAL); INDIA. Orissa, Devighat, 900 m., 22 Sep 1970, *Nair 40692* (paratype: CAL).

Description. Stems 6–15 cm, erect or suberect. Rhizophores in basal part or one-third creeping stem and branches, on ventral side in axils of stem branches. Main stems, much branched, slender, primary branches on intervals, 0.8–1.2 mm in diam. in lower part, second branches simple or forked. Axillary leaves, ovate, 0.9–1.3 × 0.5–0.8 mm, base rotundate, margin dentate, apex subacute. Ventral leaves ovate, 1.7–2 × 0.7–1 mm, base rotundate, basiscopic base slightly denticulate, acroscopic base rounded, not overlapping stem and branches, margin denticulate, apex subobtuse to subacute. Dorsal leaves ovate, 0.7–1 × 0.3–0.5 mm, oblique, margin thickened, distantly serrulate, apex acute to very slightly acuminate. Strobili solitary, terminal, compact, 4–7 × 1.5–3 mm. Sporophylls dimorphic, dorsal sporophylls ovate-oblong, margin ciliolate, apex acuminate; ventral sporophylls ovate, sub-pellucid, margin ciliolate, apex shortly acute. Megaspore yellow or dark-brown, surface granulose; microspores orange, surface smooth granulose.

Ecology. Growing in groups on moist shaded rocks and banks at the bases of hills. Alt. 1100–3700 m.

Distribution in Nepal. W, C, E.

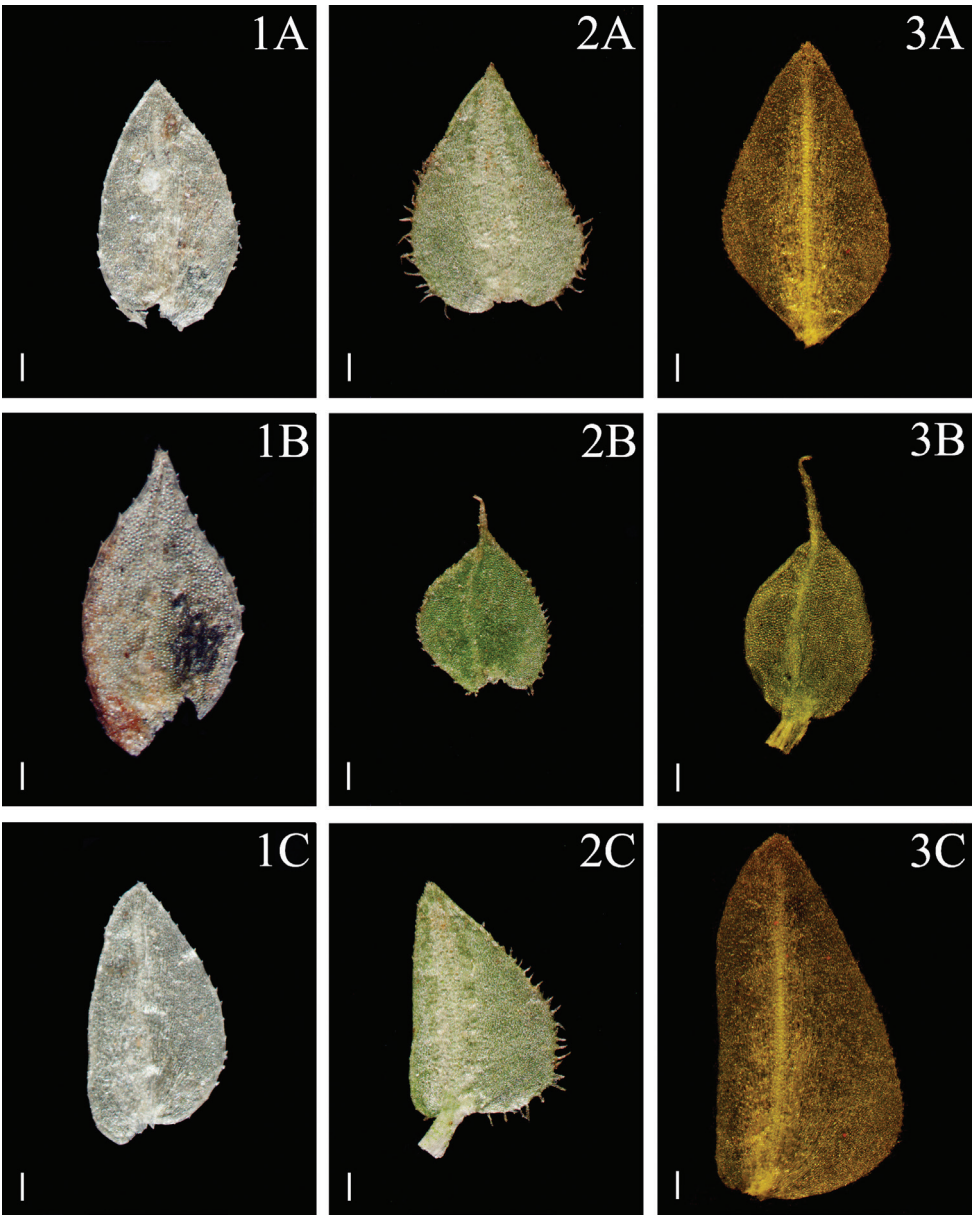

Figure 8. Morphological diversity of the leaves of Nepalese *Sealginella* species **1A–C** *S. reticulata* (*Nakaike 1760*, PE) **2A–C** *S. subdiaphana* (*Zhang 5*, PE) **3A–C** *S. tenuifolia* (*PE-Xizang Exped. PE6280*, PE). A – Axillary leaves, B – Dorsal leaves, C – Ventral leaves. Scale bars: 0.2 mm.

Nepalese threatened status: not available data.

General distribution. BANGLADESH, BHUTAN, INDIA (Assam State, Chhattisgarh, Jammu and Kashmir, Kerala, Madhya Pradesh, Meghalaya, Odisha, Rajasthan, Sikkim, Tamil Nadu, Uttarakhand, West Bengal), MYANMAR.

Chromosome number. Not available data.

Selected specimens examined:

C Nepal: KASKI: "below Mahendra Pul Power-house, N part of Pokhara. Among rocks and below cliffs on both sides of river at N entrance to Seti river gorge, 5 Jan 1998, *C.R. Fraser-Jenkins*, *L.B. Tamang*, *G. Pariyar 25841* (*FN 1819*)" (US, photo).

DOLAKHA: "Jiri, Dolakha, alt. 2000–2500 m, 3 Oct 1988, *T. Nakaike 3064*" (PE); "Jiri, Dolakha, alt. c. 2200 m, 4 Oct 1988, *T. Nakaike 3075*" "l.c. *3076*" (PE). "near Pashupatinath, alt. c. 1340 m, 5 Oct 1979, *T. Nakaike 117*" (PE); "Pasupatinath. 21 Sep 1986, *T. Nakaike 1760*" (PE).

Selaginella subdiaphana (Wall. ex Hook. & Grev.) Spring

Figs 8(2A–C), 11C, 34

Selaginella subdiaphana (Wall. ex Hook. & Grev.) Spring, Bull. Acad. Roy. Soc. Brux. 10: 232. 1843; Iwatsuki 1988; Dixit 1992; Thapa 2002; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017; Zhang 2018.

≡ *Lycopodium subdiaphanum* Wall. ex Hook. & Grev., Bot. Misc. 2: 401. 1831.

– *Lycopodium subdiaphanum* Wall. nom. nud. **Type.** INDIA. Montains of Sylhet and Kamoon. *Dr. Wallich n. 136* (syntypes: K; B [20 0147161–A]).

= *Selaginella aggesta* Spring, Monogr. Lyc. II: 89, no. 31. 1850. **Type.** INDIA. Gorval, *Griffith* (holotype: K [001067489]).

= *Selaginella glauca* Spring, Mém. Acad. Roy. Sci. Belgique 24(2): 252. 1850. **Type.** INDIA. Imperio Assam. *Mack* (H. Hooker) (holotype: K?).

= *Selaginella schlagintweitii* Hieron., Bot. Jahrb. Engl. 50: 2, 41, n. 17. 1913. **Type.** INDIA. Khasia, X 1855, *Schlagintweit 117* (holotype: B?).

= *Selaginella namdaphaensis* Sarn. Singh & Panigrahi, Ferns Fern-Allies Arunachal Pradesh 1: 64. 2005. **Type**. INDIA. Tirap District "[now Changlang District]", Miao-Vijaynagar, 40th-41st mile, 800 m., 30 Sep 1980, *S. Singh 74317* (holotype: CAL; isotype: ASSAM).

Description. Stems 10–35 cm, creeping or suberect. Rhizophores restricted to lower one-third part of main stems, 0.8–2.1 mm in diam. in lower part. Stem slender, sulcate. Axillary leaves ovate, 1.5–2.8 × 0.5–1.8 mm, in basal part cordate, margin in basal part ciliolate, in middle and upper dentate to denticulate, apex acuminate. Ventral leaves ovate to ovate-lanceolate, 1.7–3.2 × 0.8–1.7 mm, in base slightly auriculate, basiscopic base entire, acroscopic base endlanged, broadly overlapping stem and branches, margin ciliate-dentate at base, entire towards apex, apex subobtuse. Dorsal leaves ovate, 1.2–1.6 × 0.5–0.7 mm base obtuse or slightly subcordate, margin ciliolate to denticulate, apex acute to short acuminate. Strobili solitary, terminal, compact, 4.0–8.2 × 2.0–4.0 mm. Sporophylls dimorphic, dorsal sporophylls ovate, margin den-

ticulate, sub-acute; ventral sporophylls ovate, margin ciliolate, apex acute. Megaspores bright red, surface warty; microspore slightly-orangy red, surface warty.

Ecology. On damp sheltered earth banks. Alt. 350–2500 m.

Distribution in Nepal. W, C, E.

Nepalese threatened status: not available data.

General distribution. BHUTAN, CHINA (Yunnan, Xizang (Naramu County)), INDIA (Assam State, Himachal Pradesh, Jammu and Kashmir, Manipur, Meghalaya, Nagaland, ?Odisha, Punjab, Sikkim, Uttarakhand, West Bengal).

Chromosome number. 2n=16 (Loyal 1976; Loyal and Kumar 1984).

Selected specimens examined:

W Nepal: DANG: "Between Kurpani and Ghorai, alt. 4000 ft, 4 Sep 1952, *O. Polunin*, *W.R. Sykes & L.H.J. Williams 1331*" (KYO, photo).

C Nepal: RASUWA: "Langtang: between Ramche and Betrawati, 800–1800 m, 9 Sep 1986, *T. Nakaike 1427*" (PE).

KASKI: "en route from Huenda to Naudanda, alt. 1100–1300 m, 21 Sep 1976, *Y. Suehiro 190*" (KYO, photo); "l.c. *Y. Suehiro 184*(*II-1*)" (PE); "Chomrong, alt. 2200 m, 26 Sep 1976, *Y. Suehiro 2298* (*Q4-I*)" (KYO, photo).

SYANGJA: "en route from Hyenda to Naudanda, alt. 1100–1300 m, 21 Sep 1976, *Y. Suehiro 204*" (TI, photo).

KATHMANDU: "Gokarna Ban, Kathmandu, alt. 1350 m, 29 Oct 1988, *T. Nakaike 3559*" (PE); "l.c. *3551*" (PE); "Kathmandu, alt. 1350 m, 3 Sep 1954, *A. Zimmermann 1005*" (KYO, photo).

MAKAWANPUR: "Balephi Khola, 27°50'N, 85°46'E, alt. 1000 m, 22 Aug 1971, *J.F. Dobremez* DBR NEP *829*" (E00670681).

NUWAKOT: "Berdawati [Betrawati], alt. 850 m, 15 Sep 1972, *A. Maire* AMA *450*" (E00670578);

E Nepal: TAPLEJUNG: "Shewaden (2600 m)–Mewa Khola (2100 m)–Papung (2000 m), alt. c. 2400 m, 29 Jun 1972, *H. Kanai* et al. *725350B* [*873274*]" (KYO, photo).

SANKHUWASABHA: "Telok, 27°22'N, 87°50'E, alt. 1200 m, *J.F. Dobremez* DBR NEP *1323*"(E00754785); "Sankhuwasabha Distr.: Khandbari (1150 m)–Mani Bhanjyang (1150 m)–Sekaha (1450 m)–Botebus (1800 m), 27 Jul 1977, *H. Ohashi* et al. *771545*" (TI, photo).

DHANKUTA: "Dhankuta, 26°50'N, 87°20'E, alt. 400 m, 11 Oct 1971, *J.F. Dobremez* DBR NEP *1371*" (E00670582, E00670586); "Chittre, 27°06'N, 87°25'E, alt. 2200 m, *J.F. Dobremez* DBR NEP *1483*"(E00668256).

SUNSARI: "Dharan-Sanguri Bhanjyang, alt. 1300 m, 2 Jun 1972, *H. Kanai* et al. *725032*" (E00670676); "Dharan, 26°49'N, 87°18'E, alt. 800 m, 04 Sep 1971, *J.F. Dobremez* DBR NEP *1779*" (E00670604); "Dharan 400 m-Sanguri Bhanjyang 1300 m, 2 Jun 1972, *H. Kanai* et al. *725032* [*872266*]" (KYO, photo).

MORANG: "Chisapini, alt. 500 m, 26°50'N, 87°55'E, *J.F. Dobremez* DBR NEP *1170*"(E00670677 & E00754782).

***Selaginella tenuifolia* Spring**
Figs 8(3A–C), 11D, 35

Selaginella tenuifolia Spring, Mém. Bull. Acad. Roy. Sci. Belgique 24(2): 253, n. 192. 1850; Alston 1945; Iwatsuki 1975; Iwatsuki 1988; Dixit 1992; Thapa 2002; Singh and Panigrahi 2005; Fraser-Jenkins et al. 2015; Fraser-Jenkins et al. 2017; Zhang 2018. **Type.** "Mishmi Hills, *Griffith*" (syntype: K), INDIA. Khasi Hills (cited by Spring as "Gorval" in error), *Griffith* (syntype: K).

= *Selaginella aureola* Spring, Mém. Acad. Sci. Brux. 24: 244. no. 182. 1850; Alston 1945. **Type.** (lectotype, designated by Fraser-Jenkins et al. 2015) INDIA. Churra-Punjee, Khasya, [W.] *Griffith* (*182*), [in 1835], Herbarium Hookerianum 1867 (K).

Description. Stems 10–20 cm, erect. Rhizophores restricted to lower one-third part of main stems, very slender, long, 0.9–1.3 mm in diam. in lower part, lateral branches forked a few times. Stem slender, glabrous, stramineous, pinnately branched. Axillary leaves ovate or slightly ovate-lanceolate, 2.5–3.5 × 1.5–2.0 mm, margin denticulate in basal part, apex acute. Ventral leaves ovate, 3.5–4.5 × 2.0–2.8 mm oblique, in base cordate, acroscopic base endlanged, broadly overlapping stem and branches, margin denticulate, basiscopic base rounded, margin entire, apex sub-obtuse. Dorsal leaves ovate, 1.4–2.0 × 1.0–1.5 mm, oblique, in base subrounded, margin minutely dentate, apex aristate. Strobili solitary, terminal, compact, 4–8 × 1–2.5 mm. Sporophylls dimorphic, dorsal sporophylls ovate-oblong, spreading, in basal part slightly longer than apical, margin denticulate; ventral sporophylls ovate, with round base, margin denticulate, apex aristate. Megaspores brownish, surface verrucate; microspores yellowish-brown, surface irregularly verrucate.

Ecology. Terrestrial or epilithic, seasonally green, scattered in moist shady places or clayey soils in forest. Alt. 700–2200 m.

Distribution in Nepal. C, E.

Nepalese threatened status: NT (Fraser-Jenkins et al. 2015).

General distribution. CHINA (Xizang), INDIA (Assam State, Meghalaya, Sikkim, West Bengal), MYANMAR, THAILAND.

Chromosome number. Not available data.

Selected specimens examined:

C Nepal: DOLAKHA: "Jiri, Dolakha, alt. 2000–2500 m, 3 Oct 1988, *T. Nakaike 3065*" (PE); "Jiri, Dolakha, alt. 2000–2500 m, 3 Oct 1988, *T. Nakaike 3061*" (PE).

MAKAWANPUR: "above Liot village, Basmari, c. 5 km W of Hetauda, off Narayanghat road. Densely sal-forested and rocky stream-gully on slope of first range of foothills beyond (N of) the Churiya Ghats. On rocks in forest, 24 Sep 1997, *C.R. Fraser-Jenkins* et al. *25756 (FN 1734)*" (US, photo).

E Nepal: TAPLEJUNG: "Bhandukay-Yamphodin-Ghatte, 16 Nov 1963, *H. Hara* et al." (TI, photo); "Khebang-below Siling Tzokupa, 20 Nov 1963, *H. Hara* et al." (KUN, TI photo).

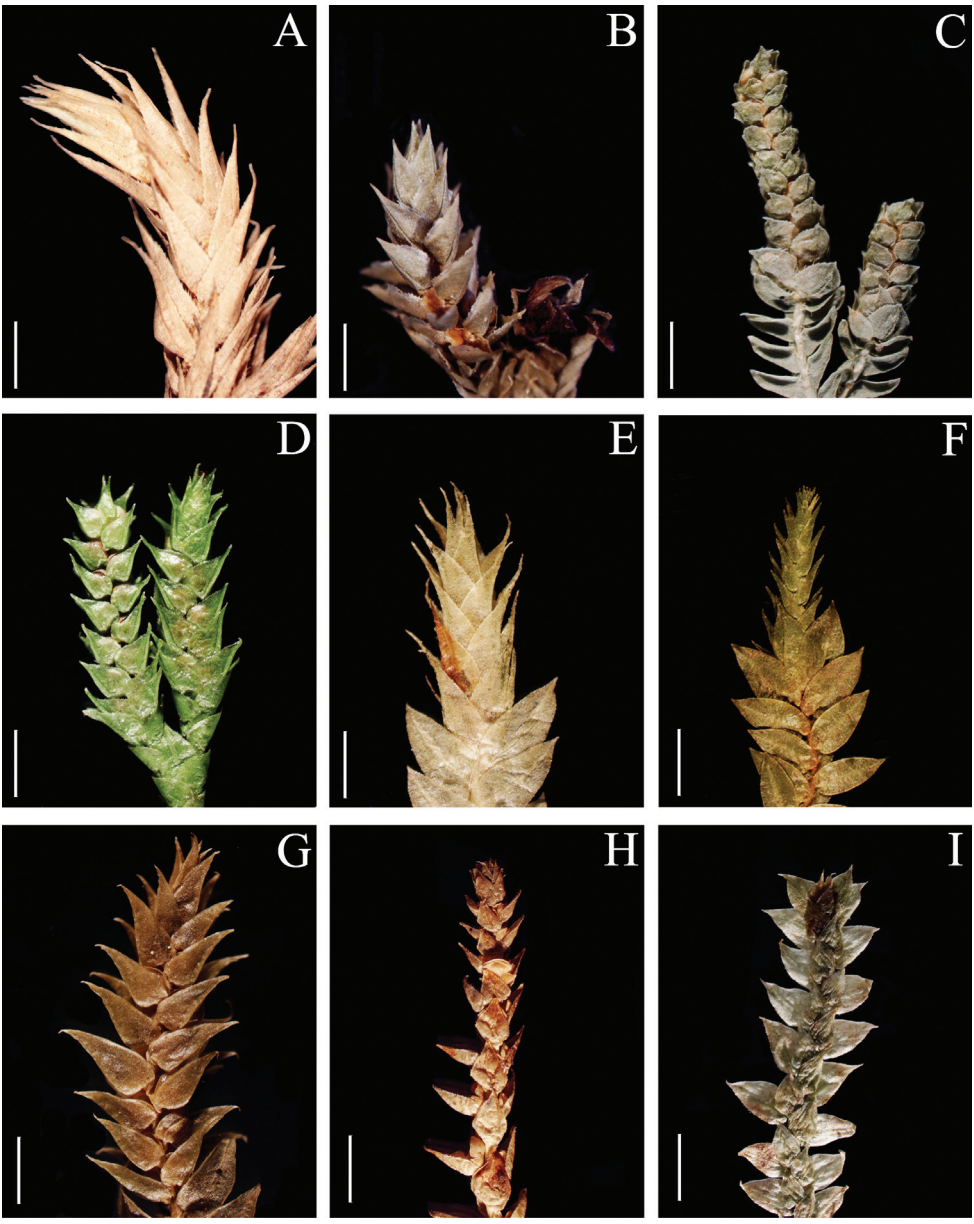

Figure 9. Diversity strobili of Nepalese *Selaginella* species **A** *S. indica* (*Nakaike 1325*, PE) **B** *S. bryopteris* (*Tabata* et al. *11989*, PE) **C** *S. fulcrata* (*Nakaike 1923*, PE) **D** *S. involvens* (*Zhang 345*, PE) **E** *S. pallida* (*Nakaike 3740*, PE) **F** *S. remotifolia* (*Nakaike 3522*, PE) **G** *S. semicordata* (*Jenkins* s.n., PE) **H** *S. helvetica* (*Zhang 0638*, PE) **I** *S. pallidissima* (*Zhang 2746*, PE). Scale bars: 1 mm (**A–G**), 2 mm (**F, H–I**).

Note. As reported by Fraser-Jenkins et al. (2015), *S. tenuifolia* is a rather uncommon low to mid altitude species, and widespread from Himalaya to Thailand. In our study (data not published) two collections were included, one from Nepal (*T. Na-*

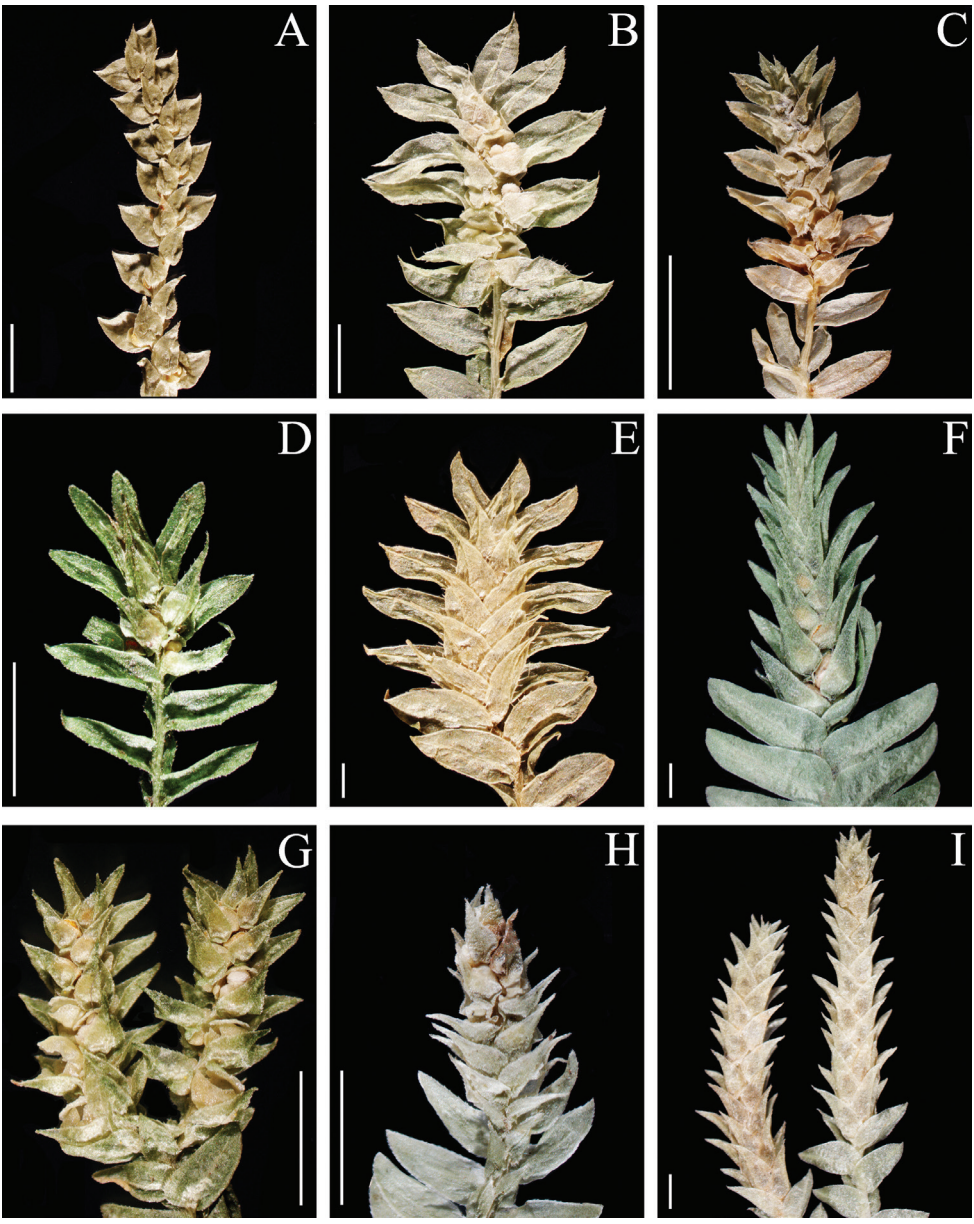

Figure 10. Diversity strobili of Nepalese *Selaginella* species **A** *S. laxistrobila* (*Nakaike 1319*, PE) **B** *S. bisulcata* (*Nakaike 3786*, PE) **C** *S. pennata* (*Nakaike 3507*, PE) **D** *S. chrysocaulos* (*Nakaike 1058*, PE) **E** *S. ciliaris* (s.n. *1225*, PE) **F** *S. monospora* (*Tabata* et al. *11051*, PE) **G** *S. trichophylla* (*Lu* & *Zhang 27625-B*, PE) **H** *S. repanda* (*Nakaike 3708*, PE) **I** *S. vaginata* (*Nakaike 1102*, PE). Scale bars: 2 mm (**A, B**), 2 mm (**C, D, G, H**), 1 mm (**E, F, I**).

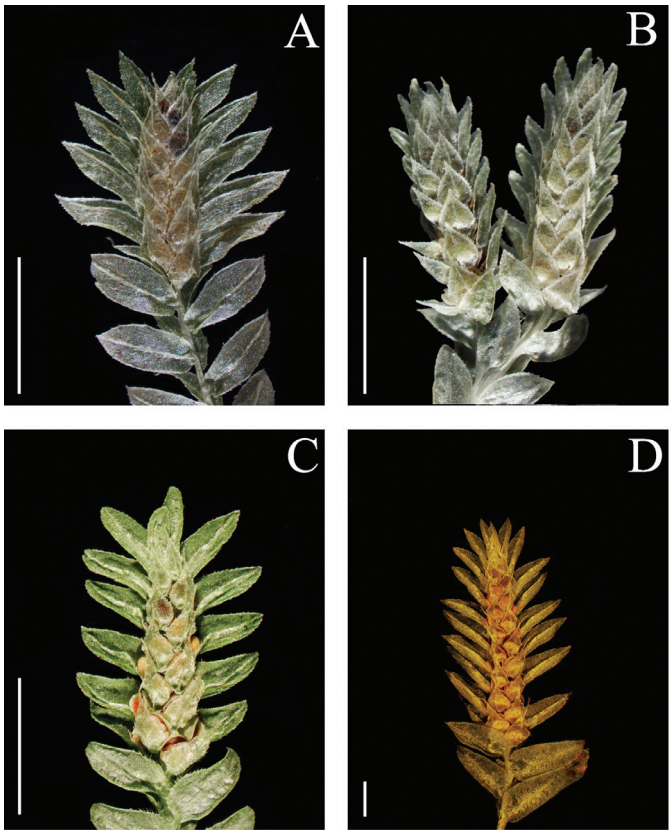

Figure 11. Diversity strobili of Nepalese *Selaginella* species **A** *S. chrysorrhizos* (*Nakaike 3708*, PE) **B** *S. reticulata* (*Nakaike 1760*, PE) **C** *S. subdiaphana* (*Zhang 5*, PE) **D** *S. tenuifolia* (*PE-Xizang Exped. PE6280*, PE). Scale bars: 1 mm (**A, D**), 2 mm (**B, C**).

kaike 3065), and another from SW Xizang (*PE-Xizang Expedition PT6280*). Examined samples were studied on three grounds: gross morphology, morphology of spores and molecular data. Results of gross morphology did not show big differentiation in morphology features for examined samples (incl. observation of ventral and dorsal leaves, shape of leaf margin, strobili, ventral and dorsal sporophylls. Ventral leaves broadly overlapping stem and branches, margin denticulate; Dorsal leaves: ovate, at apex aristate, margin denticulate. Strobili oval in shape; ventral and dorsal sporophylls at margin denticulate.

In both examined collections megaspores on the proximal and distal surfaces are covered with irregularly sized verrucae, the main surface is vermiculate, micro-sculptures are dense spinulose. Microspores on the proximal and distal surfaces are covered with irregularly sized verrucae, micro-sculptures are echinulate.

The molecular data also support the results of morphological studies.

As a result, we consider the distribution of the species not only at low and medium altitudes but also in the highlands.

Figure 12. *Selaginella indica* R.M. Tryon. **A** Habit **B** lateral branches with compact tetragonal strobilus **C** lateral branches with spirally arranged monomorphic leaves (*Cooper 4866*, E).

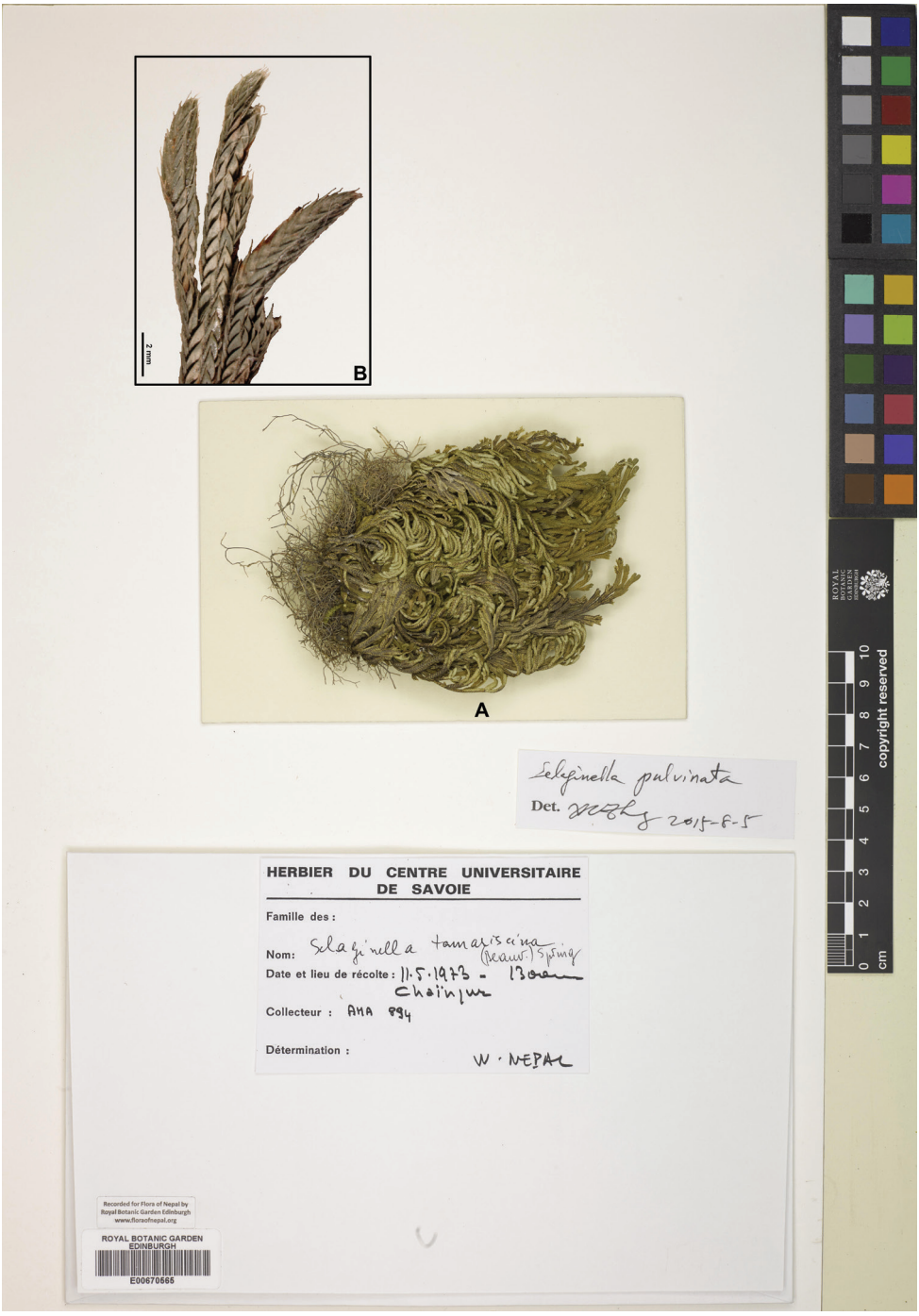

Figure 13. *Selaginella pulvinata* (Hook. & Grev.) Maxim. **A** Habit **B** fragment of the upper surface of the lateral branch showing dorsal leaves imbricate at branch (**A** *Maire* AMA *894*, E; **B** *Tabata* et al. *3520*, PE). Link: (http://data.rbge.org.uk/herb/E00670565).

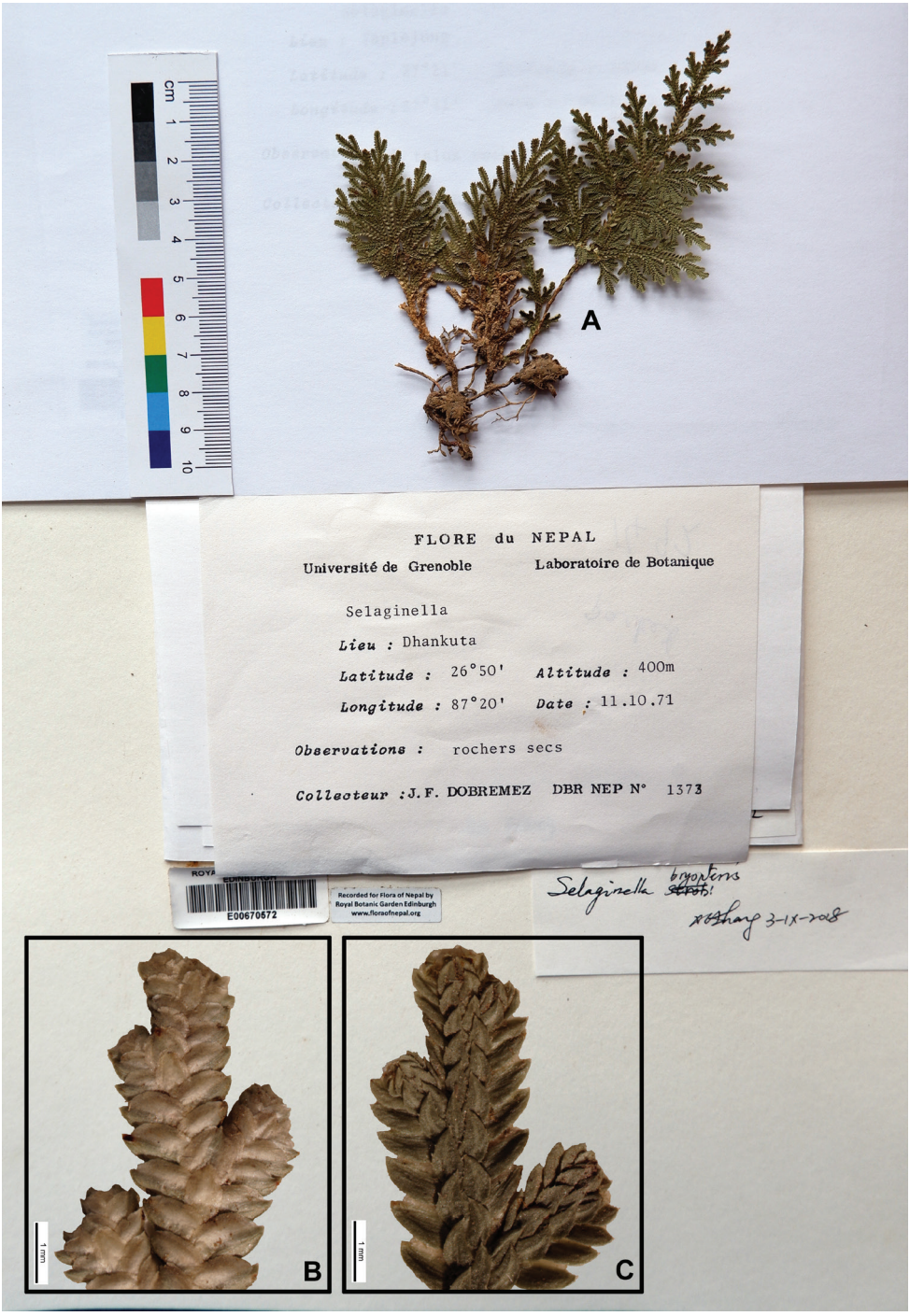

Figure 14. *Selaginella bryopteris* (L.) Baker. **A** Habit, upper surface **B** fragment of the lateral branches showing imbricate ventral leaves **C** fragment of the upper surface of the lateral branch showing dorsal leaves imbricate at branch (*J.F. Dobremez* DBR NEP *1373*, E). Link: (http://data.rbge.org.uk/herb/E00670572).

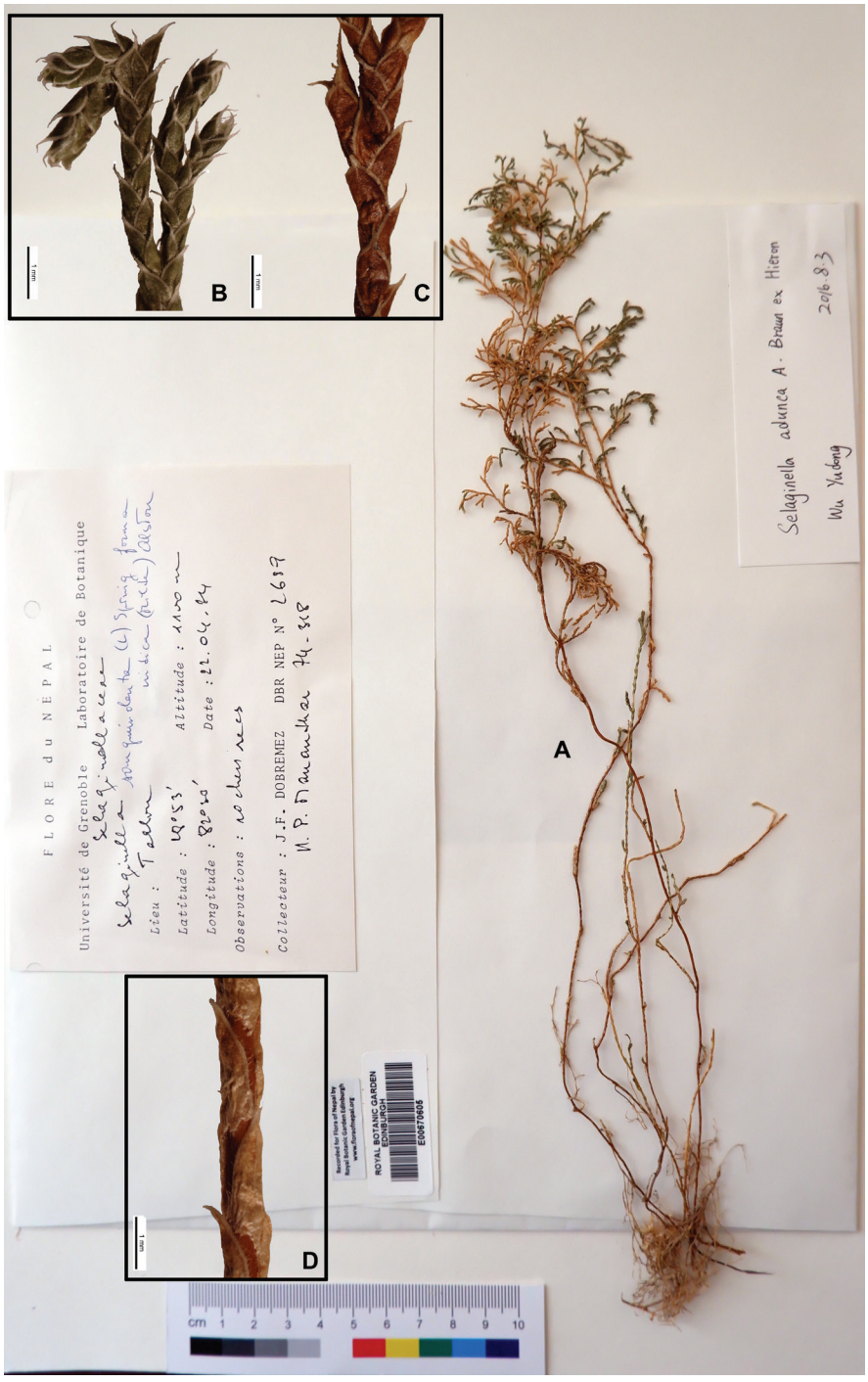

Figure 15. *Selaginella adunca* A. Braun ex Hieron. **A** Habit **B, C** fragment of the upper surface of the lateral branches showing imbricate at branch apices (**A**) and medial part lateral branches (**B**) **D** fragment of the main stem showing shape of leaves (*J.F. Dobremez* DBR NEP *2689*, E). Link: (http://data.rbge.org.uk/herb/E00670605).

Figure 16. *Selaginella fulcrata* (Buch.-Ham. ex D. Don) Spring. **A** Habit, upper surface **B** habit, lower surface **C** strobilus, upper surface **D** fragment of the upper surface of the lateral branches **E** fragment of the lower surface of the lateral branches (*O. Polunin, W.R. Sykes, L.H.J. Williams 1332*, E). Link: (http://data.rbge.org.uk/herb/E00670606).

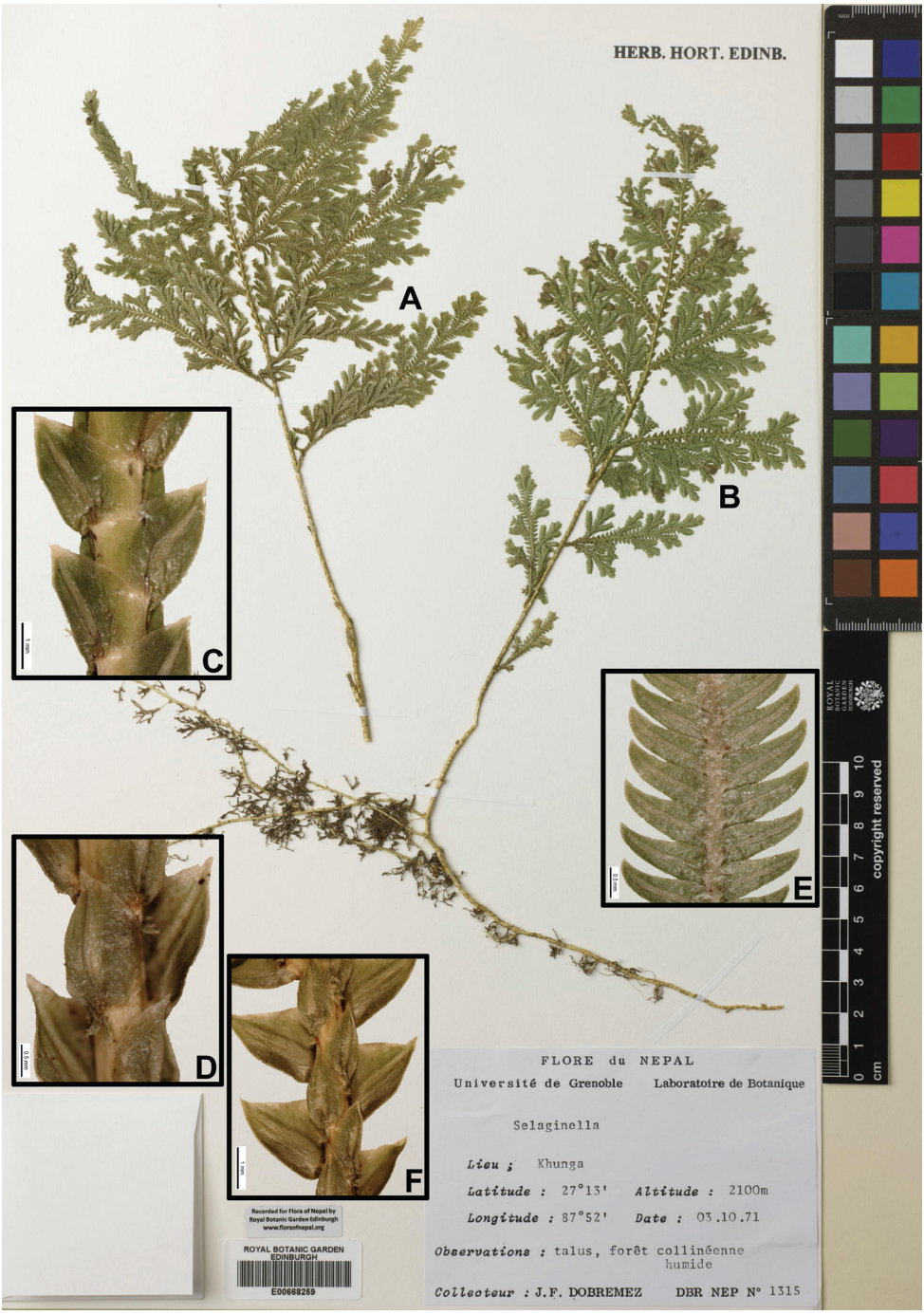

Figure 17. *Selaginella involvens* (Sw.) Spring. **A** Habit, upper surface of stem **B** habit, lower surface of stem **C** lower surface of the main stem **D** upper surface of the main stem **E** lower surface of the lateral branches **F** upper surface of the lateral branches (*J.F. Dobremez* DBR NEP *1315*, E). Link: (http://data.rbge.org.uk/herb/E00668259).

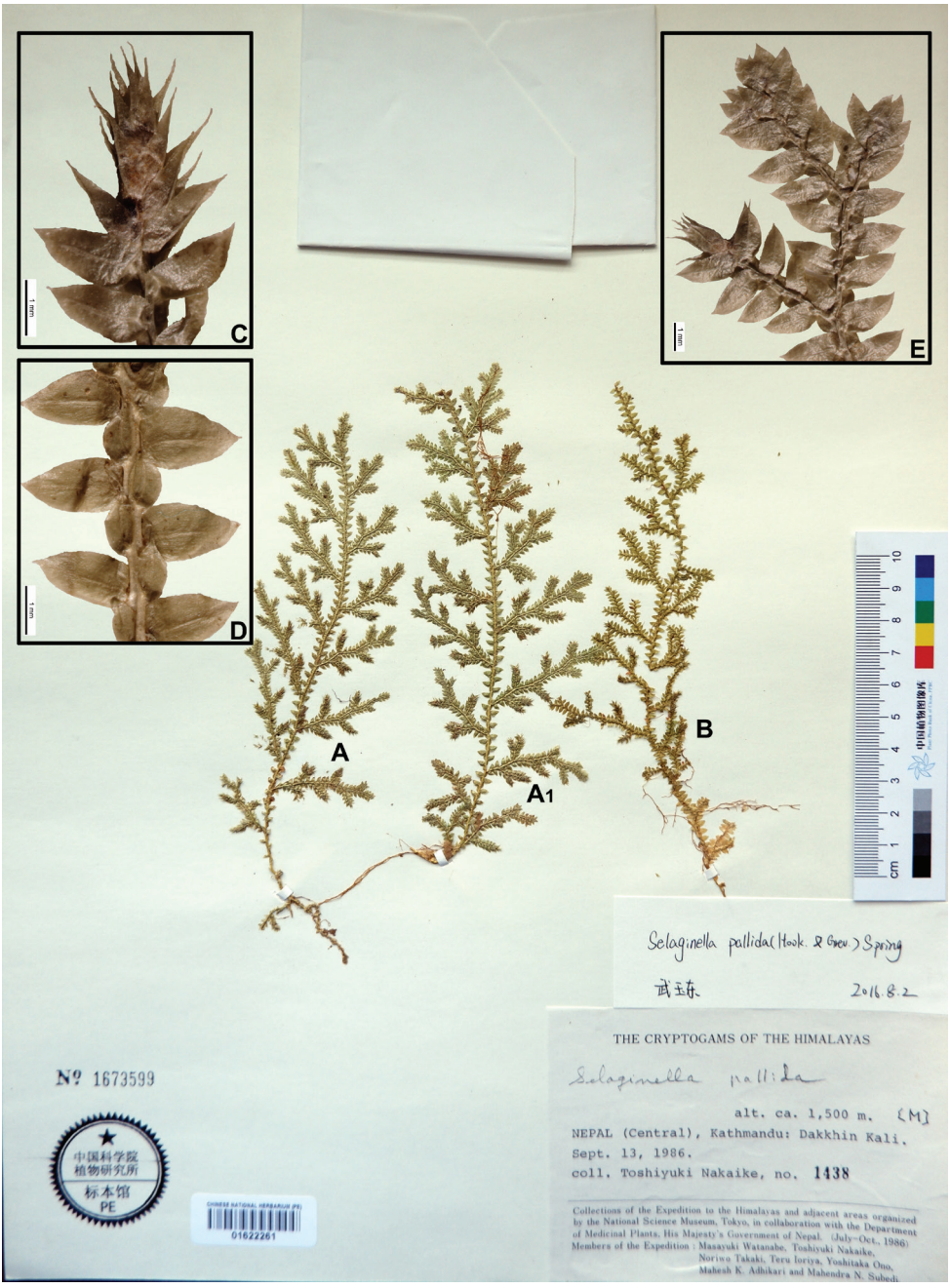

Figure 18. *Selaginella pallida* Spring. **A** (**A1**) Habit, lower surface **B** habit, upper surface **C** strobilus, lower surface **D** fragment of the upper surface of the lateral branches **E** fragment of the lower surface of the lateral branches (*T. Nakaike 1438*, PE).

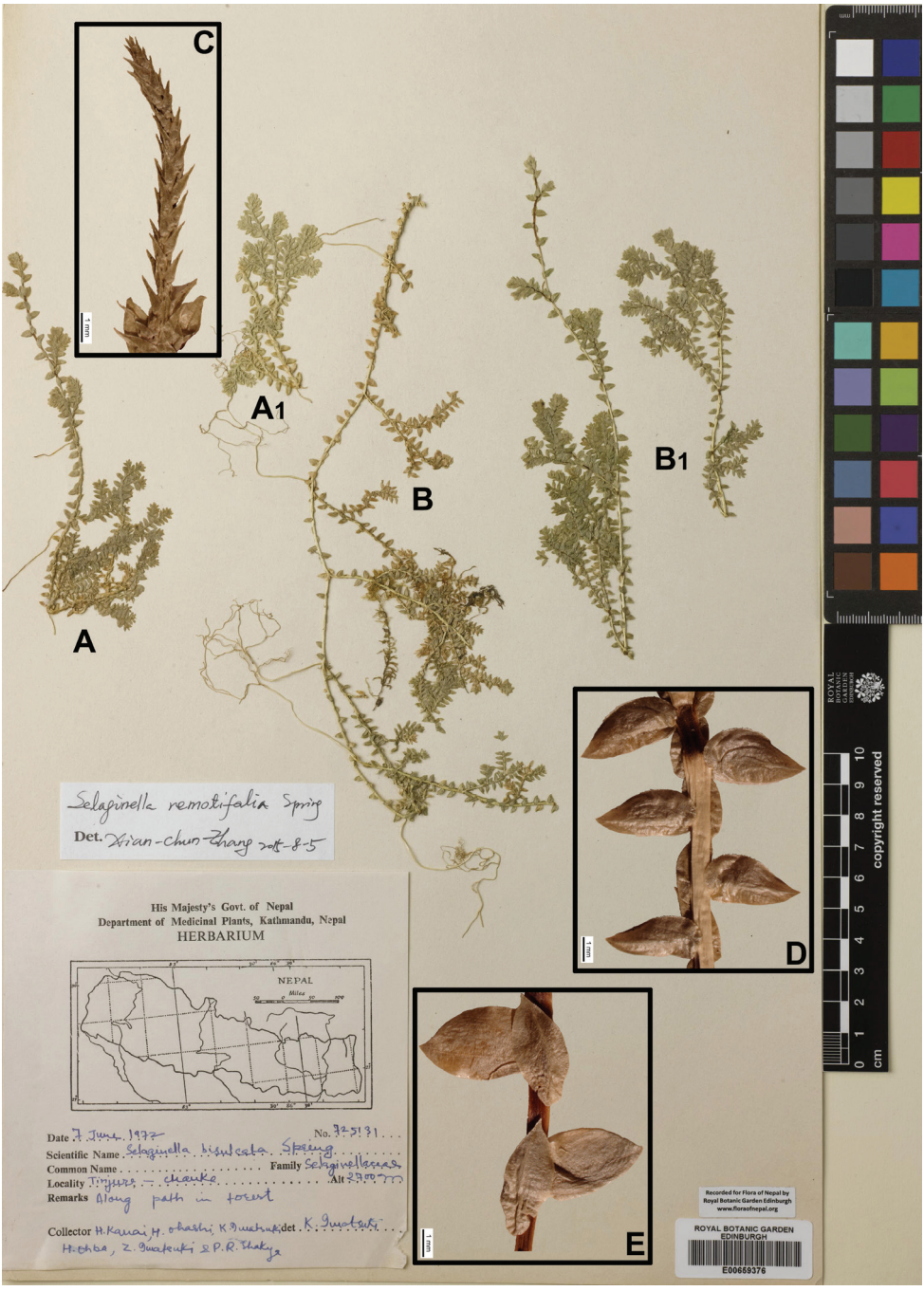

Figure 19. *Selaginella remotifolia* Spring. **A** (**A1**) Habit, upper surface of stem **B** (**B1**) habit, lower surface of stem **C** strobilus, upper surface **D** fragment of the lower surface of the lateral branches **E** Fragment of the upper surface of the lateral branches (**A, B, D, E** *H. Kanai* et al. *725131*, E; **C** *R.C. Ching 2192*, PE). Link: (http://data.rbge.org.uk/herb/E00659376).

Figure 20. *Selaginella semicordata* (Wall. ex Hook. & Grev.) Spring. **A** Habit, lower surface **B** strobilus, lower surface **C** fragment of the lower surface of the lateral branches (*Wallich* n. *126.c*, E). Link: (http://data.rbge.org.uk/herb/E00754776).

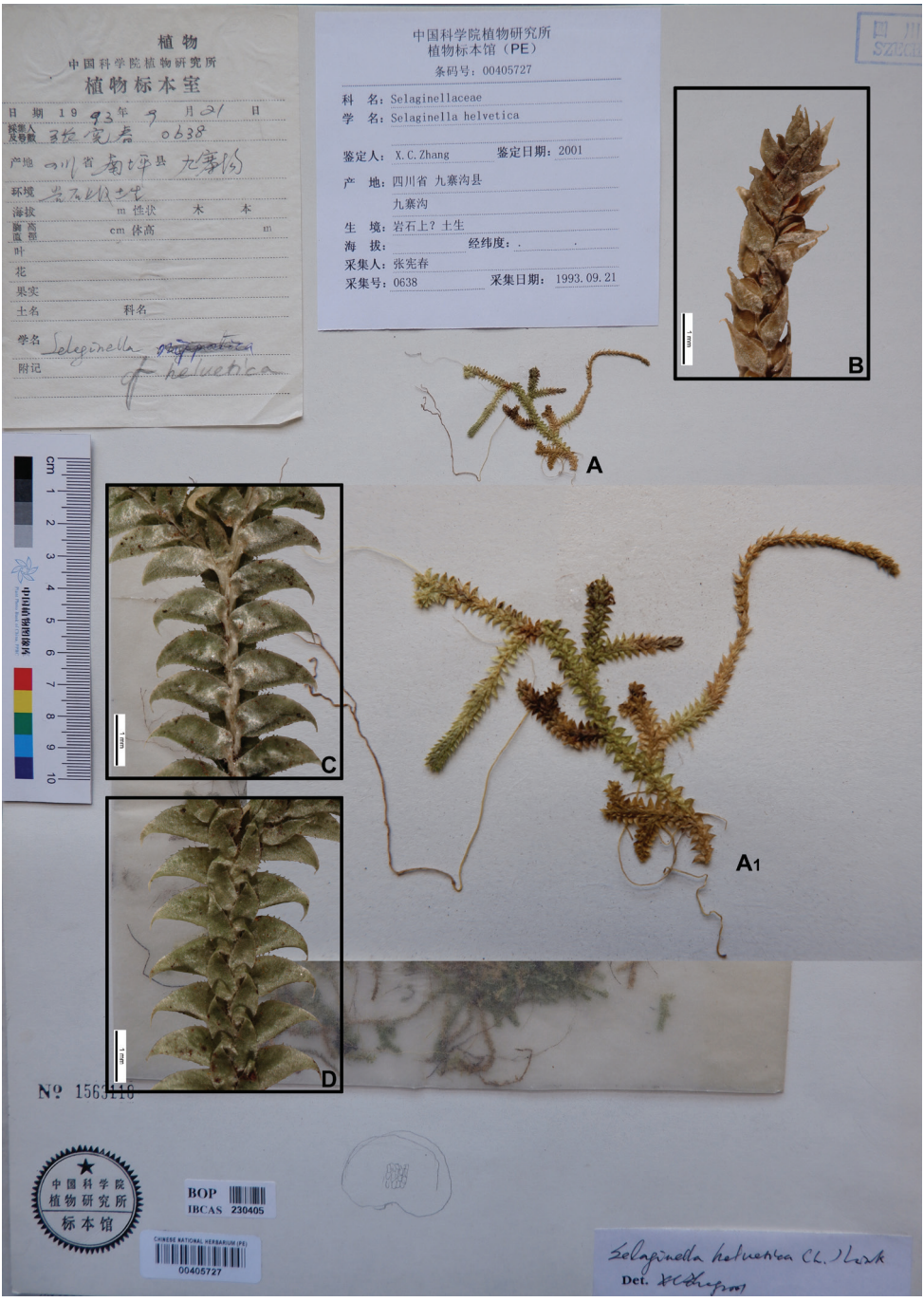

Figure 21. *Selaginella helvetica* (L.) Spring. **A** (**A1**) Habit, upper surface **B** fragment of the upper part strobilus **C** fragment of the lower surface of stem **D** fragment of the upper surface of stem (*X.C. Zhang 0638*, PE).

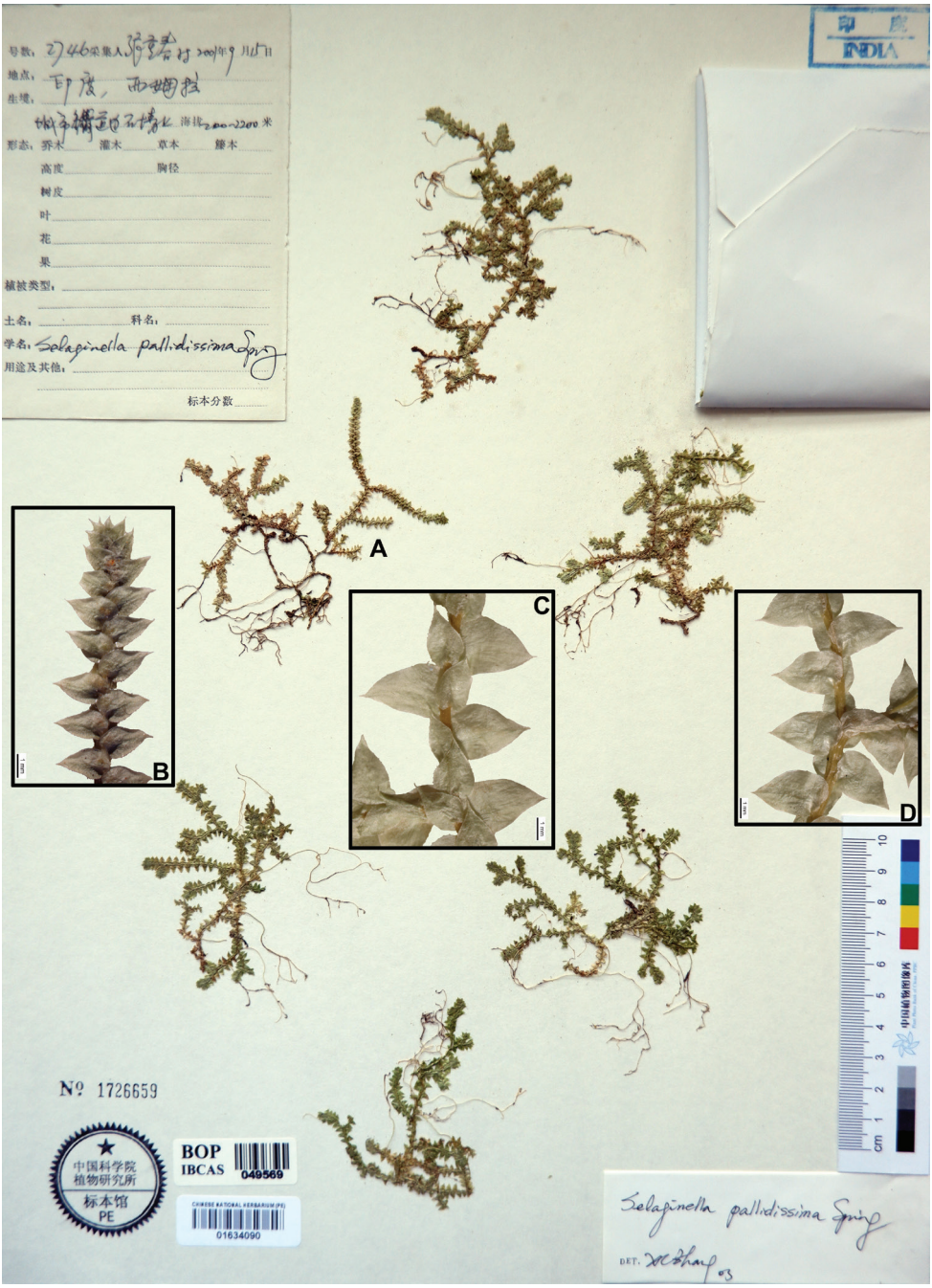

Figure 22. *Selaginella pallidissima* Spring, **A** Habit **B** strobilus, lower surface **C** fragment of the upper surface of the lateral branches **D** fragment of the lower surface of the lateral branches (*X.C. Zhang 2746*, PE).

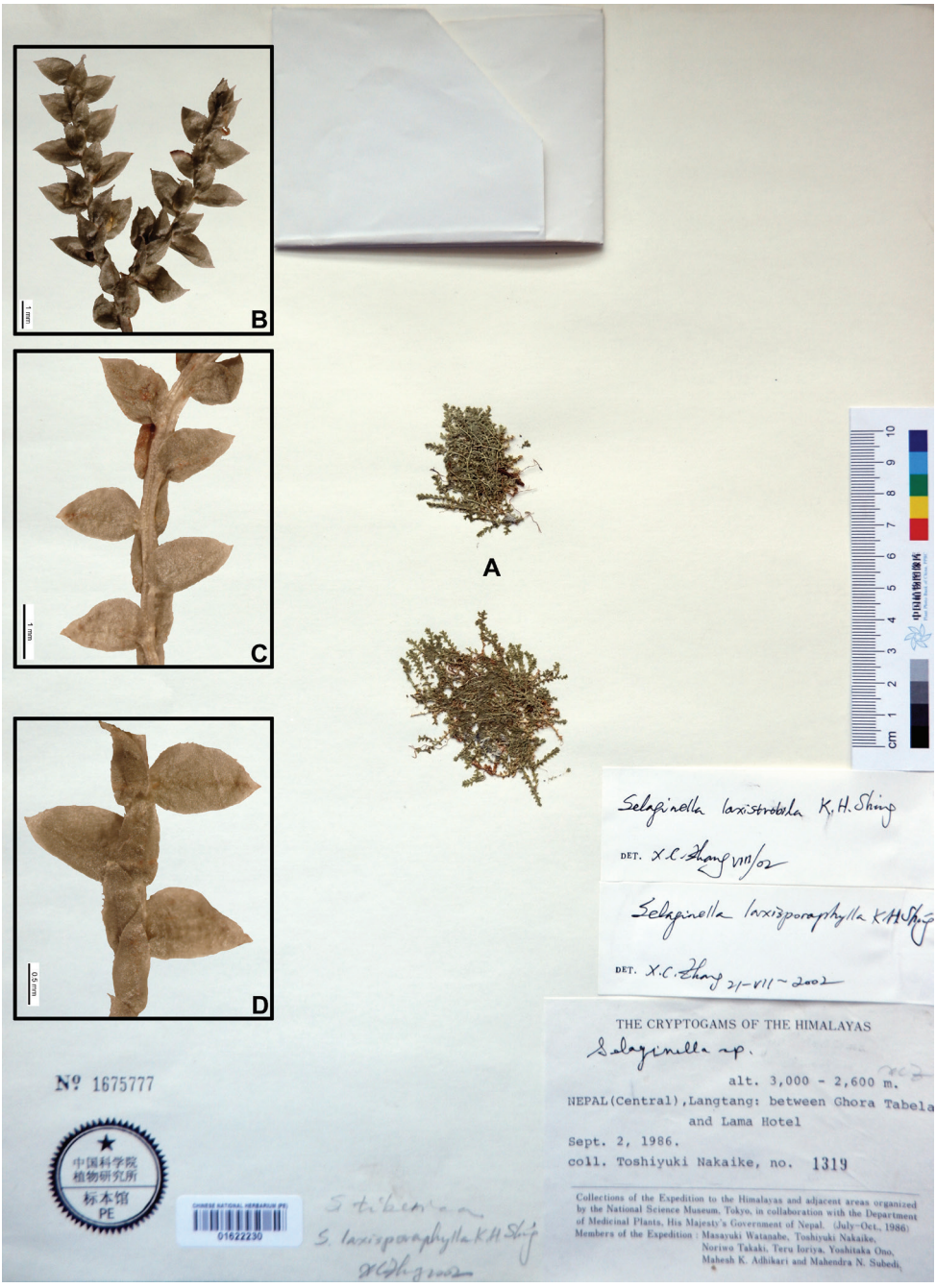

Figure 23. *Selaginella laxistrobila* K.H. Shing **A** Habit **B** Upper surface of strobilus **C** Lower surface of branches **D** Upper surface of branches (*T. Nakaike 1319*, PE).

Figure 24. *Selaginella bisulcata* Spring. **A** Habit, lower surface **B** habit, upper surface **C** strobilus, lower surface **D** fragment of the upper surface of the lateral branches **E** fragment of the lower surface of the lateral branches (*J.F. Dobremez* DBR NEP *1233*, E). Link: (http://data.rbge.org.uk/herb/E00670678).

Figure 25. *Selaginella pennata* (D. Don) Spring. **A** Habit, lower surface **B** strobilus, lower surface **C** fragment of the lower surface of the lateral branches (*J.F. Dobremez* DBR NEP *1169*, E). Link: (http://data.rbge.org.uk/herb/E00670671).

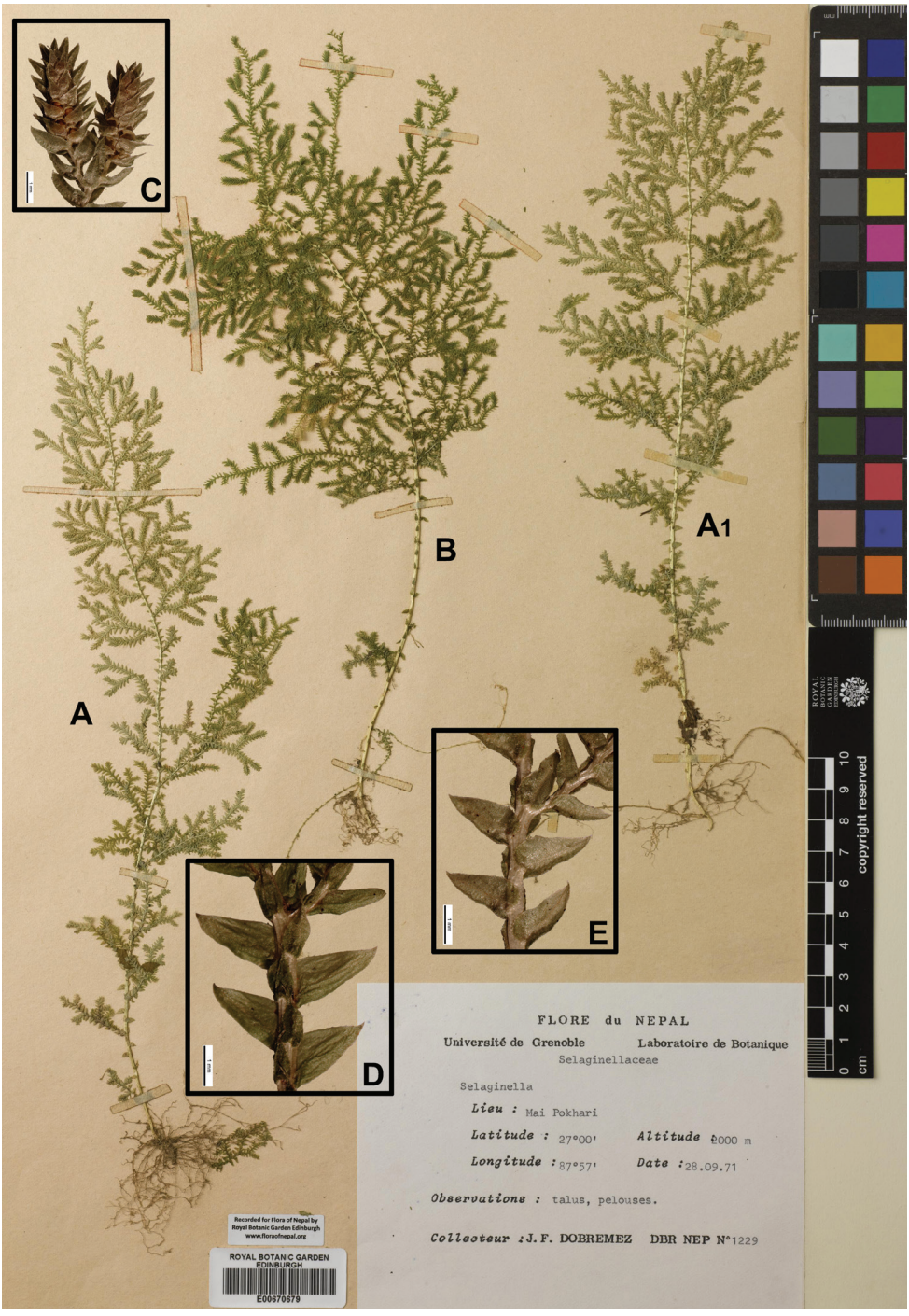

Figure 26. *Selaginella chrysocaulos* (Hook. & Grev.) Spring. **A** (**A1**) Habit, lower surface **B** habit, upper surface **C** strobilus, lower surface **D** fragment of the upper surface of the lateral branches **E** fragment of the lower surface of the lateral branches (*J. F. Dobremez* DBR NEP *1229*, E). Link: (http://data.rbge.org.uk/herb/E00670679).

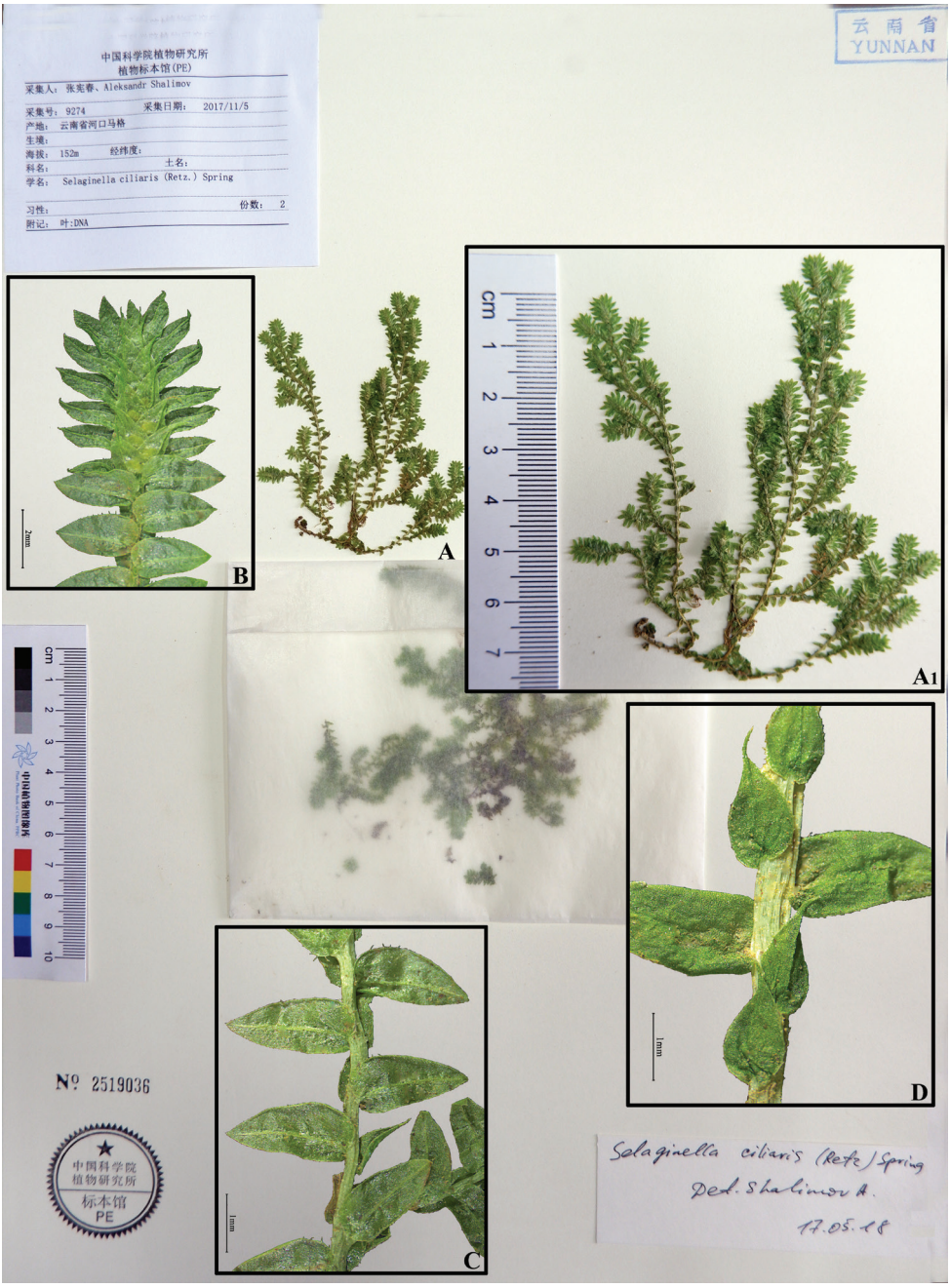

Figure 27. *Selaginella ciliaris* (Retz.) Spring **A** (**A1**) Habit, lower surface **B** Strobilus, lower surface **C** Fragment of the lower surface of the main stem **D** Fragment of the upper surface of the main stem (*X.C. Zhang* & *A. Shalimov 9274*, PE).

Figure 28. *Selaginella monospora* Spring. **A** Habit, upper surface, **B** (**B1**) Habit, lower surface **C** strobilus, upper surface **D** Fragment of the upper surface of the lateral branches **E** fragment of the lower surface of the lateral branches (*F. Henderson 13644*, E). Link: (http://data.rbge.org.uk/herb/E00754773).

Figure 29. *Selaginella trichophylla* K. H. Shing. **A** Habit **B** strobilus, lower surface **C** fragment of the upper surface of the lateral branches **D** fragment of the lower surface of the lateral branches (*Qinghai-Xizang Exped. 9451*, holotype: PE).

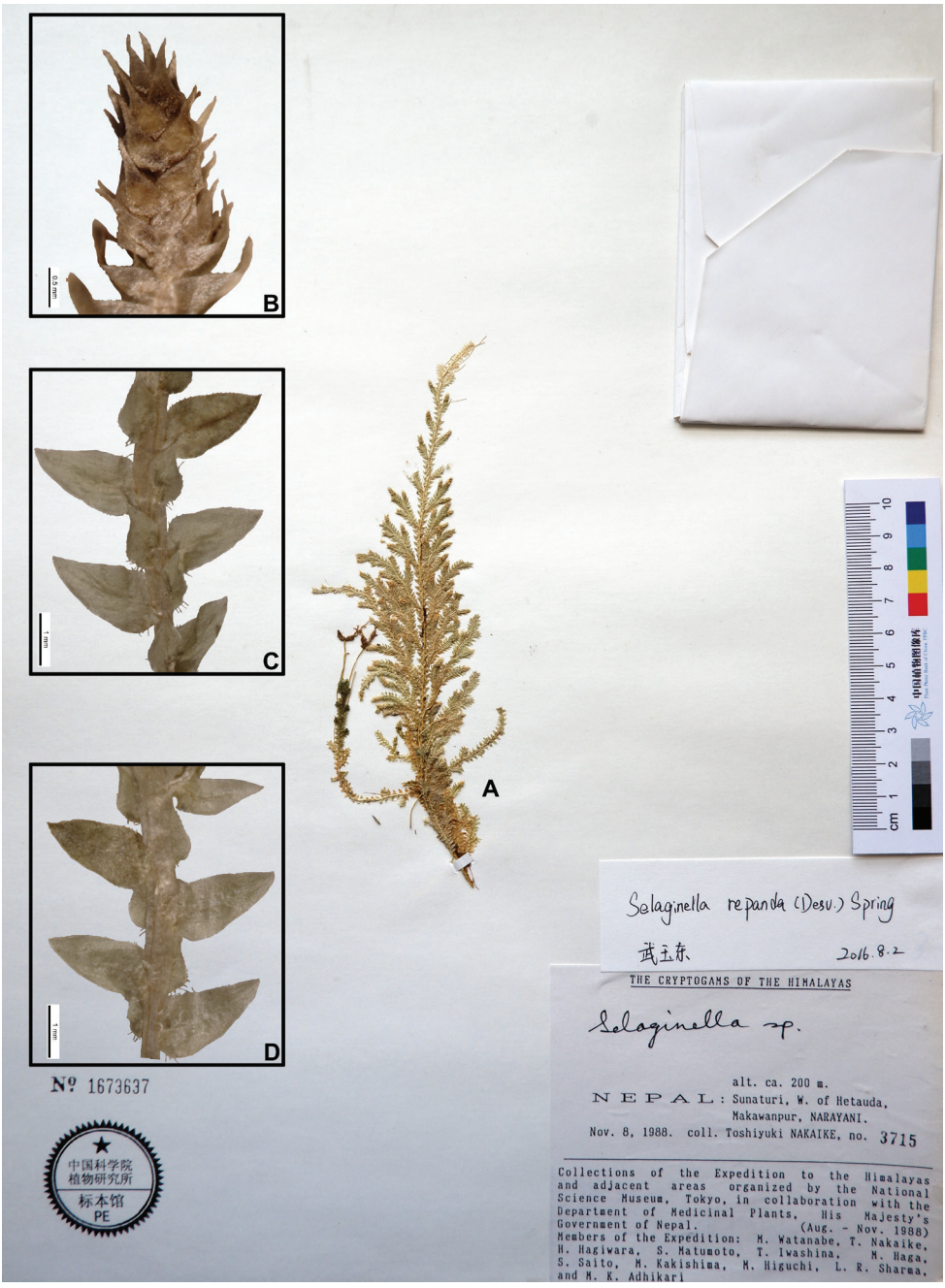

Figure 30. *Selaginella repanda* (Desv. ex Poir.) Spring. **A** Habit, lower surface **B** strobilus, lower surface **C** fragment of the upper surface of the lateral branches **D** fragment of the lower surface of the lateral branches (*T. Nakaike 3715*, PE).

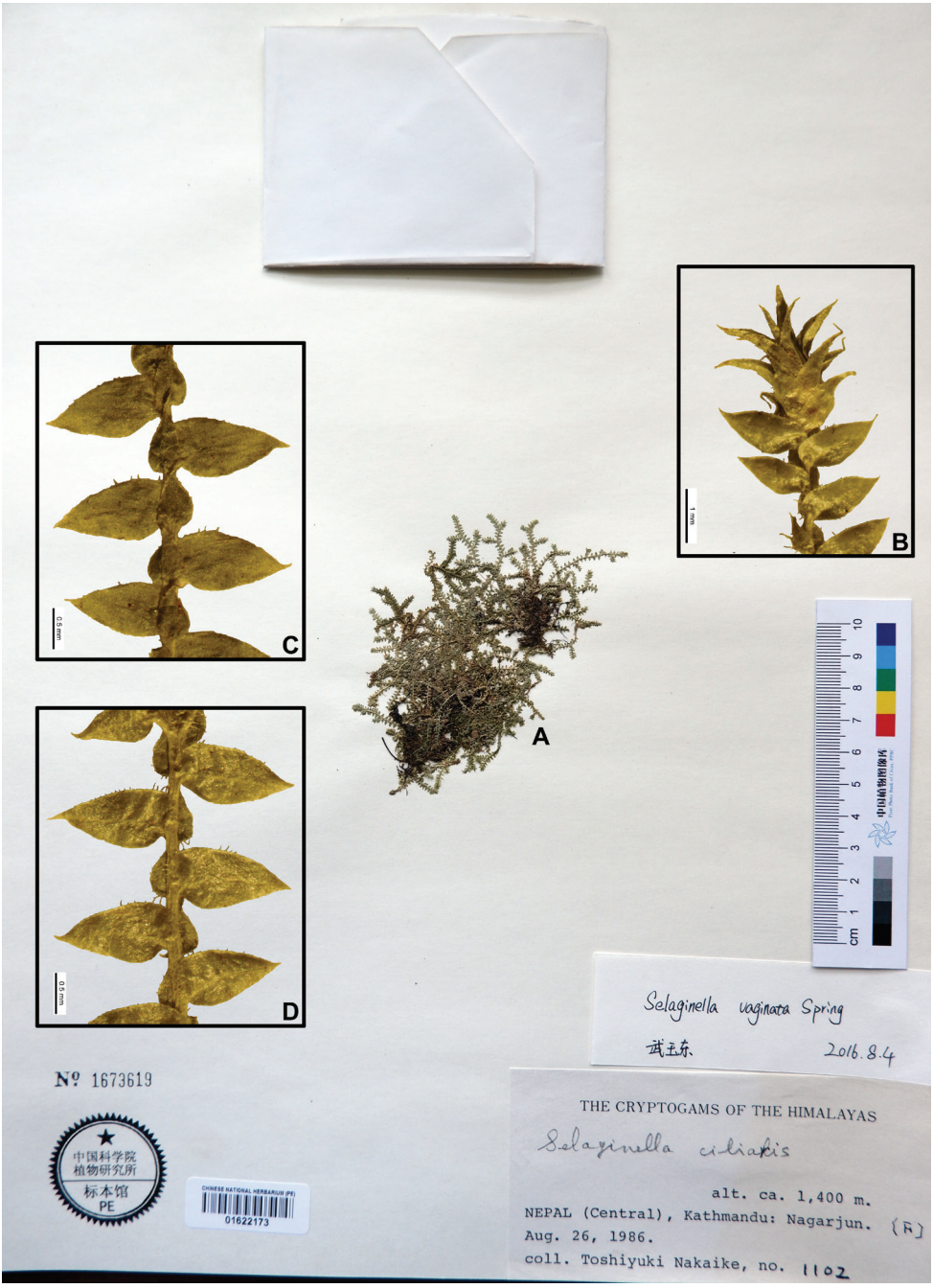

Figure 31. *Selaginella vaginata* Spring **A** Habit **B** strobilus, lower surface **C** fragment of the upper surface of the lateral branches **D** fragment of the lower surface of the lateral branches (*T. Nakaike 1102*, PE).

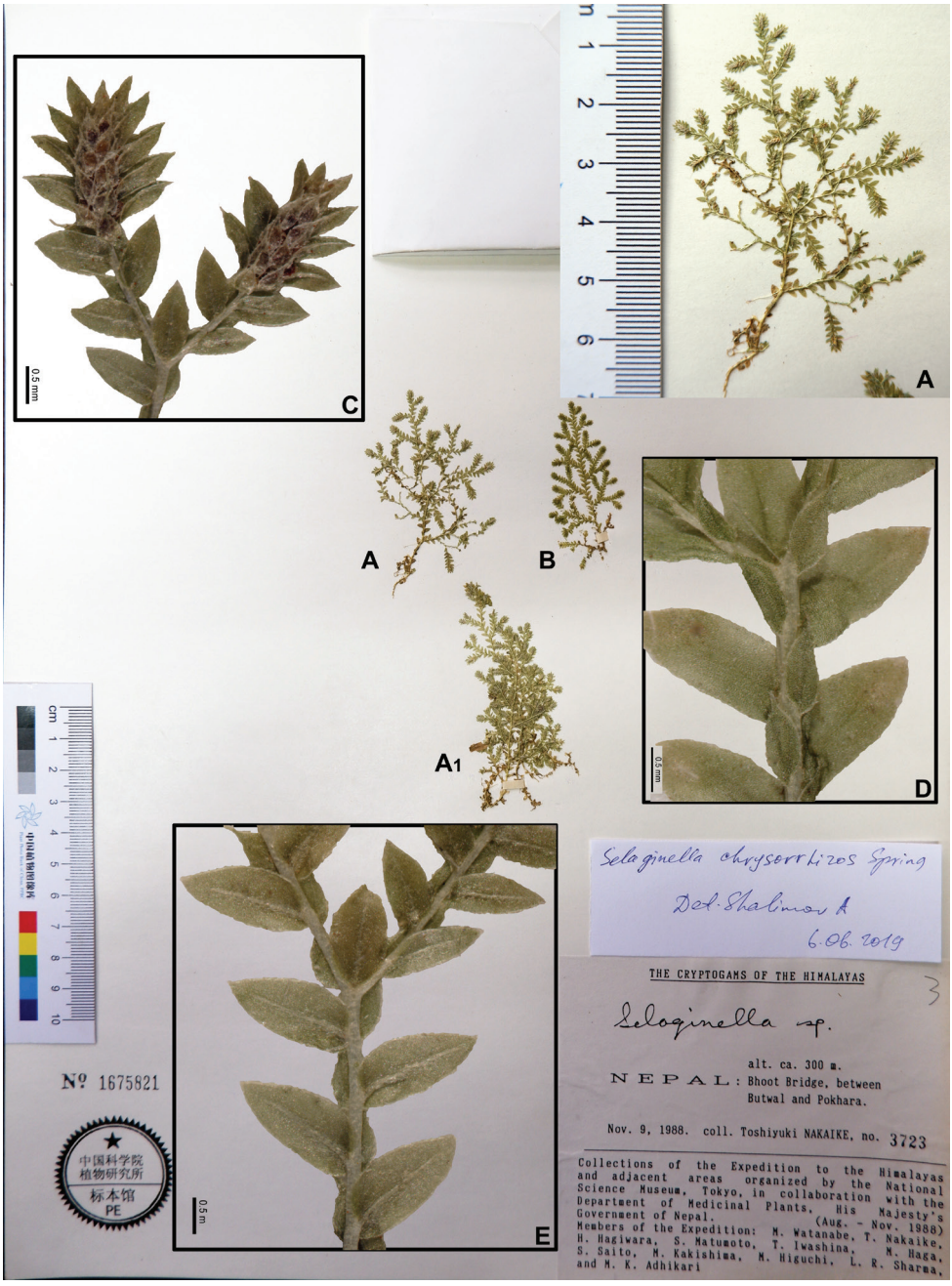

Figure 32. *Selaginella chrysorrhizos* Spring. **A** (**A1**) Habit, lower surface **B** habit, upper surface **C** strobilus, lower surface **D** fragment of the upper surface of the lateral branches **E** fragment of the lower surface of the lateral branches Spring (*T. Nakaike 3723*, PE).

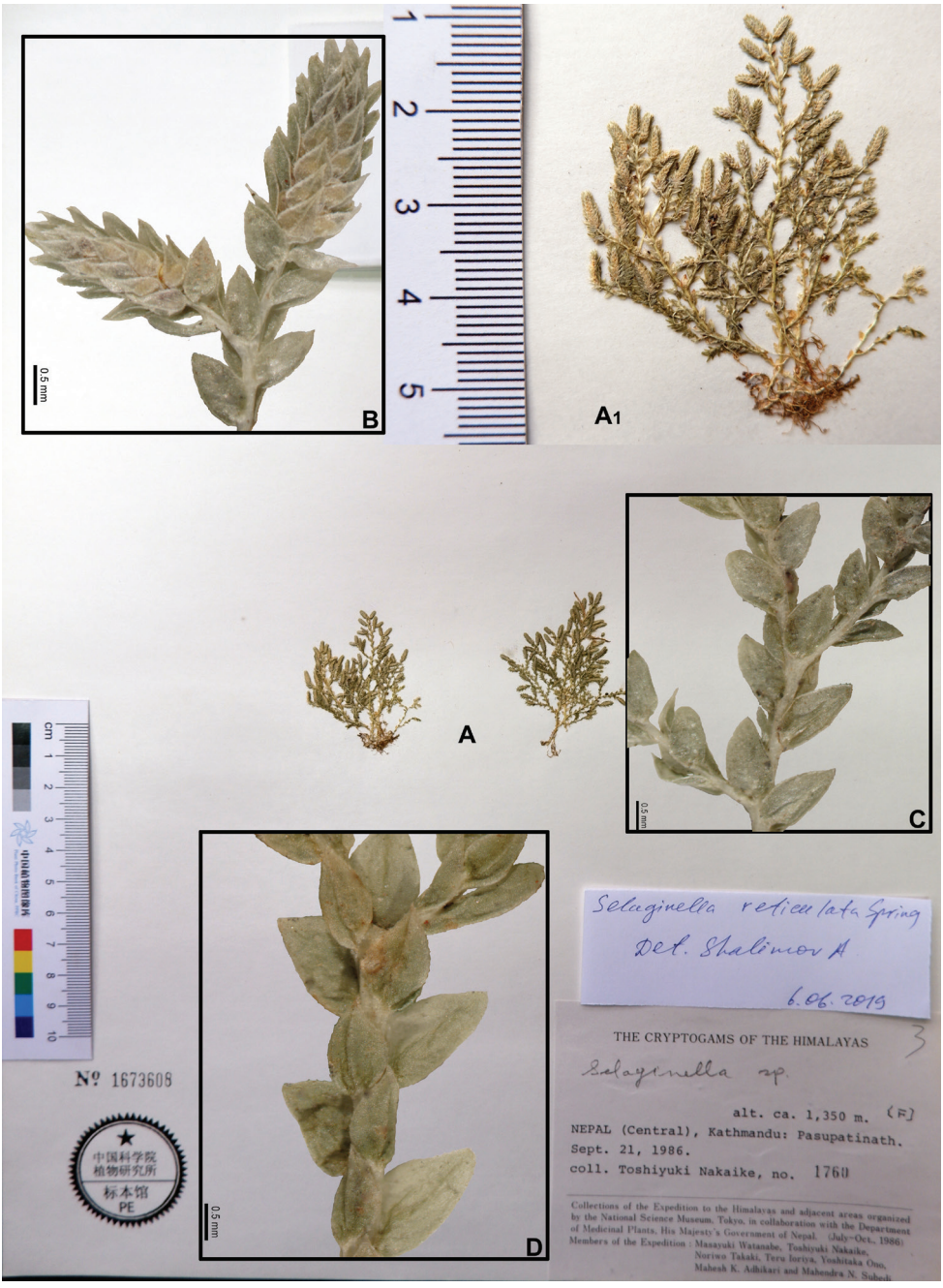

Figure 33. *Selaginella reticulata* (Hook. & Grev.) Spring. **A** (**A1**) Habit, lower surface **B** strobilus, lower surface **C** fragment of the lower surface of the lateral branches **D** fragment of the upper surface of the lateral branches (*T. Nakaike 1760*, PE).

Figure 34. *Selaginella subdiaphana* (Wall. ex Hook. & Grev.) Spring. **A**(**A1**) Habit, upper surface **B**(**B1, B2**) habit, lower surface **C** fragment of the upper surface of the lateral branches **D** fragment of the lower surface of the lateral branches **E** strobilus, lower surface (*J.F. Dobremez DBR NEP 829*, E). Link: (http://data.rbge.org.uk/herb/E00670681).

Figure 35. *Selaginella tenuifolia* Spring. **A** (**A1,A2**) Habit, upper surface (*J.H. Lance* s.n., E) **B** strobilus, lower surface **C** fragment of the upper surface of the lateral branches (**A**(**A1,A2**) *J.H. Lace* s.n., E; **B, C** *PE-Xizang Expedition* PE 6280, PE) Link: (http://data.rbge.org.uk/herb/E00800185).

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DATA PAPER

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Vascular plants dataset of the herbarium (COFC) of the University of Cordoba, Spain

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Abstract

This paper describes the herbarium (COFC) dataset of vascular plants of the University of Cordoba (SW Spain). This dataset is made up of two collections, the General collection (61,377 specimens) and the Historical collection (1,614 specimens). This study has focused mainly on the General collection, which contains the largest number of vascular plant specimens, predominantly angiosperms, mainly provincial and regional (Andalusia, Spain), but also with a good representation of other areas of the Iberian Peninsula and neighboring countries. The place of collection is specified in 99.7% of the labels, about 35% being georeferenced, and it is estimated that, currently, about 86% of the material housed in the herbarium has been databased using Elysia v1.0. software. With more than 178 families, 1,178 genera, and 3,750 species, this collection not only has educational importance, but is a valuable research tool that has been useful for the development of important works such as "Flora Vascular de Andalucía Occidental" and the "Flora iberica". The dataset described in this paper is registered with GBIF (accessible at https://doi.org/10.15468/fdzzal).

Keywords

Western Andalusia, Cordoba, COFC, herbarium collection, "Flora iberica", Spain, taxonomy, University of Cordoba, vascular plants

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Context of the COFC herbarium

The herbarium (COFC) of the University of Cordoba (Spain) is located in the Rabanales Campus, on the outskirts of the city of Cordoba. It was created in 1977 and is associated with the Department of Botany, Ecology and Plant Physiology (Botany Section, Faculty of Sciences). The herbarium, of which Prof. J.A. Devesa is currently the curator, is registered in the Index Herbariorum with the acronym COFC (Thiers 2019, http://sweetgum.nybg.org/science/ih/). It includes three botanical collections: one of fungi (Fungi-COFC, 4,827 specimens) and two of vascular plants, the Historical collection (1,614 specimens) and the General collection (61,377 specimens), the latter being the most significant. To these will be added in the future the recently created collections of bryophytes and algae, in the initial phase and barely significant. So far, 98.7% of the specimens have been databased and they can be accessed through the GBIF network (http://data.gbif.org). Some interesting data from the Historical collection are provided, but the dataset described in this paper covers exclusively the General collection.

Historical collection

The Historical collection, created by the multifaceted man of religion José de Jesús Muñoz Capilla (who lived 1771–1840), contains a total of 1,614 specimens of vascular plants arranged in 22 classes according to the Linnaean system (Infante et al. 2002). Most of the specimens were collected during the years 1792–1834, mainly in the province of Cordoba, including some from plants cultivated in gardens, but occasionally in other provinces (e.g., Seville, Jaen, Cadiz, and Madrid), by the following botanists from Cordoba: Jesús Muñoz Capilla, Rafael Mariano León y Gálvez (1772–1811), Rafael Entrena y Camacho (1786–1835), and the Cádiz-born Antonio Nicolás Cabrera y Corro (1762–1827). This collection was ceded by the relatives of Muñoz Capilla in the mid-nineteenth century to the Special School of Veterinary Medicine (González Soriano 1923), an institution that more recently would become the Veterinary Faculty and the germ of the current University of Cordoba. The herbarium was restored and carefully inventoried by Jordano and Ocaña (1955, 1957), and in the 1970s, after the creation of the University of Cordoba, it was ceded to the facilities of the COFC herbarium. The collection houses some 900 species; only 17% of the labels provide some information about the place of collection, which in many cases is limited to the province, and for only about 5% is the year of collection stated. Its importance lies in its historical and cultural value, since it also contains plants collected by and/or annotations of important botanists with whom it maintained contact (Laza Palacios 1944), among them Mariano Lagasca (1776–1839), Félix Haenseler (1767–1841) and Edmond Boissier (1810–1885). The data in this collection can be consulted at https://doi.org/10.15468/f3tcb6.

General collection

The General collection has a total of 61,377 specimens that have been recorded with different herbarium number, and there are more than 12,000 duplicate specimens of the gatherings. This collection is the fourth largest among the Andalusian collections in terms of the number of specimens (based on the information obtained from the National Biodiversity Information Node 2015), after SEV, COA and MGC (Table 1). It contains material collected for the most part over the last 40 years from explorations and studies carried out by researchers from the Department of Botany, Ecology and Plant Physiology, undergraduate and post-graduate studies related to teaching and, in minor measure, exchanges with or donations by other herbaria. The collection comprises a wide representation of vascular plants – especially angiosperms– from the province of Cordoba and, to a lesser extent, from other Spanish regions, as well as a modest representation from bordering countries and other parts of the world. It mainly includes wild plants, with a minimum representation of ornamental plants (around 950 specimens). In recent years the collection has been enhanced, mainly by a large number of collections made in the Iberian Peninsula for taxonomic revision of various genera, especially *Centaurea* L. (Asteraceae) and *Festuca* L. (Poaceae), within the "Flora iberica" project. This is one of the Spanish herbaria with greater representation of these genera. The herbarium, therefore, includes an important sample of the vascular plant biodiversity of the Iberian Peninsula, especially that of Western Andalusia (SW Spain), so it is not only essential for the knowledge and study of local flora, but also has been

Table 1. The main Andalusian herbaria (Source: https://www.gbif.org, accessed 2019). (*) Information from the National Biodiversity Information Node (2015), available at https://www.gbif.es/wp-content/uploads/2018/02/GBIF.ES_Inf_Col_2014.pdf. Acronyms of the herbaria according to Thiers (2019).

Acronyms	Collection	Institution	Estimated number of specimens (year of estimate)*	Number of records published in GBIF (accessed 2019)
SEV	Herbarium of the University of Seville	University of Seville	350,000 (2007)	226,498
COA	COA Herbarium	Botanical Garden of Cordoba	80,000 (2008)	39,835
MGC	MGC-Cormof Herbarium	Department of Plant Biology, Faculty of Sciences	74,683 (2012)	78,930
COFC	COFC Herbarium of the University of Cordoba: General collection	Department of Botany, Ecology and Plant Physiology, Faculty of Sciences	72,000[1] (2019)	60,566
GDA	Collection of vascular plants of the herbarium of the University of Granada	University of Granada	1,442 (2011)	55,219[2]
HUAL	Herbarium of the University of Almeria	University of Almeria. Department of Plant Biology and Ecology	24,304 (2012)	14,971
JAEN	Herbarium of vascular plants	University of Jaen. Faculty of Experimental Sciences	34,000 (2012)	No data
UPOS	Herbarium of the University Pablo de Olavide	University of Pablo de Olavide	10,000 (2008)	No data

[1] Estimation of sheets of unmounted and unfiled specimens; [2] It including the GDAC herbarium.

very useful for "Flora de Andalucía Occidental" (Valdés et al. 1987) and, currently, the "Flora iberica" (Castroviejo 1986–2019, http://www.floraiberica.org/).

This collection regularly increases, by about 1,250 specimens per year, and the dataset is periodically uploaded to the GBIF portals. The data referring to this collection can be found at https://doi.org/10.15468/fdzzal (entries through 2018–12–31), except for the data related to the genus *Festuca*, which have not been uploaded yet since they are still under study.

Taxonomic coverage

The collection of vascular plants has 61,377 specimens belonging to 178 families, 1,178 genera, and 3,750 species. Of the specimens in the collection, 97.8% are identified at the species level and the remaining 2.2% (about 1,350 specimens) only at the level of the genus, awaiting their review by a specialist.

The majority of the specimens in the collection are angiosperms (Angiospermae) belonging to the classes Magnoliopsida (49,140 specimens; 80.06%) and Liliopsida (10,893 specimens; 17.75%). These are followed, in terms of representation, by ferns and related groups, with 991 specimens (1.61%) and the following distribution: class Polypodiopsida (740 specimens), Equisetopsida (139 specimens), Lycopodiopsida (107 specimens), and Psilotopsida (5 specimens). Finally, for gymnosperms (Gymnospermae) there are 353 specimens (0.58%), with the following distribution: Cycadopsida (2 specimens), Ginkgoopsida (1 specimen), Gnetopsida (51 specimens), and Pinopsida (299 specimens). In

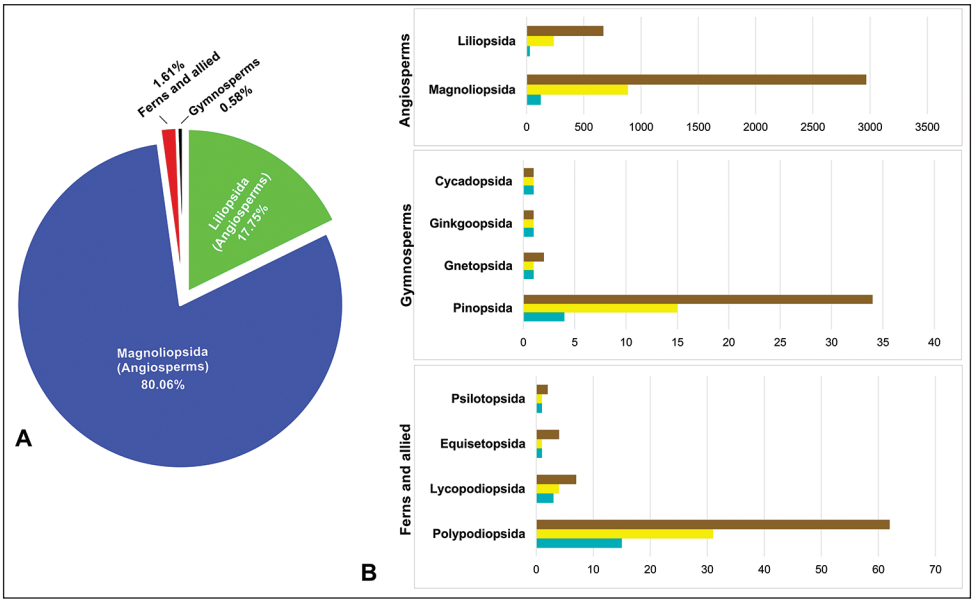

Figure 1. Taxonomic coverage of the General collection dataset in terms of specimens (**A**). Number of species (brown), genera (yellow), and families (light blue) within each class (**B**).

terms of diversity, Magnoliopsida (124 families, 886 genera, and 2,966 species), Pinopsida (4 families, 15 genera, and 34 species), and Polypodiopsida (15 families, 31 genera, and 62 species) are the most diverse classes within each large group of vascular plants (Fig. 1).

The ten families that contribute most, in percentage terms, to the plant specimens conserved in the herbarium are: Asteraceae (8,625 specimens; 14.05%), Fabaceae (7,929 specimens; 12.92%), Poaceae (6,324 specimens; 10.30%), Lamiaceae (3,105 specimens; 5.06%), Caryophyllaceae (2,156 specimens; 3.51%), Plantaginaceae (2,033 specimens; 3.31%), Brassicaceae (1,851 specimens; 3.02%), Apiaceae (1,707 specimens; 2.78%), Ranunculaceae (1,319 specimens; 2.15%), and Boraginaceae (1,111 specimens; 1.81%) (Fig. 2).

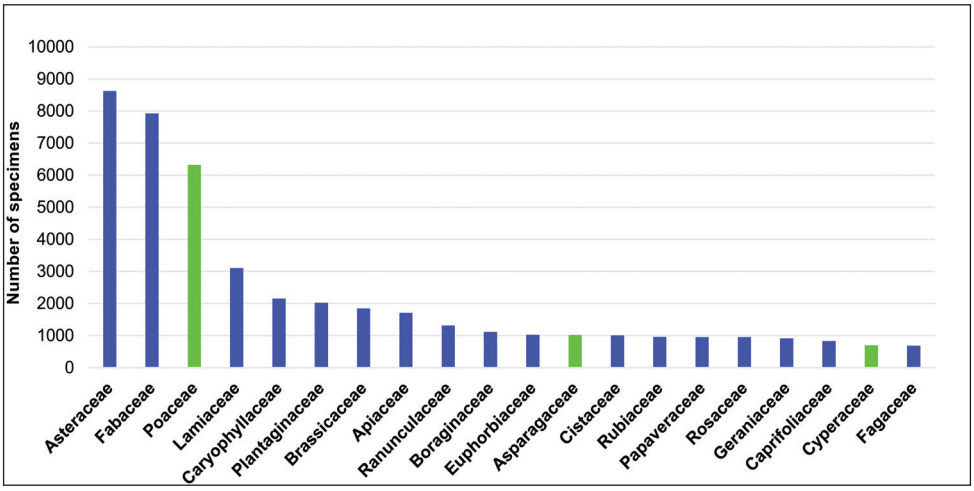

Figure 2. Families with greater representation in the General collection. In blue, families of Magnoliopsida; in green, families of Liliopsida.

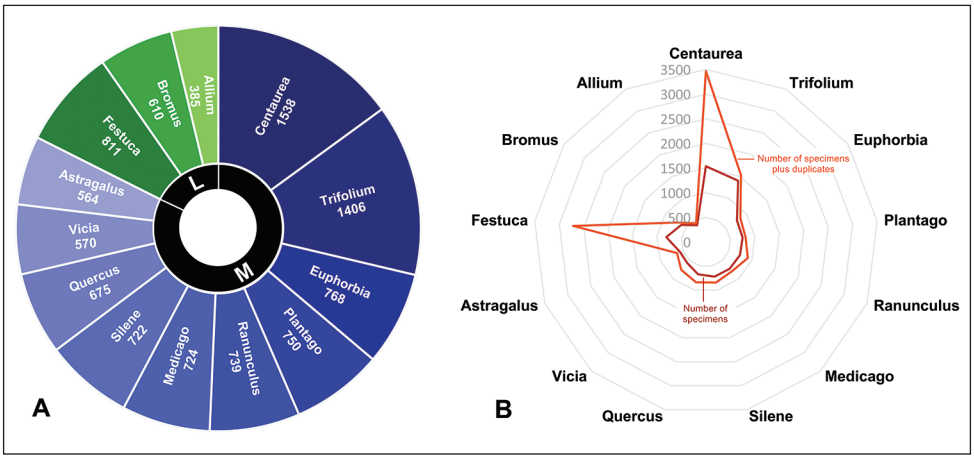

Figure 3. Genera with greatest number of specimens in the General collection (**A**). In blue, genera of Magnoliopsida (M); in green, genera of Liliopsida (L). Number of specimens collected for each genus plus associated duplicates (**B**).

Among the best represented genera are *Centaurea* (1,538 specimens), *Trifolium* (1,406 specimens), *Festuca* (811 specimens), *Euphorbia* (768 specimens), *Plantago* (750 specimens), *Ranunculus* (739 specimens), *Medicago* (724 specimens), *Silene* (722 specimens), *Quercus* (675 specimens), and *Bromus* (610 specimens) (Fig. 3). The two genera with the highest specific diversity are *Centaurea* (102 spp.) and *Festuca* (59 spp.), followed by *Trifolium* (41 spp.), *Silene* (40 spp.), *Euphorbia* (37 spp.), *Ononis* (37 spp.), *Genista* (35 spp.), *Ranunculus* (34 spp.), *Astragalus* (28 spp.), and *Teucrium* (27 spp.).

Taxonomic ranks

Kingdom: Plantae

Phylum: Tracheophyta

Class: Cycadopsida, Equisetopsida, Ginkgoopsida, Gnetopsida, Liliopsida, Lycopodiopsida, Magnoliopsida, Pinopsida, Polypodiopsida, Psilotopsida.

Family: Acanthaceae, Adoxaceae, Aizoaceae, Alismataceae, Amaranthaceae, Amaryllidaceae, Anacardiaceae, Annonaceae, Apiaceae, Apocynaceae, Aquifoliaceae, Araceae, Araliaceae, Araucariaceae, Arecaceae, Aristolochiaceae, Asparagaceae, Asphodelaceae, Aspleniaceae, Asteraceae, Athyriaceae, Balsaminaceae, Begoniaceae, Berberidaceae, Betulaceae, Bignoniaceae, Blechnaceae, Boraginaceae, Brassicaceae, Bromeliaceae, Butomaceae, Buxaceae, Cactaceae, Campanulaceae, Cannabaceae, Capparaceae, Caprifoliaceae, Caryophyllaceae, Casuarinaceae, Celastraceae, Ceratophyllaceae, Cistaceae, Cleomaceae, Clusiaceae, Colchicaceae, Commelinaceae, Convolvulaceae, Coriariaceae, Cornaceae, Crassulaceae, Cucurbitaceae, Culcitaceae, Cupressaceae, Cycadaceae, Cymodoceaceae, Cynomoriaceae, Cyperaceae, Cystopteridaceae, Cytinaceae, Davalliaceae, Dennstaedtiaceae, Didiereaceae, Dioscoreaceae, Drosophyllaceae, Dryopteridaceae, Ebenaceae, Elaeagnaceae, Elatinaceae, Ephedraceae, Equisetaceae, Ericaceae, Escalloniaceae, Euphorbiaceae, Fabaceae, Fagaceae, Frankeniaceae, Garryaceae, Gentianaceae, Geraniaceae, Ginkgoaceae, Grossulariaceae, Haloragaceae, Heliotropiaceae, Hydrangeaceae, Hydrocharitaceae, Hypericaceae, Iridaceae, Isoetaceae, Juglandaceae, Juncaceae, Juncaginaceae, Lamiaceae, Lauraceae, Lentibulariaceae, Liliaceae, Linaceae, Linderniaceae, Lycopodiaceae, Lythraceae, Magnoliaceae, Malvaceae, Marantaceae, Marsileaceae, Martyniaceae, Melanthiaceae, Meliaceae, Menispermaceae, Menyanthaceae, Molluginaceae, Montiaceae, Moraceae, Musaceae, Myricaceae, Myrtaceae, Nephrolepidaceae, Nyctaginaceae, Nymphaeaceae, Oleaceae, Onagraceae, Ophioglossaceae, Orchidaceae, Orobanchaceae, Osmundaceae, Oxalidaceae, Paeoniaceae, Papaveraceae, Passifloraceae, Paulowniaceae, Phrymaceae, Phyllanthaceae, Phytolaccaceae, Pinaceae, Piperaceae, Pittosporaceae, Plantaginaceae, Platanaceae, Plumbaginaceae, Poaceae, Polemoniaceae, Polygalaceae, Polygonaceae, Polypodiaceae, Portulacaceae, Potamogetonaceae, Primulaceae, Proteaceae, Pteridaceae, Rafflesiaceae, Ranunculaceae, Resedaceae, Rhamnaceae, Rosaceae, Rubiaceae, Ruppiaceae, Rutaceae,

Salicaceae, Salviniaceae, Santalaceae, Sapindaceae, Saxifragaceae, Scrophulariaceae, Selaginellaceae, Simaroubaceae, Smilacaceae, Solanaceae, Tamaricaceae, Taxaceae, Tetradiclidaceae, Thelypteridaceae, Thymelaeaceae, Tropaeolaceae, Typhaceae, Ulmaceae, Urticaceae, Verbenaceae, Violaceae, Vitaceae, Zygophyllaceae.

Geographic coverage

Most of the specimens in the collection are from Spanish territory (60,847 specimens; 99.14%), with the peninsular area being the best represented (Fig. 4). Less than 1% of the specimens come from bordering countries, such as Portugal (316 specimens), Morocco (185 specimens), and France (11 specimens). The specimens collected elsewhere –in Andorra (5 specimens), Norway (4 specimens), Switzerland (2 specimens), Great Britain (2 specimens), Ireland (1 specimen), Israel (1 specimen), Italy (1 specimen), and the USA (1 specimen) –, have a symbolic presence, representing only 0.03% of the collection.

Within Spain, Andalusia (Southern Spain) is the region with the highest number of specimens; specifically, within Andalusia, the province of Cordoba has the greatest representation (46,505 specimens), followed by Seville (2,244 specimens), Jaen (1,714 specimens), Huelva (1,640 specimens), and Cadiz (1,396 specimens) (Fig. 4).

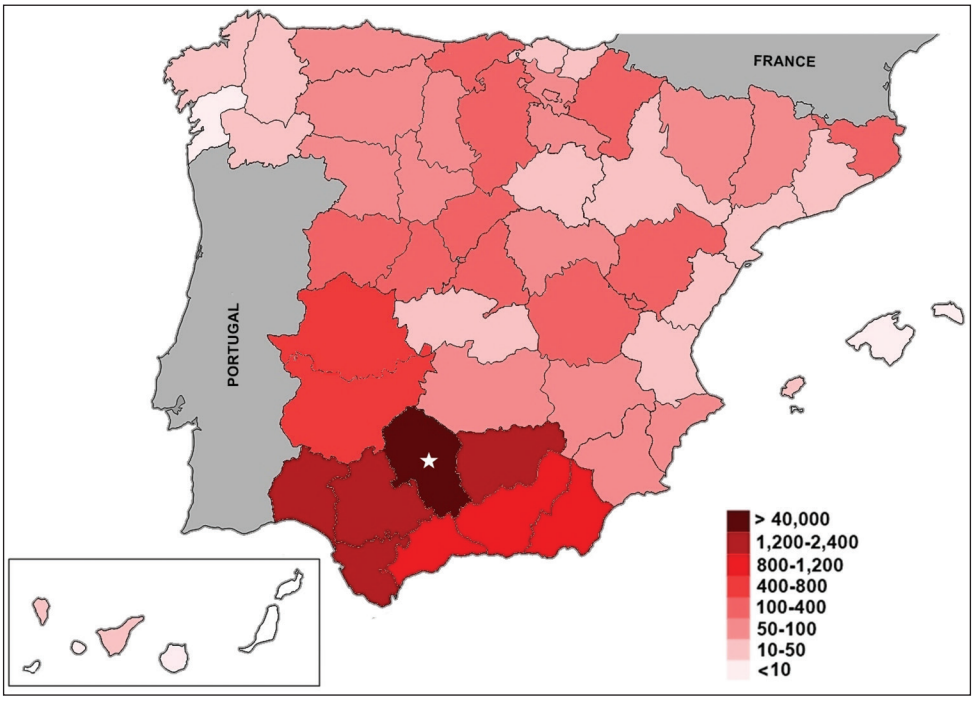

Figure 4. Geographical distribution (provincial representation) of specimens of the General collection in Spain. The star marks Cordoba province.

In the province of Cordoba, an important collection effort was made immediately after creation of the herbarium (Fig. 5). This has included all the territories of the Sierra Morena natural areas (northern half of the province), and the Campiña and Sierra Subbetica in the southern half. These include the territories of the Cardeña–Montoro and Sierra de Hornachuelos Natural Parks, in the Sierra Morena, and the Natural Park of the Sierra Subbetica and the Natural Reserves of the Humid Areas, in the South of Cordoba province.

Temporal coverage

The collection includes specimens collected from 1935 to the present (Fig. 5). The oldest specimens correspond mainly to particular donations and exchanges, mainly involving renowned Spanish botanists such as José Cuatrecasas (1903–1996), Salvador Rivas Goday (1905–1981), Francisco Bellot (1911–1983), Bartolomé Casaseca (1920–1998), and José Vicente Cordeiro Malato-Beliz (1920–1993). The largest number of specimens (about 44,300 specimens, with 6,300 duplicates) was collected at the end of the 1970s and in the mid-1980s, coinciding with the years of creation of the University of Cordoba and COFC (Fig. 5). In this period, the source of the material was mainly PhD theses on flora and chorology, involving lecturers and contracted staff of the Department of Botany, Ecology and Plant Physiology, and also the surveys and taxonomic revisions of genera within the framework of the project "Flora Vascular de Andalucía Occidental" (Valdés et al. 1987). Subse-

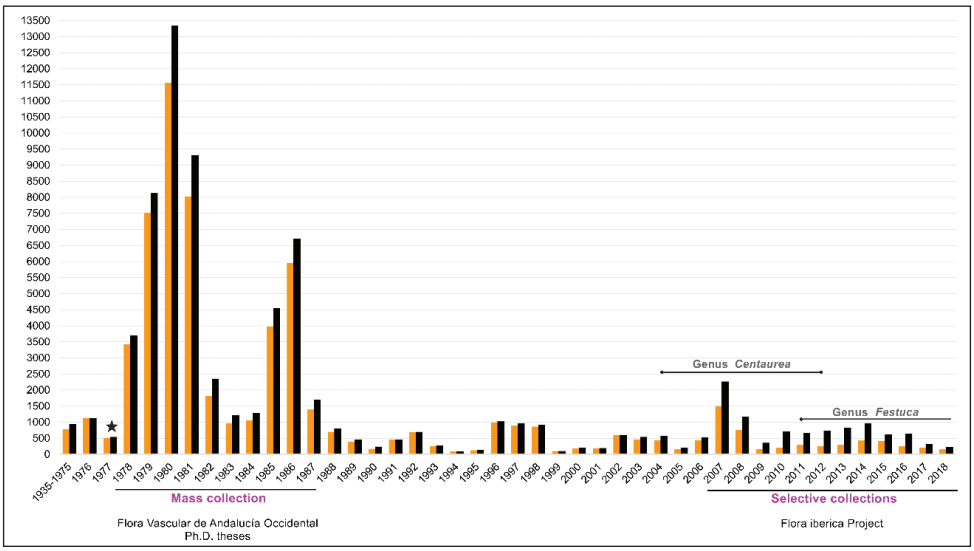

Figure 5. Number of specimens (orange), and specimens plus associated duplicates (black) collected between the years 1935 and 2018. The principal highlights are indicated, and the star marks the year of creation of COFC.

quently, the material incorporated into the herbarium had its origin in more or less periodic collections carried out throughout the province of Cordoba, from which numerous chorological publications of local interest were derived. A new boost to the collection took place during the period 2007–2018 (about 4,900 specimens, with 4,600 duplicates, Fig. 5). In this case mainly due to the collections made in the Iberian Peninsula as part of the "Flora iberica" project (National Plan of R+D+i of the Government of Spain; see the later section Funding of the maintenance and databasing of the herbarium), and this is around 8% of the specimens that the collection houses.

On the other hand, as expected, high seasonality can be seen in the collections: more contributions are made in spring and summer than in winter. Thus, the months of greatest collection effort are April, May and June (almost 40,000 specimens); while the minor ones are December, January and November (only about 2,500).

Step description

Plant processing procedures

The usual procedures for the processing and storage in the herbarium of the plant material have been employed. The fresh material is dried by pressing, sometimes with simultaneous drying using an oven or heater. When it is dry, and prior to storage, the rotary freezing technique (at -18 °C) is used for four days in order to conserve the material and prevent its destruction by fungi and insects, thus avoiding subsequent infestations. This procedure is repeated approximately every six months. The specimens are stored in boxes inside compactor cabinets located in an isolation unit with controlled temperature and humidity. The families are arranged alphabetically, as are the genera within each family and the species within each genus.

Labeling

Once processed, the specimens go along the assembly line, where they are assembled and labeled. Subsequently, they are assigned a COFC accession number and databased using Elysia v1.0. software (Pando et al. 1996–2016). It is estimated that 99.7% of the labels in the collection specify the place of collection. The information on the labels is heterogeneous as regards the origin of the material, and depends largely on the collector and his/her purpose. A complete label includes taxonomic information related to the identity of the sample (scientific name and authorship) and information on the place of collection: country, province, municipality, a more precise geographic location, GPS coordinates (and the projection system), altitude, ecological or descriptive data, date, field number, and collector(s) and identifier name(s).

Quality control

The care and control of the collection includes its monitoring through the management and registration of all incoming and outgoing botanical gatherings that are the responsibility of the Herbarium Service, with the curator's supervision. The process includes space planning, sample relocation, sample assembly and repair, freezing to minimize the potential for insect infestation, and general repairs. Periodic checks are made in the storage area of the collections to detect possible effects of insects and harmful fungi.

The quality control is mainly performed at three levels:

1. **In the identification phase/taxonomic criteria:** For their inclusion in the herbarium, the specimens must be identified at the level of the species and, if appropriate, the infraspecific category, although for many genera there is material without identification of the species that is waiting to be reviewed by specialists. The main works used to identify the material are: "Flora Vascular de Andalucía Occidental" (Valdés et al. 1987), "Flora Vascular de Andalucía Oriental" (Blanca et al. 2009), "Flora iberica" (Castroviejo 1986–2019), and "Flora Europaea" (Tutin et al. 1964–1980). In cases where a modification of the original identification is made, it is reflected in the database as a revision. Currently, work is being done on the organization and delimitation of families according to The Angiosperm Phylogeny Group III (APG III 2009) and IV (APG IV 2016). Regarding nomenclature, it is checked with several taxonomic authorities, such as The Plant List (http://www.theplantlist.org/), Tropicos (http://www.tropicos.org), IPNI (The International Plant Names Index, http://www.ipni.org/), and Euro+Med PlantBase (the information resource for Euro-Mediterranean plant diversity, http://ww2.bgbm.org/EuroPlusMed/), as well as the valid name recognized in "Flora iberica" (http://www.floraiberica.es/).
2. **Georeferencing and technical validation:** It is estimated that only 33% of the specimens in the collection contain information regarding the coordinates (UTM, MGRS, or geographic) of the place of origin, with greater or lesser precision. At present, the georeferencing of the collection is being done using MGRS coordinates (1 km^2 of precision) based on the information contained in the original label, using the tools of Google Earth (http://www.google.com/earth/index.html) and Iberpix (http://www.ign.es/iberpix2/visor/). These coordinates are automatically transformed into geographic coordinates (latitude and longitude are expressed in decimal degrees in the WGS84 datum) when the herbarium information is transferred to the GBIF portal.
3. **In the phase of databasing and data export to the GBIF/Data records network:** The first stage of the databasing of the collection was carried out with Herbar v3.7.1 software (Pando et al. 1994–2010), but afterwards all the information in the collection was transferred to Elysia v1.0 software (Pando et al. 1996–2016), which is

the one used today. It is estimated that around 86% of the material housed in the herbarium has been databased. The first transfer of data from COFC to the GBIF portal included data for the period 2006–2012 (56,081 records), and very recently the corresponding data up to and including 2018 were exported (a total of 60,566 records, excluding *Festuca*). The Darwin Core biodiversity standards were used (DarwinTest v3.3 tool; Ortega-Maqueda and Pando 2008) before uploading the information to the GBIF portal. The Darwin Core file (http://rs.tdwg.org/dwc/), encoded in UTF-8, is generated regularly and is available for download on the GBIF data portal via the Integrated Publishing Toolkit (IPT) of the University of Cordoba (version 1.8, published 2019; https://ipt.gbif.es/resource?r=herbariocofc#versions), through the GBIF Spanish network. The list of elements in the Darwin Core standard published through the GBIF network as well as their definitions and other information of interest can be found at https://dwc.tdwg.org.

Funding of the maintenance and databasing of the herbarium

COFC herbarium does not yet have its own funding. Since its creation, it has been dependent on the personnel and resources of the Department of Botany, Ecology and Plant Physiology of the University of Cordoba. Only more recently has it received additional funding, fruit of the efforts made by the two Curators who have been in charge, Profs. E. Ruiz de Clavijo (1977–2010) and J. A. Devesa (2011–present). It had two grants at the beginning of the databasing of the collection (Complementary Funding of the Ministry of Education and Science), and since 2011 it has benefitted from the work of technical personnel hired for the maintenance, databasing, and georeferencing of the collection, in some cases financed by the Government of Spain, and in others by the Junta de Andalucía. These grants and contracts are summarized below.

Funding received for the initial digitalization of the collection

Funding body: Ministry of Education and Science
Reference: CGL2007-28813-E
Lead researcher: E. Ruiz de Clavijo
Duration: January 2008 to December 2008
Amount: 32,900 euros
Funding body: Ministry of Education and Science
Reference: CGL2008-02241-E/BOS
Lead researcher: E. Ruiz de Clavijo
Duration: January 2009 to December 2009
Amount: 23,000 euros

Contracts of the complementary actions framework

Program: Adaptation of the Herbaria of the Faculty of Sciences of the University of Cordoba to the GBIF framework (Subprogram: Complementary Actions)
Funding body: Ministry of Science, Innovation, and Universities
Lead researcher: E. Ruiz de Clavijo
Duration: July 2006 to April 2007
Program: Adaptation of the Herbaria of the Faculty of Sciences of the University of Cordoba to the GBIF framework (Subprogram: Complementary Actions)
Funding body: Ministry of Science, Innovation, and Universities
Lead researcher: E. Ruiz de Clavijo
Duration: January 2008 to December 2008
Program: Adaptation of the Herbaria of the Faculty of Sciences of the University of Cordoba to the GBIF framework (Subprogram: Complementary Actions)
Funding body: Ministry of Science, Innovation, and Universities
Lead researcher: E. Ruiz de Clavijo
Duration: March 2009 to December 2009 (extended until 30–10–2010)

Contracts for technical staff member:

Program: Technical Personnel to Assist Research
Funding body: Ministry of Science and Innovation
Reference: PTA2010-3438-I
Lead researcher: J. A. Devesa
Duration: February 2011 to January 2014
Program: Technical Personnel to Assist Research
Funding body: Ministry of Education and Vocational Training
Reference: PTA2017-13723-I
Lead researcher: J. A. Devesa
Duration: 2019–2021

Contracts from the Youth Employment Plan:

Program: National Youth Guarantee System
Funding body: Ministry of Employment and Social Security
Lead researcher: PEJ-2014-A-82677
Researcher: J. A. Devesa
Duration: 2016–2017
Program: National youth guarantee system and the youth employment operational program
Funding body: Junta de Andalucía
Reference: EJ-17-Herb

Lead researcher: J. A. Devesa
Duration: June 2017 to May 2018
Program: National youth guarantee system and the youth employment operational program
Funding body: Junta de Andalucía
Reference: EJI-17-RNM-260
Lead researcher: J. A. Devesa
Duration: January 2018 to July 2019
Program: National youth guarantee system and the youth employment operational program
Funding body: Ministry of Economy, Industry, and Competitivity, and Junta de Andalucía
Reference: EJI-17-RNM-260
Lead researcher: J. A. Devesa
Duration: March 2019 to February 2020

Pending or delayed tasks

The following activities are being prioritized by the technical staff.

a) **Mounting, databasing, and inclusion of specimens from old collections:** About 10,000 sheets of unmounted and unfiled specimens that accumulated in the period 1977–1987 are pending allocation of a sheet number or accession number, as well as databasing and inclusion in the General collection. Also, some 4,000 sheets have been allocated an accession number, but their data have not been registered in the database, probably due to a lack of technical personnel during that period and/or the absence of standardized databases. All this material has been identified, and most of it has been mounted. It has been arranged by family in distinctive blue boxes; currently, it is being databased using Elysia v1.0.

These data were not available and so these specimens were not included in the taxonomic analysis or geographical coverage of this paper.

b) **Update the software and publication of data in GBIF:** First, the migration of the database to the new version 2.0 of the Elysia software (Pando et al. 2019) will be carried out. Regarding the publication of the data in GBIF, the records of *Festuca* need to be uploaded. This will be done once the study of its taxonomy and nomenclature has been completed (estimated date: December 2019). However, this paper has taken into account these records (811 so far) for the description of the collection.

Interest and use of the collection

The General collection of COFC is fundamental for our knowledge of the Andalusian flora, and had great importance in the writing of the "Flora Vascular de Andalucía Occidental" (Valdés et al. 1987). It contains a vast representation of specimens from the province of Cordoba, whose study has deepened our knowledge of its flora, reflected in numerous publications in the last 20 years (e.g., Ruiz de Clavijo and Devesa 2010, López Tirado and Hidalgo 2014, López Tirado et al. 2013, 2015, Martínez-Sagarra et al. 2016, Muñoz et al. 2017, Reyes et al. 2017, Devesa et al. 2018, in press, among the most recent). It has also been fundamental for the taxonomic studies that have been carried out in the "Flora iberica" project (Castroviejo 1986–2019), especially from 2007 to the present, a period in which four subprojects have been developed, coordinated by Dr. J.A. Devesa from the University of Cordoba (projects CGL2008-02982-C03-03; CGL2011-28613-C03-02; CGL2014-52787-C3-3-P; CGL2017-85204-C3-3-P, of the Government of Spain). These focused mainly on the preparation of the taxonomic syntheses of the genera *Centaurea* (Devesa et al. 2014) and *Festuca* (taxonomic revision in progress), two of the most complex genera of the peninsular flora with an excellent representation in the collection. It is estimated that 16% of all the material preserved in the collection corresponds to duplicates, and these are especially common for the genera *Centaurea* (1,904 duplicates, Fig. 3B) and *Festuca* (1,906 duplicates, Fig. 3B), and for whose taxonomic synthesis abundant material was necessary in order to cover all their diversity, even at the population level (e.g., Invernón and Devesa 2013, Devesa 2016, Martínez-Sagarra and Devesa 2015, 2019, López et al. 2016, 2017). Besides, much of the material conserved in COFC also been used in morphological and biogeographic studies (Aedo et al. 2015, Cano et al. 2017, Devesa et al. in press), molecular and phylogeographic studies (Arnelas et al. 2018, Benítez-Benítez et al. 2018), foliar anatomy studies (Martínez-Sagarra et al. 2017), and genome size analysis (Martínez-Sagarra et al. work in progress).

In addition, 34 types (7 holotypes and 27 isotypes) of various described taxa of the Iberian Peninsula are preserved in COFC (Table 2).

Dataset description

Object name: Darwin Core Archive Dpto de Botánica, Ecología y Fisiología Vegetal (COFC). Facultad de Ciencias. Universidad de Córdoba
Character encoding: UTF-8
Format name: Darwin Core Archive format
Format version: 1.0
Distribution: https://doi.org/10.15468/fdzzal
Publication date of data: 2019-07-19
Language: Spanish
Licences of use: Creative Commons Attribution Non Commercial (CC-BY-NC) 4.0 License

Metadata language: Spanish
Date of metadata creation: 2019-06-18
Hierarchy level: Dataset

Table 2. Type material of vascular plants conserved in COFC. Acronyms of the herbaria according to Thiers (2019). Holotypes and isotypes are listed in order of publication of the taxa.

Type	Taxon and authority	Publication	Herbarium voucher	Collection location (direct quote)
Holotype	*Centaurea susannae* Invernón & Devesa	Phytotaxa 74: 42, 43 (2012)	COFC 57935 (1 isotype in COFC)	Algarve, Cabo de San Vicente, 6 May 2010
Holotype	*Centaurea molesworthiae* E. López, Devesa & García Rojas	Nordic J. Bot. 30: 422 (2012)	COFC 59475 (1 isotype in COFC)	Cádiz, Tarifa, Sierra de Ojén, Loma de El Chivato, 19 June 2010
Holotype	*Centaurea susannae* var. *paivae* Invernón & Devesa	Acta Bot. Malac. 38: 66 (2013)	COFC 60956 (1 isotype in COFC)	Algarve, Aljezur, Monte Clérigo […], 5 June 2012
Holotype	*Centaurea stuessyi* Arnelas, Devesa & E. López	Phytotaxa 115: 43, 45 (2013)	COFC 57443 (1 isotype in COFC)	Tarragona, Rasquera, balneario de Cardó, 1 July 2009
Holotype	*Mantisalca cabezudoi* E. Ruiz & Devesa	Nordic J. Bot. 32: 18, 19 (2014)	COFC 31890 (1 isotype in COFC)	Granada, Jerez del Marquesado, barranco de Alcázar, 13 June 2007
Holotype	*Festuca greuteri* Martínez-Sagarra & Devesa	Phytotaxa 395: 253 (2019)	COFC 65825 (1 isotype in COFC)	Granada, Sierra de Guillimona, puerto de la Losa, 4 June 2014
Holotype	*Festuca greuteri* subsp. *camarolensis* Martínez-Sagarra & Devesa	Phytotaxa 395: 257 (2019)	COFC 65824 (9 isotypes in COFC)	Málaga, Villanueva del Rosario, Sierra de Camarolos, 10 June 2015
Isotype	*Erica andevalensis* Cabezudo & Rivera	Lagascalia 9: 224 (1980)	COFC 12422 (Holotype in SEV)	Huelva, Zalamea la Real, 21 July 1979
Isotype	*Silybum* × *gonzaloi* Cantó, Sánchez Mata & Rivas Mart. [*S. eburneum* Cosson & Durieu x *S. marianum* (L.) Gaertner]	Itin. Geobot. 15: 707 (2002)	COFC 61148 (Holotype in MAF)	Ciudad Real, Pedro Muñoz, laguna del Retamar, 8 May 2001
Isotype	*Centaurea catellanoides* subsp. *talaverae* E. López & Devesa	Acta Bot. Malac. 33: 60 (2008)	COFC 30665 (Holotype in UNEX)	Toledo, Noblejas, carretera en dirección a Dos Barrios, 7 July 2005
Isotype	*Centaurea beturica* E. López & Devesa	Anales Jard. Bot. Madrid 65: 334 (2008)	COFC 30719 (Holotype in UNEX)	Badajoz, camino hacia La Garganta, 10 July 2005
Isotype	*Centaurea castellanoides* subsp. *arundana* E. López & Devesa	Acta Bot. Malac. 3: 60 (2008)	COFC 30681. (Holotype in UNEX)	Málaga, Parque Natural de la Sierra de las Nieves […], 10 July 2004
Isotype	*Centaurea langei* subsp. *dominguezii* E. López, Devesa & Arnelas	Ann. Bot. Fenn. 48: 7 (2011)	COFC 30666 (Holotype in UNEX)	Salamanca, presa de Aldedávila de la Ribera, 1 July 2003
Isotype	*Orobanche subbaetica* Triano & A. Pujadas	Acta Bot. Malac. 39: 275 (2014)	COFC 61244 (Holotype in COA)	Córdoba, Las Angosturas, 22 May 2010
Isotype	*Foeniculum sanguineum* Triano & A. Pujadas	Acta Bot. Mal. 40: 75 (2015)	COFC 62161 (Holotype in COA)	Cádiz, Benamahoma, Sierra de Grazalema, 19 June 2006
Isotype	× *Tritordeum martinii* A. Pujadas [*Triticum durum* Desf. × *Hordeum chilense* Roem. & Schult.]	Acta Bot. Malac. 41: 327 (2016)	COFC 63411 (Holotype in COA)	Córdoba, La Carolota, finca El Patronato, 29 May 2016
Isotype	*Poa flaccidula subsp. guadianensis* F.M. Vázquez	Folia Bot. Extremad. 9: 66 (2016)	COFC 62937 (Holotype in HSS)	Badajoz, Nogales, Los Madroñales, 9 March 2015
Isotype	*Festuca discreta* F.M.Vázquez	Folia Bot. Extremad. 10: 66 (2016)	COFC 62911 (Holotype in HSS)	Badajoz, Puebla del Maestre, proximidades del rio Viar, 8 May 1998
Isotype	*Narcissus nevadensis* subsp. *herrerae* Algarra, Blanca, Cueto & J. Fuentes	Phytotaxa 371(2): 134 (2018)	COFC 66040 (Holotype in GDA)	Granada, Jayena, Sierra de Almijara, barranco de la Culebra, 9 April 2016

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RESEARCH ARTICLE

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Saxifraga damingshanensis (*S.* sect. *Irregulares*, Saxifragaceae), a new species from Guangxi, China

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Abstract

Saxifraga damingshanensis (Saxifragaceae), a new species from Damingshan Nature Reserve in Guangxi Province, is described and illustrated. A morphological comparison between the new species and its putative relatives, *S. mengtzeana* and *S. luoxiaoensis*, is presented. The new species is morphologically similar to *S. mengtzeana*, but it can be easily distinguished by its non-peltate leaf, both surfaces of mature leaf blade covered with white glandular trichome, petals 3-veined and margin entire. Phylogenetic analysis, based on two chloroplast DNA regions (*matK* and *psbA-trnH*), confirmed that the new species belongs to *S.* sect. *Irregulares*. The new species is currently only known from Damingshan, Guangxi and we assign it an IUCN Red List preliminary status as Data Deficient.

Keywords

China, chloroplast gene, phylogeny

Introduction

Saxifraga L. (Saxifragaceae) is widely distributed throughout the Northern Hemisphere and comprises ca. 440–450 species (Pan et al. 2001; Tkach et al. 2015a, b). Numerous previous molecular phylogenetic studies suggested that *Saxifraga* is monophyletic, providing that *S.* sect. *Micranthes* (Haw.) D.Don is excluded and the genus *Micranthes* Haw. recognised. (Soltis et al. 1996; Prieto et al. 2013; Deng et al. 2015; Tkach et al. 2015a, b). *Saxifraga* sect. *Irregulares* Haw., characterised by long-petiolate leaves, leaf-

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less flowering stems with small bracts, stamens with club-shaped filaments and pollen grains with numerous microchannels in the tectum, is the earliest-diverging named clade in *Saxifraga* (Soltis et al. 2001; Zhang et al. 2015; Tkach et al. 2015b).

In China, *Saxifraga* comprises 216 species, of which seven species belong to *S.* sect. *Irregulares*, according to the "Flora of China" (Pan et al. 2001). Recently, some new species of *S.* sect. *Irregulares* were discovered in China, including *S. daqiaoensis* F.W.Wang & F.W.Xing (Wang et al. 2008), *S. kegangii* D.G.Zhang, Y.Meng & M.H.Zhang (Zhang et al. 2017), *S. luoxiaoensis* W.B.Liao, L.Wang & X.J.Zhang (Zhang et al. 2018) and *S. shennongii* L.Wang, W.B.Liao & J.J.Zhang (Zhang et al. 2019).

During a botanical expedition to Damingshan National Nature Reserve, Wuming district, central Guangxi Province in September 2018, we discovered an unknown species of *Saxifraga* in Longtou Peak. Its mature leaves are densely covered with white trichomes and the abaxial surface is densely purple-spotted. After carefully checking specimens and literature, as well as morphological and molecular studies, we confirm that it is a new species of *Saxifraga* and it is described below.

Materials and methods

We collected more than 20 living individuals of the presumed new species for comparisons and taxonomical treatment. Specimens of *Saxifraga* sect. *Irregulares*, available at herbaria (PE, IBSC, SYS and IBK) and digital photos of all herbarium specimens of *S. luoxiaoensis*, *S. mengtzeana* Engl. & Irmsch., preserved in the Chinese Virtual Herbarium (http://www.cvh.org.cn/), have been checked. Five main characters (leaf shape, leaf margin, spots on the abaxial surface of leaf, petal shape and trichomes on plants) of these three species were compared both in the wild and in the herbarium.

To determine the systematic position of *Saxifraga damingshanensis*, we further sampled five individuals of the presumed new species for a phylogenetic study. The geographic sampling information of these individuals was recorded by a Garmin GPS unit (GPSMAP 62sc, Taiwan) and the voucher specimens were deposited at Sun Yat-sen University Herbarium (**SYS**) (Table 1). The final molecular dataset comprises 19 accessions representing eight species of *S.* sect. *Irregulares*, of which five accessions were newly generated and 14 accessions were downloaded from GenBank (Table 1).

The total DNA was extracted with the modified CTAB method (Doyle and Doyle 1987). The *psbA-trnH2* and *matK* intergenic regions were amplified using previously reported primers (Tate and Simpson 2003; Zhang et al. 2019). PCR amplifications were performed following Chen et al. (2016). Sequences were aligned with MEGA version 6.0 and subsequently manually adjusted (Tamura et al. 2013). Phylogenetic reconstructions were carried out with Maximum Likelihood (ML) and Bayesian Inference (BI) analyses. ML was run by IQ-Tree 1.6.10 with 20,000 ultrafast bootstraps and SH-like approximate likelihood ratio test (aLRT) of 10,000 replicates (Nguyen et al. 2015). BI was executed in MrBayes version 3.2 (Ronquist et al. 2012), with four chains for at least 20,000,000 generations to make the average standard deviation of

Table 1. Voucher information and GenBank accession numbers for sequence data of *Saxifraga damingshanensis* phylogenetic analysis used in this study.

Species	Voucher	*matK*	*psbA-trnH2*
Saxifraga damingshanensis	**W. Y. Zhao 1208; Damingshan, Guangxi**	**MK976729**	**MK976724**
	W. Y. Zhao 1209; Damingshan, Guangxi	**MK976730**	**MK976725**
	W. Y. Zhao 1210; Damingshan, Guangxi	**MK976731**	**MK976726**
	W. Y. Zhao 1211; Damingshan, Guangxi	**MK976732**	**MK976727**
	W. Y. Zhao 1212; Damingshan, Guangxi	**MK976733**	**MK976728**
Saxifraga mengtzeana	FHZ-1608; Yuanbao Mountion, Guangxi	MK092518	–
Saxifraga rufescens	YLDP197D; Yulong Mountion, Yunnan	MH116857	MH117313
Saxifraga stolonifera	LXP-13- 24775(1); Yanling country, Hunan	MK092557	MK092599
	LXP-13- 24775(2); Yanling country, Hunan	MK092558	MK092600
	LXP-13- 24775(3); Yanling country, Hunan	MK092551	MK092593
	LXP-13- 24775(4); Yanling country, Hunan	MK092552	MK092594
Saxifraga epiphylla	Q. Fan 15680(1); Qingchengshan, Sichuan	MK092519	–
	Q. Fan 15680(2); Qingchengshan, Sichuan	MK092520	–
Saxifraga daqiaoensis	RY-2017-031(1); Daqiao Town, Guangdong	MK092533	MK092575
	RY-2017-031(2); Daqiao Town, Guangdong	MK092534	MK092576
Saxifraga luoxiaoensis	LXP-13-24717(1); Nanfengmian, Jiangxi	MK092539	MK092581
	LXP-13-24717(2); Nanfengmian, Jiangxi	MK092540	MK092582
Saxifraga shennongii	LXP-13-24778(1); Yanling country, Hunan	MK092527	MK092569
	LXP-13-24778(2); Yanling country, Hunan	MK092528	MK092570
	LXP-13-24769(1); Yanling country, Hunan	MK092521	MK092563
	LXP-13-24769(2); Yanling country, Hunan	MK092522	MK092564

*All vouchers are deposited in the Sun Yat-sen University Herbarium (SYS); "/" represents missing data.

split frequencies (ASDFs) < 0.01, sampling every 1000 generations with the first 25% sampled trees discarded as burn-in. The 50% majority-rule consensus trees were finally generated. For both ML and BI analyses, F81+F+I was detected as the best-fitting nucleotide substitution model on the basis of Bayesian Information Criterion (BIC) detected by ModelFinder (Kalyaanamoorthy et al. 2017).

Results

Morphological comparison

In morphology, the putative new species is closely related to *Saxifraga mengtzeana* and their morphology comparisons are presented in Table 2. These two species share such features as having stolons absent, inflorescences and pedicels covered with glandular hairs, white flowers without pink markings and base of three short petals with yellow plot. However, the new species differs from *S. mengtzeana* by having leaf base cordate to deep cordate (vs. usually peltate), leaves papery or nearly leathery (vs. leathery), adaxial surface of the mature leaf with glandular trichome (*vs*. nearly glabrous) and longest petal 3-veined, margin entire (vs. 8-veined, margin sparsely denticulate). Moreover, *S. damingshanensis* flowers from August to October, while *S. mengtzeana* flowers from March to August.

Table 2. Morphological comparisons amongst *Saxifraga damingshanensis*, *S. luoxiaoensis* and *S. mengtzeana*.

Characters	*Saxifraga damingshanensis*	*S. luoxiaoensis*	*S. mengtzeana*
Leaf shape	rounded or ovate, never peltate	reniform, never peltate	± peltate, ovate
Leaf texture	papery or leathery	papery	leathery
Leaf base	cordate to deep cordate	cordate	± cordate
Leaf margin	5–10-lobed, lobes entire, sparsely glandular hairy	margin 7–9-lobed, usually double serrate	crenate, inconspicuous glandular hairy
Abaxial surface of leaf blade	with glandular trichome and purple spots	glabrous with red or brown spotted	sparsely hispid and brown spotted
Second longest petal	lanceolate oblong, 13–17 × 2 mm, 3-veined	lanceolate oblong, ca. 8–20 mm × 1.3–3 mm, 3–5-veined	narrowly ovate, ca. 9 × 2.2 mm, 3-veined
First longest Petal	lanceolate, 1.8–2.2 cm × 1.5–2.5 mm, 3-veined, margin entire	linear lanceolate, 16–25 mm × 1.3 – 3 mm, 3–5-veined, margin entire	sublanceolate, 19 × 3.4 mm, 8-veined, margin sparsely denticulate
Stamens	3.5–4.5 mm long	4.3–5.6 mm long	ca. 6 mm long
Flowering period	August to October	April to June	May to August

Phylogenetic placement of *Saxifraga damingshanensis* within *S.* sect. *Irregulares*

The concatenated sequences of *matK* (740 bp) and *psbA-trnH2* (297 bp) are 1037 bp in length and 81 parsimony-informative sites were detected. Our results showed that *S.* ser. *Rufescentes* J.T.Pan is monophyletic (SH-aLRT: 100; LP: 100; PP: 1.00, Fig. 1) which is coincident with the previous study (Zhang et al. 2018). The putative new species, *S. damingshanensis*, was nested into *S.* ser. *Rufescentes* J.T.Pan and was strongly supported as sister to a clade consisting of *S. luoxiaoensis*, *S. daqiaoensis* and *S. shennongii* (SH-aLRT: 97; LP: 98; PP: 1.0).

Discussion

Based on its basal leaves with long petiolate, flower zygomorphic and stamens with club-shaped filaments, the new species could be placed within *S.* sect. *Irregulares*. Our phylogeny also supports the inclusion of *Saxifraga damingshanensis* within *S.* sect. *Irregulares* (Fig. 1). All examined individuals of *S. damingshanensis* clustered into a single lineage, thus corroborating the evidence for the new species status, based on morphology.

Our study also recovered a sister relationship of the new species with a clade comprising *Saxifraga luoxiaoensis*, *S. daqiaoensis* and *S. shennongii*. The close relationship amongst these species was also supported by their similar morphological characteristics. All four species have white glandular trichomes on leaf and inflorescence and white and entire petals. However, *S. damingshanensis* differs from the latter three species by having mature leaf and petiole with glandular trichomes (vs. mature leaf sparsely hispid or glabrous) and the abaxial surface of the leaf blade with purple spots (vs. usually yellow-brown spots). Furthermore, their phenology and distribution are different. *Saxifraga damingshanensis* is flowering from August to October (vs. April to June) and endemic to Damingshan, Guangxi (*vs*. Guangdong, Jiangxi and Hunan).

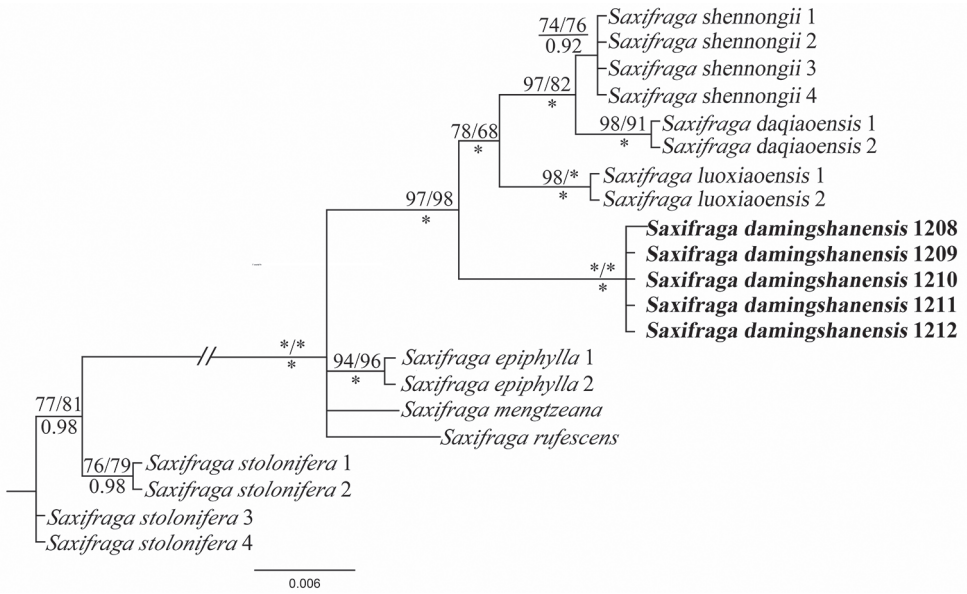

Figure 1. Bayesian consensus tree of *Saxifraga damingshanensis* and related species derived from two chloroplast regions. Numbers above branches are the value of SH-like approximate likelihood ratio test (aLRT) and bootstrap value of the Maximum Likelihood (LP); numbers below branches indicate Bayesian posterior probability (PP). Asterisks denoted (*) the values of 100 or 1.00 for LP/PP. The new species is shown in bold.

Taxonomic treatment

Saxifraga damingshanensis **W.B.Liao, W.Y.Zhao & J.H.Jin, sp. nov.**
urn:lsid:ipni.org:names:77202383-1
大明山虎耳草

Type. China. Guangxi: Nanning city, Damingshan Nature Reserve, Longtou Peak, 23°22'58.48"N, 108°30'21.56"E, 1542 m alt., 19 September 2018, *W.Y.Zhao 1208* (Holotype SYS!; Isotypes SYS!, IBSC!). (Fig. 2)

Diagnosis. *Saxifraga damingshanensis* is morphologically most similar to *S. mengtzeana*, but differs by its leaf blade with glandular trichome and purple spots abaxially, short stamens and petal entire.

Description. Perennial herbs, 15–30 cm tall. Stolons absent. Rhizomes rather short (ca. 0.3–0.7 cm), sparsely glandular trichomes. Basal leaves forming a rosette, petiole 5–15 cm long, fleshy and translucent, sparsely short glandular trichomes (ca. 2 mm); petiole base sheathed, margin with sparsely glandular trichomes; leaf blade rounded or ovate, base cordate to deep cordate, papery or leathery, 2.0–5.7 × 2.5–5.5 cm, apex obtuse, margin inconspicuous 7–15-lobed with sparsely glandular trichomes, lobes entire, adaxially dark green, densely covered glandular trichomes (2.5–4 mm), abaxially grey, sparsely covered with glandular trichomes (1.5–2.5 mm), densely covered with purple spots; palmate veins 7–11, both surfaces inconspicuous. Cauline leaves 1–2, triangular-lanceolate, 5.0–6.0 ×

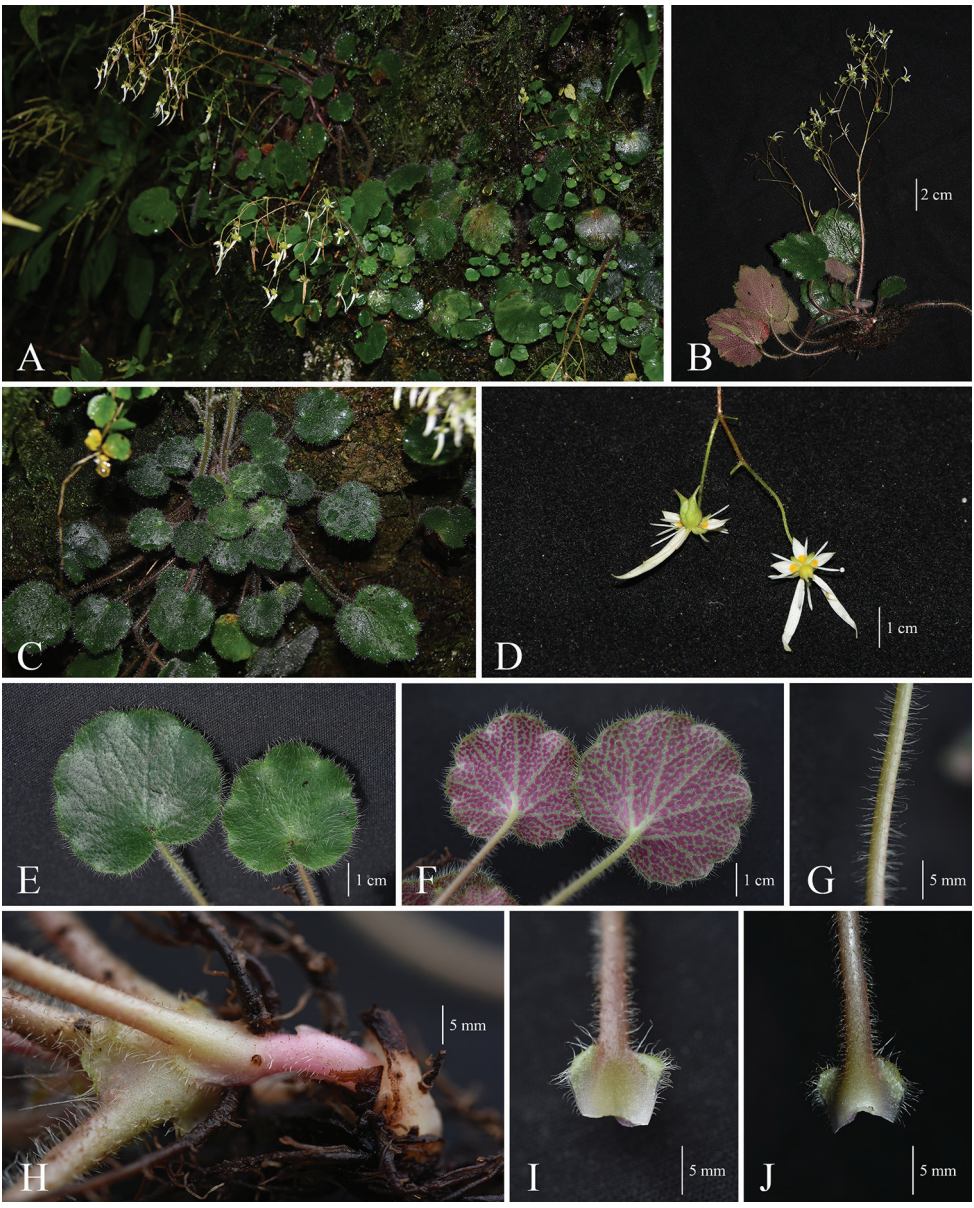

Figure 2. *Saxifraga damingshanensis* **A** Habit **B** whole plant **C** basal leaves rosette with long petiole, plant cover white trichomes **D** flower and fruit, pedicel slender with short trichomes, filaments clavate **E** adaxial leaf surface dark green, sparsely glandular piliferous **F** abaxial leaf surface grey, sparsely glandular piliferous and purple spotted **G** petiole with glandular piliferous **H** rhizomes cover sparsely glandular piliferous, petiole base sheathed **I** adaxial surface of sheath, glabrous, margin with glandular piliferous **J** abaxial surface of sheath, upper with sparse glandular piliferous.

1.5–2.0 mm, margin with sparsely glandular trichomes. Inflorescence paniculate, 15–30 cm long, 10–35-flowered; branches 4–5 cm, sparsely short glandular trichomes (0.5–1.0 mm), 2–6(-8)-flowered; pedicels slender, 1.5–2.5 cm long, sparsely short glandular trichomes (ca. 0.5 mm); bracts linear, 1.5–2.5 × 0.5–0.8 mm, margin with short glandular trichomes. Flowers zygomorphic; sepals 5, spreading, narrowly ovate, 2.0–2.5 × 1.0 mm, apex obtuse, base connate, adaxially glabrous, abaxial surface and margin with sparsely short glandular trichome, becoming denser proximally, 3 veins inconspicuous. Petals 5, white; shortest 3 petals equal, ovate, base with yellow spots, 3–3.5 × 1.5 mm, apex acute, base rounded, triplinerved; the other two petals lanceolate, first longest petal lanceolate, 18–22 × 1.5–2.5 mm, apex acuminate, margin entire, glabrous, 3-veined; second longest petal narrowly ovate, 1.3–1.7 × 0.2 cm, apex acuminate, margin entire, glabrous, 3-veined. Stamens 10, filaments clavate, 3.5–4.5 mm long. Ovary ovoid, 1.5–2.5 mm long; disc obscure; carpels 2, proximally connate about 3/4; styles 2, divergent, 1.5–2 mm long. Capsule ovoid, 4–5 × 3–4 mm. Seeds elongate-ellipsoid, yellowish-brown or dark brown, the two ends slightly bent, ca. 0.6 mm, surface 3-ribbed.

Phenology. Flowering from August to October, fruiting from September to November.

Etymology. The species epithet is based on the mountain name, Damingshan and the Latin suffix, *-ensis*, of origin, where the new species was collected.

Distribution, ecology and conservation status. Only three populations of *Saxifraga damingshanensis* were discovered from Damingshan National Nature Reserve, Guangxi Province. It was observed to grow on damp cliffs and rocks in broad-leaved forests at altitudes between 1300 and 1650 m. Its known localities are well protected and more field investigations are needed to determine its wild distribution. Therefore, we suggest listing the new species as Data Deficient (DD) based on the IUCN Red List Criteria (IUCN 2019).

Additional specimens examined (paratypes). China. Guangxi: Nanning city, Damingshan Nature Reserve, Longtou Peak, Blackwood cliff, 23°22'58.48"N, 108°30'21.56"E, 1542 m alt., 19 September 2018, *W.Y.Zhao 1209* (SYS!); same locality, 1500 m alt., 19 September 2018, *W.Y.Zhao 1210* (SYS!); same locality, 1522 m alt., 19 September 2018, *W.Y.Zhao 1211* (SYS!); same locality,1480 m alt., 19 September 2018, *W.Y.Zhao 1212* (SYS!); Wuming county, Xiaolu village, Damingshan, 1420 m alt., 26 August 1958, *Y.C.Chen 325* (IBK18155!).

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RESEARCH ARTICLE

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Reinstatement of the Chinese endemic species *Styrax zhejiangensis*

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Abstract

Styrax zhejiangensis has been treated as a synonym of *S. macrocarpus*. Examination of herbarium specimens and observation of wild living plants demonstrates that *S. zhejiangensis* is a distinct species and is clearly distinguishable from *S. macrocarpus* through its flowering phenology in which leaves and flowers open simultaneously, its smaller corolla lobes and filaments, and its white-stellate-pubescent seeds. On this basis, we reinstate *S. zhejiangensis* as an accepted species. Photographic images and a distribution map of the two species are provided. A lectotype of *S. zhejiangensis* is also designated.

Keywords

Flowering phenology, Styracaceae, *Styrax zhejiangensis*, *S. macrocarpus*, synonym

Introduction

Styrax zhejiangensis S.M. Hwang & L.L. Yu (Hwang 1983) (Styracaceae) was described on the basis of four specimens of one collection, *X. Y. He 29344* (IBSC, HHBG, NAS; Fig. 1A), from Jiande, Zhejiang Province, China. In the protologue, the authors stated that this species was similar to *S. macrocarpus* Cheng (Cheng 1938) (Fig. 1B), but differed by its bush-like habit, broadly elliptic to ovate-oblong leaves, smaller fruits, and sparsely white-stellate seeds. It was recognized by later authors, including Hwang (1987), Li and Ding (1989), Fang (1992), and Hwang and Grimes (1996), but was

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Figure 1. Lectotype sheet of *Styrax zhejiangensis*, China, Zhejiang, Jiande, *X. Y. He 29344* (IBSC) (**A**) and holotype sheet of *S. macrocarpus*, China, Hunan, Yizhang, Mang mountain, *W. C. Cheng s.n.* (PE) (**B**).

synonymized with *S. macrocarpus* by Huang et al. (2003). Huang et al. (2003) purported that there were no essential morphological differences between the two species emphasized by Hwang (1983) other than the presence of stellate trichomes on the seeds in *S. zhejiangensis* versus their absence in *S. macrocarpus*, a difference which they regarded as taxonomically trivial. According to Huang et al. (2003), *S. macrocarpus* sensu lato is a species with a disjunct distribution between southeastern Hunan and western Guangdong (Fig. 2).

After critical examinations of the relevant *Styrax* specimens in major Chinese herbaria, combined with our field observations in the type localities of each entity, we find that *S. zhejiangensis* is a species distinct from *S. macrocarpus*, differing from it in a combination of taxonomically significant morphological characters. Here we provide updated detailed morphological descriptions of these two species, a table of their morphological character differences, a distribution map, photographic images, and conservation assessments.

Material and methods

Morphological comparisons were made through herbarium studies and field observations. Herbarium studies were conducted in AU, BNU, CSFI, HHBG, IBK, IBSC, JXAU, KUN, NAS and PE. Field observations were made in the type localities

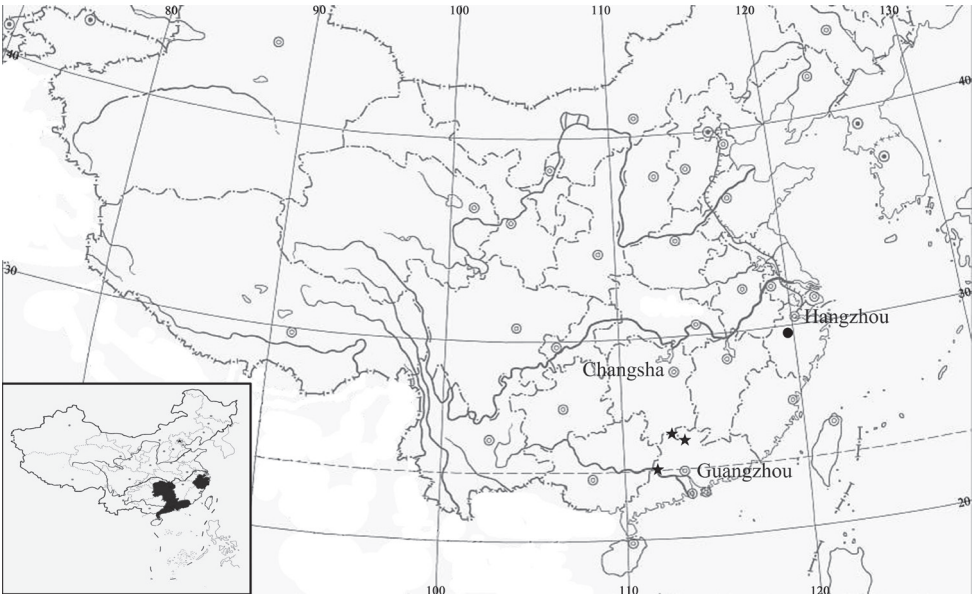

Figure 2. Distribution map of *Styrax zhejiangensis* ([INSERT FIGURE 003]) and *S. macrocarpus*.

of *Styrax zhejiangensis* in Jiande, Zhejiang Province, and *S. macrocarpus* on Mang Mountain, Hunan Province. Moreover, we use IUCN Red List categories (IUCN 2012) to evaluate the conservation status of the two species.

Results and discussion

Styrax zhejiangensis differs from *S. macrocarpus* in a combination of morphological characters (Table 1, Figs 3–5). *S. zhejiangensis* produces flowers and leaves simultaneously (vs. flowers before the leaves in *S. macrocarpus*), has smaller flowers (4.0–5.5 cm vs. 6.0–7.5 cm in diameter) with shorter corolla lobes (1.8–2.7 cm vs. 2.8–3.8 cm) and stamens (10–12 cm vs.14–16 cm), and has a seed surface with sparse to dense white-stellate trichomes (vs. glabrous). Furthermore, *S. zhejiangensis* is shrub-like, 1.5–3 m (only one individual reaches 7 m in our observation), with multiple branches from the base, whereas *S. macrocarpus* is tree-like, often over 7 m and with single stem. The pubescence on the corolla also helps to distinguish the two species, with *S. zhejiangensis* having inconspicuous pubescence or being glabrous, and *S. macrocarpus* having conspicuous pubescence.

Li and Ding (1989) and Hwang and Grimes (1996) described the flowering phenology for *Styrax zhejiangensis* and *S. macrocarpus* and they have been confirmed in our field observation, and undoubtedly serve as a diagnostic character. Li and Ding (1989) also pointed out that the species can also be distinguished by the size of the corolla lobes and numbers of stamens. We observed a substantial difference in the size of their corolla lobes, but no distinct difference in the numbers of their stamens, with 13 to

Table 1. Morphological differences between *Styrax zhejiangensis* and *S. macrocarpus*.

Taxonomic traits	*Styrax zhejiangensis*	*Styrax macrocarpus*
Stem	1.5–3 (–7) m, shrub-like habit	6–9 (–12) m, tree-like or small tree-like habit
Petiole	Upper 1–3 mm, middle nearly absent	Both upper and middle 2–5 mm
Flowering phenology	Leaves and flowers open simultaneously	Flowers open before leaves
Flower diameter	4.0–5.5 cm	6.0–7.5 cm
Corolla lobe length	1.8–2.7 cm	2.8–3.8 cm
Corolla lobe pubescence	inconspicuous or absent	Conspicuous
Stamens, number	13 to 16	11 to 15
Stamen, length	10–12 mm	14–16 mm
Seeds	with stellate trichomes	without stellate trichomes

16 stamens for *S. zhejiangensis* and 11 to 15 for *S. macrocarpus*. Huang et al. (2003) pointed out that the number of stellate trichomes distributed on the seed surface of *S. zhejiangensis* varies from several to dozens, which is consistent with our observation, and they considered that this character by itself cannot be used to distinguish *S. zhejiangensis* from *S. macrocarpus*. However, it should be noted that the seed surface of *S. macrocarpus* is glabrous by our observation, never with stellate trichomes. Thus, combined with the other differences observed, warrant the treatment of *S. zhejiangensis* as an accepted species distinct from *S. macrocarpus*.

Taxonomic treatment

***Styrax macrocarpus* Cheng (Cheng 1938: 398)**
Fig. 1B, 4, 5 A2, B2, C2, D2

Type. CHINA. Hunan: Yizhang, Mang Mountain, 800 m, 21 August 1937, *W. C. Cheng 7000* [from protologue] (holotype PE00027927!; isotype PE 00027979!)

Description. Trees 6–9(–12) m tall, with a single stem, deciduous. Branchlets subterete, densely gray-brown stellate-pubescent, glabrescent. Leaves alternate, two most proximal leaves on each shoot subopposite to opposite; leaf blade broadly elliptic to ovate-oblong, 5.5–15.0 × 3.0–6.0 cm, papery, glabrous but veins stellate-pubescent, elliptic to obovate-elliptic; apex acute; base cuneate, broadly cuneate or rounded; margin subentire or apically slightly serrate; secondary veins 6 to 10 pairs, tertiary veins subparallel; adaxially plane or slightly sunken, abaxially raised. Petiole 2–5 mm long. Pedicel 9–13 mm long, densely white-stellate-tomentose; bracteoles 6–10 mm long, ovate-lanceolate. Flowers solitary, axillary, opening before leaves. Calyx 5–8 × 6–9 mm, membranaceous, densely gray-stellate-tomentose and sparsely stellate-pubescent; teeth 5 or 6, deltoid, unequal, 2–3 mm, subglabrous. Corolla diameter 6.0–7.5 cm, white, tube 3–4 mm long; lobes 6 or 7, elliptic-obovate, 2.8–3.8 × 1.5–2.5 cm. Stamens 11 to 15, 14–16 mm long, shorter than corolla; filaments 7–10 mm long, basally densely white-stellate-pubescent; anthers 5–7 mm long. Fruit solitary, axillary, ovoid, 2–3 × 2.0–2.5 cm, densely gray-stellate-pubescent, apex shortly pointed. Seeds ovoid-ellipsoid, irregularly rugose, glabrous.

Figure 3. *Styrax zhejiangensis* (Jiande, Zhejiang, China) **A** habitat and habit **B** inflorescence **C** leaf blades **D** flower (top view) **E** flower (back view) **F** flower (side view) **G** opened flower **H** corolla lobes **I** sepals (two sepals pulled apart at the lobe margins of one calyx) **J** stamens. Photographed by Yu-Qing Ruan and Ming Tang.

Distribution and habitat. *Styrax macrocarpus* is distributed between southeastern Hunan and western Guangdong (Fig. 2). It grows in sparse forests, valleys or at forest margins at elevations between 130 and 230 m a.s.l.

Phenology. Flowering from mid- to late April and fruiting in August and September.

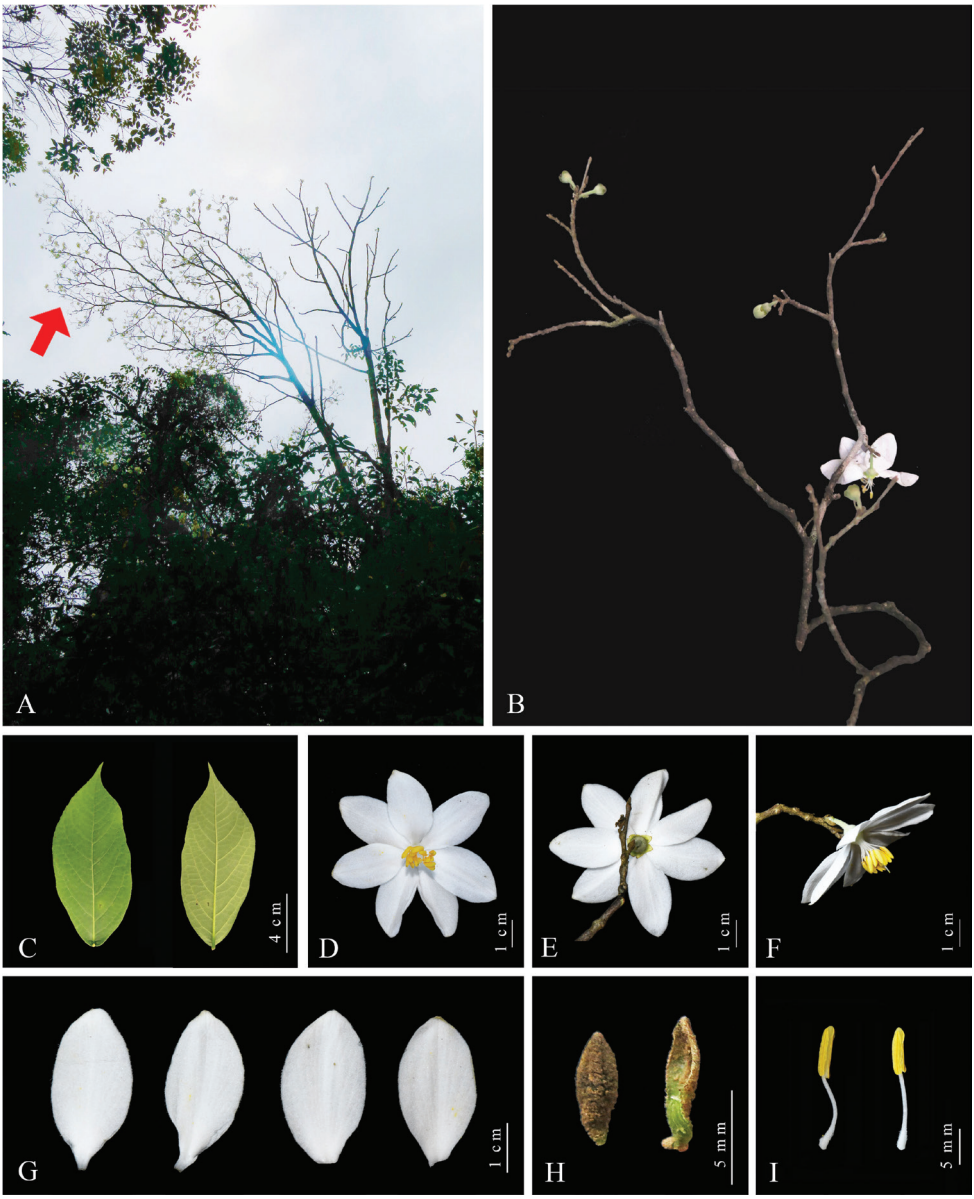

Figure 4. *Styrax macrocarpus* (Yizhang, Hunan, China) **A** habitat and habit; red arrow indicates *S. macrocarpus* **B** inflorescence **C** leaf blades in adaxial (left) and abaxial (right) view **D** flower (top view) **E** flower (back view) **F** flower (side view) **G** corolla lobes **H** sepals (two sepals pulled apart at the lobe margins of one calyx) **I** stamens. Photographed by Yu-Qing Ruan and Ming Tang.

Additional specimens examined. CHINA. Hunan: Yizhang, *S.H. Chun 2889* (AU, IBK, IBSC, KUN, PE), *5408* (IBSC), *Central South Forestry Institute internship team 02-3 195* (CSFI), *M.S Huang 112743* (IBSC), *H.S. Liao 15727* (CSFI), *P.H.*

Liang & X.H. Xu 85107 (IBK, IBSC), *S.R. Lin & K.W. Liu 50285* (CSFI), *X.Q. Liu 28884* (IBK, IBSC, NAS, PE), *Y.Q. Ruan & Y.L. Liu 34* (JXAU), *J.G. Xiao 4142* (CSFI), *anonymous 137* (IBSC), *anonymous 1017* (CSFI). Guangdong: Fengkai, *G.L. Shi 14815* (IBSC), *Q.S. Yue 5185* (IBSC); Ruyuan, L. Wu & Y. Tong 3192 (IBSC), Z.L. Chen *30610* (IBSC).

Notes. The two specimens collected from Mengla County, Yunnan (*Y. M. Xia 245*, HITBC) and Yulin, Guangxi (*Y.S. Wu 0289*, IBK) respectively, which were also designated as *Stytax macrocarpus* on the sheets, are confirmed to be wrongly identified and should be *S. chinensis* (Liang 1980: 230), a widely distributed species in the southernmost provinces of China such as Guangdong, Guangxi, Yunnan, Fujian, as well as Southeast Asia. *S. chinesis* could be easily distinguished from *S. macrocarpus* by its bigger (8–23 × 3–12 cm vs 5.5–15.0 × 3.0–6.0 cm), thick-leathery leaves (vs papery) leaves.

***Styrax zhejiangensis* Hwang (Hwang 1983: 75)**
Fig. 1A, 3, 5A1, B1, C1, D1

Type. CHINA. Zhejiang: Jiande, northeast of Long River, along stream, 27 June 1958, *X. Y. He 29344* (lectotype, here designated, IBSC0002732!; isolectotype IBSC0497542!; isolectotype HHBG-HZ044271!; isolectotype NAS00072216!).

Description. Shrubs, 1.5–3(–7) m tall, often branched at base, deciduous. Branchlets subterete, brown to grayish brown, glabrous. Leaves alternate but subopposite on basal part of branchlet; leaf blade broadly elliptic to ovate-oblong, 2.5–8.0 × 2.0–5.0 cm, papery, adaxially glabrous, abaxially glabrous but veins sparsely stellate-villous, base broadly cuneate to rounded, margin denticulate to subentire, apex acute, secondary veins 5 to 10 pairs, tertiary veins reticulate; adaxially plane or slightly sunken, abaxially raised. Petiole: those of upper leaves 1–3 mm, those of middle nearly sessile. Pedicel 7–13 mm long, densely white-stellate-tomentose; Flowers solitary, axillary, opening simultaneously with leaves. Calyx 5–8 × 5–10 mm, membranaceous; teeth 5 or 6, deltoid, unequal, 1.0–2.5 mm, apex white-glandular-dotted. Corolla diameter 4.0–5.5 cm, white, tube 3–4 mm long; lobes 6 to 8, elliptic-obovate, 1.8–2.7 × 1.0–1.6 cm. Stamens 13 to 16, 10–12 mm long, shorter than corolla; filaments 5–8 mm long, basally densely white-stellate-pubescent; anthers 4–5 mm long. Fruit solitary, axillary, ovoid, 1.8–2.0 × 1.0–1.2 cm, densely gray-stellate-pubescent, apex shortly pointed. Seeds ovoid-ellipsoid, irregularly rugose, sparsely or densely white-stellate-pubescent.

Distribution and habitat. *Styrax zhejiangensis* is only found in Jiande, Zhejiang Province, distributed in Taohuawu, Long River Forest Area (Fig. 2). It grows in sparse forests or at forest margins at elevations between 130 and 230 m a.s.l.

Phenology. Flowering in early April and fruiting in August and September.

Additional specimens examined. CHINA. Zhejiang: Jiande, *G.Y. Li et al. L 0150* (PE); *G.Y. Li et al. L 0154* (PE); *Y.Q. Ruan & Y.L. Liu RL 31* (JXAU); *Y.Q. Ruan & Y.L. Liu RL 46* (JXAU).

Figure 5. Morphological comparison between *Styrax zhejiangensis* (**A1, B1, C1, D1**) and *S. macrocarpus* (**A2, B2, C2, D2**). **A1, A2** Flower **B1, B2** corolla lobes **C1, C2** stamens **D1, D2** seed (Note the enlarged stellate trichomes in the red circle in figure **D1**). Photographed by Yu-Qing Ruan and Ming Tang.

Conservation status of *Styrax zhejiangensis* and *S. macrocarpus*

Styrax zhejiangensis is a narrowly distributed species; it is only found in Jiande with a population of less than 100 individuals. Despite the wide distribution of *S. macrocarpus*, it is mainly distributed on Mang Mountain and is not common. According to our observation, the natural regeneration of both of the two species is very poor. Following IUCN Red List categories (IUCN 2012), we categorize *S. zhejiangensis* as critically endangered under criteria B and D and *S. macrocarpus* as endangered under criteria B.

Acknowledgements

We are grateful to Dr. Chen Ren, Dr. Peter W. Fritsch and Dr. Yasen Mutafchiev for their valuable comments on the manuscript. We also thank the curators of AU, BNU, CSFI, HHBG, IBK, IBSC, JXAU, KUN, NAS and PE for access to their specimens and allowing us to use their scanned images of specimens. This work was supported by the National Natural Science Foundation of China (grant no 31960043, 31500166) and the Science and Technology Research Project of Jiangxi Education Department (grant no. GJJ170255).

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RESEARCH ARTICLE

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Synsepalum chimanimani (Sapotaceae), a new species from the Chimanimani Mountains of Mozambique and Zimbabwe, with notes on the botanical importance of this area

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Abstract

Synsepalum chimanimani S.Rokni & I.Darbysh., **sp. nov.**, a small tree endemic to the forests of the southern foothills of the Chimanimani Mountains of Mozambique and Zimbabwe, is described and illustrated. The differences in morphology and distribution between the new species and the related *S. kaessneri* and *S. muelleri*, with which it has been confused, are clarified. The new species is globally Endangered due to ongoing habitat loss within its restricted range. The botanical importance and conservation of the Chimanimani foothills is also discussed, and they are highlighted as a candidate Important Plant Area.

Keywords

conservation, herbarium, Important Plant Area, Makurupini, taxonomy

Introduction

Synsepalum (A.DC.) Daniell is a genus of approximately 35 species of evergreen shrubs or trees native to tropical Africa (Pennington 1991; Borg et al. 2019). The species and groups of species in this genus are often very distinct, which has caused previous authors to attempt to subdivide it into a number of smaller genera including *Afrosersalisia* A.Chev., *Pachystela* Radlk. and *Vincentella* Pierre (see, for example, Hemsley 1968; Kupicha 1983), resulting in an extensive synonymy. However, the characters used to

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define these genera have a reticulate pattern of variation, and the lack of correlation between these characters precludes any subdivision of this group except on a single character basis, which results in different groupings according to which character is weighted. This unsatisfactory generic classification led to the segregate genera being united under *Synsepalum* by Pennington (1991).

In a recent molecular phylogenetic study by Borg et al. (2019), which used nuclear ribosomal DNA and plastid trnH–psbA sequences to elucidate relationships within and between *Synsepalum* and *Englerophytum* K.Krause, neither genus was supported as monophyletic. This study identified six major lineages within this clade, and provided morphological evidence in support of these lineages. However, only 11 species of *Synsepalum* and eight (out of 19) species of *Englerophytum* were sampled in this study, and the authors concluded that more morphological and molecular data are required before making final taxonomic decisions regarding the placement of species in this clade and whether or not to reinstate some of the former segregate genera.

The new species of *Synsepalum* described here, recorded from the lowland forests of the Chimanimani Mountains on the border of Mozambique and Zimbabwe, has previously been treated as conspecific with *S. kaessneri* (Engl.) T.D.Penn. (Kupicha 1983, as *Afrosersalisia kaessneri* (Engl.) J.H.Hemsl.). *Synsepalum kaessneri* is otherwise a rare species of lowland forest in the Eastern Arc Mountains and adjacent lowlands of Kenya and Tanzania, with the nearest populations nearly 1,500 km NNE of the Chimanimani Mountains. However, few previous collections were available from Mozambique and Zimbabwe, and only fruiting and sterile specimens had been collected until recently. Further specimens of the Chimanimani *Synsepalum* species were collected in October 2013 in the foothills of the southern Chimanimani massif in Mozambique by Bart Wursten, including the first specimen from this area bearing flowers (*Wursten BW897*). Additional specimens of the same taxon from the same area were collected by M. Cheek and J. Timberlake et al. in 2015 under a Darwin Initiative project focussing on the conservation of the Chimanimani forest zone in Mozambique (Timberlake et al. 2016a). Examination and comparison of these new collections with existing collections of *Synsepalum kaessneri* showed that, although the plants collected in Mozambique and adjacent Zimbabwe are very similar and closely related to *Synsepalum kaessneri*, they differ in several characters and so are considered to be different, allopatric species.

In their comprehensive guide to the trees and shrubs of Mozambique, Burrows et al. (2018, p. 744) included the Chimanimani taxon within *Synsepalum muelleri* (Kupicha) T.D.Penn. (formerly *Vincentella muelleri* Kupicha), a species that occurs in submontane forest in northern Mozambique and southern Malawi (Kupicha 1983). The plants in the photographs in Burrows et al. (2018) (*Wursten BW887* and *BW897*) are the Chimanimani taxon rather than *Synsepalum muelleri* sensu stricto. There are several notable differences between the two taxa, and they are clearly not conspecific.

In this paper we describe the Chimanimani taxon as a new species and clarify the differences in morphology and distribution between our new species and *S. kaessneri* and *S. muelleri*. We also present a distribution map and list of specimens examined for the three species and discuss the conservation and botanical importance of the Chimanimani foothills.

Methods

Specimens of *Synsepalum* species in the Kew herbarium (**K**), the British Museum of Natural History (**BM**), Institute for Agricultural Research of Mozambique (**LMA**), National Herbarium and Botanic Garden, Harare (**SRGH**) and on loan from Meise Botanic Garden Herbarium (**BR**) were examined. Online herbaria **BR** (http://www.botanicalcollections.be/#/en/home), **LISC** (http://maerua.iict.pt/colecoes/herb_simplesearch.php), **WAG** (https://bioportal.naturalis.nl/?language=en), **E** (https://data.rbge.org.uk/search/herbarium/), **MO** (https://www.tropicos.org/) and **US** (https://collections.nmnh.si.edu/search/botany/) (acronyms according to Thiers 2019), JSTOR Global Plants and the Flora of Mozambique website (Hyde et al. 2019) were also checked and all specimens with images available are cited. The countries in the "Specimens examined" sections are listed alphabetically.

Thirty qualitative and quantitative characters were examined in specimens of *S. kaessneri* and the newly described species (see Suppl. material 1). Measurements were made using a Leica Wild M8 stereo microscope and a graduated ruler (0.5 mm graduations). All characters were measured on dry material, except internal floral characters which were measured from a rehydrated flower. The terminology used follows Beentje (2010). The distribution map (Fig. 3) was produced in SimpleMappr (https://www.simplemappr.net) using georeferenced point localities.

In the Discussion section the application of Important Plant Areas (IPA) criteria follows Darbyshire et al. (2017). The abbreviations used for IUCN Red List assessments follow IUCN (2012).

Taxonomic treatment

Synsepalum chimanimani **S.Rokni & I.Darbysh., sp. nov.**
urn:lsid:ipni.org:names:77202384-1
Figures 1A–K, 2

Tulestea kaessneri sensu Aubréville in Adansonia Sér. 2, 12(2): 191–192 (1972), pro parte quoad *Wild*, *Goldsmith & Müller 6645*, non (Engl.) Aubrév. sensu stricto.

Afrosersalisia kaessneri sensu Kupicha in Flora Zambesiaca 7(1): 217 (1983), pro parte quoad spec. ex Mozambique & Zimbabwe, non (Engl.) J.H.Hemsl.

Synsepalum kaessneri sensu Pennington in Gen. Sapotac.: 249 (1991), pro parte, non (Engl.) T.D.Penn. sensu stricto.

Synsepalum muelleri sensu Burrows et al. in Trees & Shrubs Mozambique: 744 (2018), pro parte – photographs and reference to distribution in Haroni-Makurupini Forest; non (Kupicha) T.D.Penn.

Synsepalum sp. aff. S. kaessneri (Engl.) T.D.Penn., Hyde et al. in Flora of Mozambique (2019).

Type. MOZAMBIQUE. Manica Province: Magorogodo hills, Zomba Community, 19°54'28"S, 33°11'4"E, c. 559 m alt., fl. and fr. 28 October 2013, *B.T. Wursten BW897* (holotype: BR!, BR0000020700003)].

Diagnosis. This species differs from *Synsepalum kaessneri* (Engl.) T.D.Penn. in the generally smaller (7.9–12.6 x 1.7–3.4 cm versus 9.8–16.7 x 2.8–5.2 cm) narrowly elliptic leaves with a long and narrow acuminate tip versus oblanceolate leaves with a short and broad acuminate tip (see illustration, Fig. 1E, L); flowers sessile or almost so with pedicels less than 1 mm long (extending to 2 mm long in fruit) versus flowers stalked with pedicels 1–3 mm long (extending to 3–5 mm in fruit); shorter corolla tube (0.75–0.8 mm long versus 1.2 mm long) and shorter (1.45–1.5 mm versus 1.8–1.9 mm), broadly ovate versus ovate corolla lobes; anthers with elliptic thecae with a minute, inconspicuous point at the apex of the connective versus arrow-head shaped anthers with oblong thecae with a conspicuous apiculate apex to the connective. Table 1 shows the distinguishing characters between the two species.

It has previously been confused with *Synsepalum muelleri* (Kupicha) T.D.Penn. but is easily separated by the very faint secondary venation and no visible tertiary venation versus clearly visible secondary and reticulate tertiary venation; no stipules versus persistent subulate stipules 2–7 mm long; whitish-green flowers with a very short corolla tube and wide-spreading lobes versus white tubular flowers with the tube markedly longer than the lobes; corollas less than 2.5 mm long versus 7–10 mm long; exerted stamens versus included stamens; minute staminodes versus no staminodes; fruit 1–1.3 cm long with a very short (0.5 mm long) style versus larger fruit 2–3 cm long with a 5–7 mm long persistent style; glabrous fruit except for hairs at the tip around the base of the style versus fruit covered with rust-coloured hairs.

Description. Small tree or shrub up to 4 m high. Bark brown and finely fissured. Branching repeatedly subterminal ("*Terminalia*-style") with leaves confined to branch apices. Older stems glabrous with finely fissured brownish-grey bark, young shoots, buds and petioles of young leaves with indumentum of appressed, very fine rust-coloured hairs. Hairs medifixed, less than 0.5 mm long, tips sharp. Stipules absent. Leaves with petiole 3–5 mm long, often sparsely hairy to glabrous on older leaves; lamina narrowly elliptic to rarely oblanceolate, 7.9–12.6 x 1.7–3.4 cm, apex long acuminate with a narrow rounded tip, margins entire and repand, base attenuate; midrib raised on both surfaces with striations on the midrib below, lateral veins very faint above, more distinct below, pinnate, curving towards the margin, 9–15 pairs of lateral veins, no visible tertiary venation; both surfaces finely rugose and glabrous except for sparse scattered hairs along the midrib on the lower surface, particularly on younger leaves; hairs very fine, rust-coloured, medifixed, less than 0.5 mm long, tips sharp. Flowers in clusters in leaf axils and along the branches below the leaves, small and whitish-green, sessile or almost so, pedicels less than 1 mm long (extending to 2 mm long in fruit), pedicels and external surface of calyx lobes covered with sub-appressed, medifixed, very fine rust-coloured hairs. Calyx cup-shaped, 5-lobed, lobes nearly free, imbricate, elliptic, 1.2–1.3 x 1–1.1 mm, with hyaline margins, glabrous internally. Corolla 5-merous, fused at base, tube up to 0.8 mm long, lobes involute, broadly ovate, 1.45–1.5 mm long, rounded at apex. Stamens attached at base of petals, filaments 0.6 mm long,

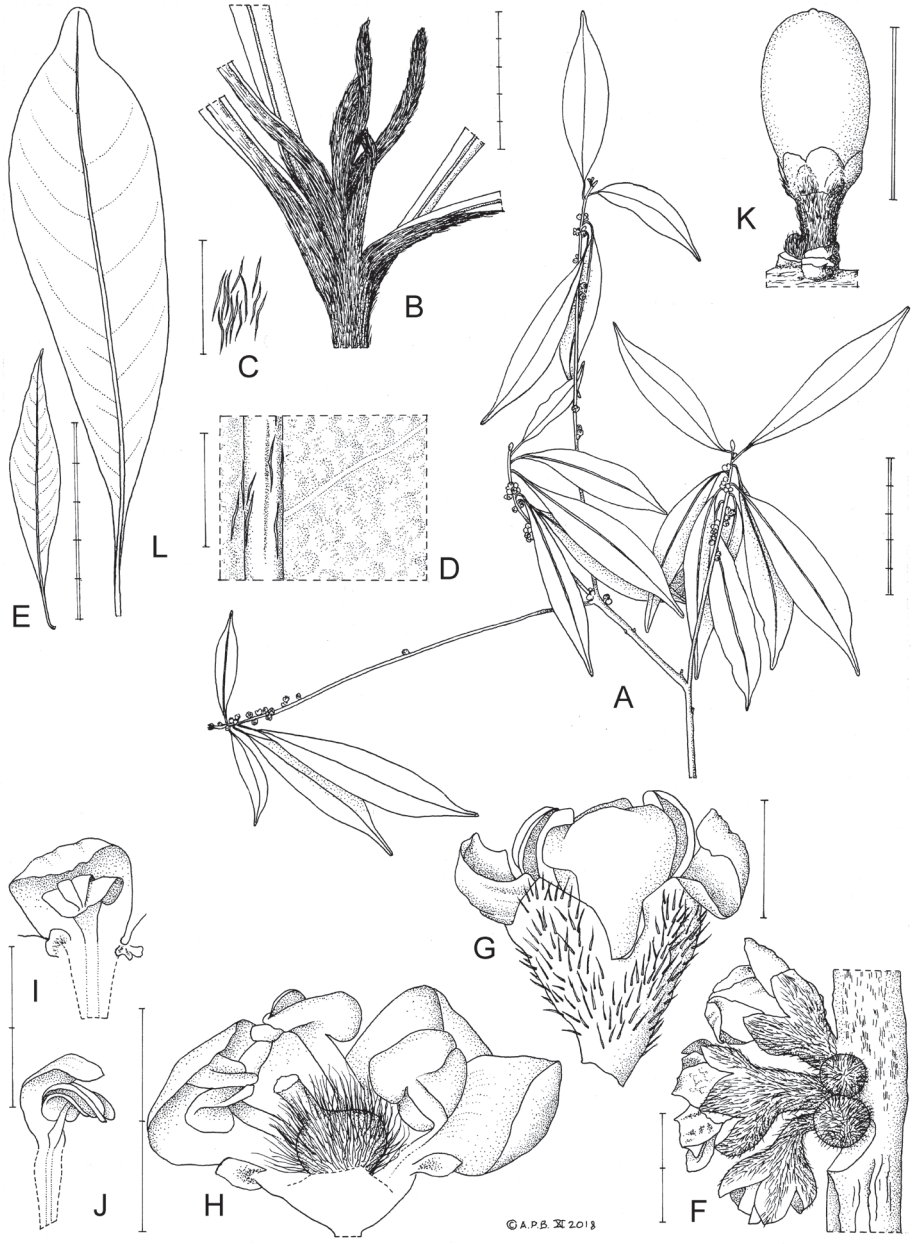

Figure 1. *Synsepalum chimanimani* (**A-K**) and *Synsepalum kaessneri* (L) **A** habit **B** stem apex with apical buds/young leaves and petioles showing indumentum **C** medifixed hairs on stem **D** abaxial leaf surface showing sparse medifixed hairs on midrib **E** leaf showing (faint) secondary veins **F** flower cluster showing bud, open flower and partially opened flower **G** flower, side view (hydrated) **H** corolla after removal of two petals and stamens (hydrated) **I** stamen and staminodes in situ on petal, inner face bases of neighbouring petals shown **J** side view of stamen and petal (staminodes omitted) **K** immature fruit (from photograph) **L** leaf (abaxial) of *Synsepalum kaessneri*. **A, D-K** drawn from *B.T. Wursten BW897* (BR0000020700003) **B, C** from *Timberlake et al. 6197* (K001291035) **L** drawn from *Magogo & Glover 280* (K). Scale bars: 1mm (Single bar); 2 mm and 5 mm (graduated single bar); 1 cm (double bar); 5 cm (graduated double bar). Drawn by Andrew Brown, November 2018.

Figure 2. *Synsepalum chimanimani* **A** habit and leaves **B, C** flowering stems **D** flowers **E** immature fruit (Photographs by Bart Wursten).

anthers 0.9–1 mm long, the two thecae elliptic with a tiny, inconspicuous point at the apex of the connective. Staminodes minute, alternating with the petals and stamens, divided and irregularly shaped. Ovary densely hairy, with a few hairs extending onto the style, ovoid, 1mm long, style 0.5 mm long. Fruit fleshy, red when ripe, solitary, ellipsoid, 10–13 x 6–8 mm (measurements taken from dried material), with calyx and corolla persisting at base and with persistent style at apex, glabrous except for a few hairs at apex around base of style. Seed compressed-ellipsoid, 12 x 7 x 3 mm, glossy brown, with duller elliptic scar c. 5 mm wide extending the length of the seed, cotyledons large, plano-convex, endosperm absent (fide Kupicha 1983).

Distribution and ecology. Known only from lowland, moist forests in the foothills of the southern Chimanimani mountains of Mozambique and Zimbabwe. It has been recorded from three localities: the Haroni-Makurupini Forest in Zimbabwe, and the Maronga forest (Maronga Community) and Thekeza forest (Zomba Community) in Mozambique. It occurs in the understorey of moist evergreen and semi-deciduous forests at an altitude of 305–560 m. In the Maronga Community area at the base of the Chimanimani Mountains, where this species is locally frequent, most of the area is covered by moist evergreen forest. The dominant tree here is *Newtonia buchananii*

Table 1. Diagnostic characters for separating *Synsepalum chimanimani* from *Synsepalum kaessneri*.

Character	*Synsepalum chimanimani*	*Synsepalum kaessneri*
Leaf shape	Narrowly elliptic to rarely oblanceolate	Oblanceolate
Leaf apex	long acuminate, tip narrow, rounded	short acuminate with a broad rounded tip
Leaf width (mm)	17–34	28–52
Leaf length (mm)	79–126	98–167
Leaf length: width ratio	3.1–5.83	2.7–4.14
Pedicel length (mm) – flowers	Flowers sessile or almost so – pedicel less than 1 mm long	Flowers stalked – pedicel 1–3 mm long
Pedicel length (mm) – fruit	2	3–5
Corolla lobes – shape	Broadly ovate	Ovate
Corolla lobes length (mm)	1.45–1.5	1.8–1.9
Corolla lobes length: width ratio	1–1.21	1.29–1.36
Corolla tube length (mm)	0.75–0.8	1.2
Corolla – total length (mm)	Less than 2.5 mm	c. 3 mm
Stamens	Anthers 0.9–1 mm long, thecae elliptic with a minute, inconspicuous point at the apex of the connective	Anthers 1.25 mm long, arrow-head shaped, thecae oblong with conspicuous apiculate apex to connective

(Baker f.) G.C.C.Gilbert & Boutique with *Maranthes goetzeniana* (Engl.) Prance and *Xylopia aethiopica* (Dunal) A.Rich. also common. *Funtumia africana* (Benth.) Stapf forms a high sub-canopy along with *Aporrhiza nitida* Gilg, *Bligbia unijugata* Baker, *Millettia stuhlmannii* Taub., *Synsepalum brevipes* (Baker) T.D.Penn. and *Trilepisium madagascariense* DC. The understorey is dominated in some areas by *Drypetes arguta* (Müll. Arg.) Hutch. and other locally abundant shrubs include *Rinorea convallarioides* (Baker f.) Eyles, *Rinorea ferruginea* Engl., *Tabernaemontana ventricosa* Hochst. ex A.DC., *Tricalysia pallens* Hiern and the rare *Vepris drummondii* Mendonça. There are also many lianas (Timberlake et al. 2016a).

Phenology. Plants were collected in flower in July (buds) and October (open), and in fruit in October and December. Flowering occurs at the end of the dry season and beginning of the rainy season, the main rainy season in the Chimanimani area being from November to late March or April (Timberlake et al. 2016b).

Etymology. The specific epithet is taken from the Chimanimani mountains to which the species is confined.

Conservation status. *Synsepalum chimanimani* S.Rokni & I.Darbysh, sp. nov. has been assessed as Endangered under IUCN criterion B (EN B1ab(iii)+2ab(iii); Rokni et al. 2018, as *Synsepalum* sp. nov.). It is estimated to have an extent of occurrence (EOO) and area of occupancy (AOO) of only 16 km^2 and is known from fewer than five locations. Although part of its population is well protected within the core zone of the Chimanimani Trans-Frontier Conservation Area (TFCA), it is threatened by extensive destruction and degradation of its forest habitat within the buffer zone of the TFCA, particularly within the Maronga and Zomba communities of Mozambique (see Discussion for further information on threats in this area).

Specimens examined. MOZAMBIQUE. Manica Province: Magorogodo hills, Zomba Community, 19°54.467'S, 33°11.067'E, alt. c. 559 m, fl. and fr. 28 Octo-

ber 2013, *Wursten BW897* (BR!, BR0000020700003); Survey Plot 3, Magorogodo hills, Zomba Community, alt. 548 m, st. 28 October 2013, *Wursten BW887* (BR!); Sussundenga Dist., Maronga community, base of Chimanimani Mountains, Forest plot 002, 19°58.417'S, 33°5.233'E, alt. 341 m, st. 14 November 2015, *Timberlake et al. 6196* (LMA!); Sussundenga Dist., Maronga community at base of Chimanimani Mountains, 19°58.928'S, 33°4.948'E, alt. 330 m, st. 17 November 2015, *Timberlake et al. 6197* (K!, K001291034; LMA!); Sussundenga Dist., Chimanimani foothills, Zomba community, Thekeza Forest, 19°54.717'S, 33°11.433'E, alt. 386 m, st. 30 June 2015, *Cheek 17963* (K!, K001291036); Sussundenga Dist., Chimanimani foothills, Zomba community, Last House Thekeza, 19°54.533'S, 33°11.303'E, alt. 542 m, fl. buds 2 July 2015, *Cheek 18027* (K!, K001291037); Southern tip Chimanimani Mts. near Haroni-Makurupini Forest, alt. +/- 1000 ft [c. 305 m], st. 28 May 1969, *Müller 1085* (SRGH!). **ZIMBABWE.** Manicaland Province: Chimanimani District, Haroni/Makurupini Forest, alt. 1300 ft [396 m], fr. 4 December 1964, *Wild*, *Goldsmith & Müller 6645* (K!, K001291026; BR!, BR0000020184520; SRGH!); Chimanimani District, Makurupini-Haroni Forest, st. 22 April 1973, *Mavi 1437* (K!, K001291028; SRGH!).

Synsepalum kaessneri (Engl.) T.D.Penn., Pennington in Gen. Sapotac.: 249 (1991)

Sersalisia kaessneri Engl., Engler in Mon. Afr. Pflanzen. 8: 31 (1904) (genus queried by original author).

Pouteria kaessneri (Engl.) Baehni, in Candollea 9: 280 (1942) (genus queried by author).

Afrosersalisia kaessneri (Engl.) J.H.Hemsl., Hemsley in Kew Bull. 20: 483 (1966); in F.T.E.A., Sapotaceae: 44 (1968).

Tulestea kaessneri (Engl.) Aubrév., Aubréville in Adansonia Ser. 2, 12(2): 191–192 (1972), pro parte quoad *T. Kässner 398*.

Type. KENYA. Kwale County: Makoni near Mombasa, fl. 20 March 1902, *T. Kässner 398* (B, holotype, destroyed; BM!, isotype, BM000925429; K!, isotype, K000430647).

Specimens examined. KENYA. Kwale County: Makoni near Mombasa, fl. 20 March 1902, *Kässner 398* (B, holotype, destroyed; BM!, isotype, BM000925429; K!, isotype, K000430647); Shimba Hills, Makadara Forest, Kwale Area, alt. 320 m [1050 ft], fr. 6 May 1968, *Magogo & Glover 1017* (K!); Shimba Hills, Shimba Forest area near Kwale, alt. 381 m [1250 ft], fl. 15 March 1968, *Magogo & Glover 280* (K!; BR!, BR0000020184513). Kilifi County: Mangea, Top forest, 3°16.000'S, 39°43.000'E, alt. 500 m, fr. 9 Jan 1992, *Robertson 6563* (K!; US!, 02704855; MO, EA). **TANZANIA.** Tanga Region: East Usambara Mountains, Kwamgumi Plot 4, 4°56.000'S, 38°43.000'E, alt. 300 m, st. 23 July 2001, *Luke et al. 7510* (K!, EA). Morogoro Region: Kimboza Forest Reserve c. 48–50 km Morogoro to Matombo Road, alt. c. 300–350 m, st. 9–17 July 1983, *Rodgers*, *Hall and Mwasumbi WAR 2609* (K!, DSM); Mkungwe Catchment Forest Reserve, slopes NW of the ridge, alt. 775 m, fr. 25 Jan 2001, *Jannerup & Mhoro*

0287 (K!, C); Uluguru Mountains, in the valley leading South from Bigwa Mission, alt. 700–1100 m, fl. 27–29 September 1988, *Pócs & Knox 88189/B* (K!)

Aubréville (1972) also cites a specimen from Gabon collected in December 1971: '*A. Hladik 1878*, Ile de l'éléphant, Makokou, petit arbre, forêt partiellement inondable. Fruit rouge vermillon mangé par les chimpanzés.' No herbarium is cited, and we have not seen this specimen. From the illustration and description, this specimen seems to have fruit with a definite point to the apex and a persistent style longer than 1 mm, and longer petioles (1.5–2.5 cm versus less than 1 cm long) and the flowers are also slightly larger than *S. kaessneri* at 3.75 mm in total length. This is very likely to represent a different species and is excluded here. *S. kaessneri* is not listed in the recent Gabon checklist (Sosef et al. 2006).

Habitat and ecology. Moist evergreen and dry semi-deciduous forests. Altitude 300–1100 m.

Phenology. Flowering September & March. Fruiting January & May.

Synsepalum muelleri (Kupicha) T.D.Penn., Pennington in Gen. Sapotac.: 249 (1991)

Vincentella muelleri Kupicha in Candollea 33 (1): 37, fig. 4 (1978); Kupicha in Sapotaceae Flora Zambesiaca 7(1): 228 (1983).

Type. MALAWI. Southern Region: Mulanje District, Ruo Gorge, alt. 900 m, fl. and fr. 1 September 1970, *T. Müller 1463* (K!, holotype, K000049396; SRGH, isotype).

Specimens examined. MALAWI. Southern Region: Mulanje Mountains, Ruo Gorge at the Savani stream crossing, alt. 1250 m, fr. 30 September 1986, *Chapman & Chapman 8104* (K!, K000049398; E!, E00330780; MO); Mulanje Mountains, Litchenya Plateau, along the perimeter fire trace near the crater lip, alt. 1920 m, fr. 12 November 1986, *Chapman & Chapman 8209* (K!, K000049399; E!, E00330776; MO); Mulanje Mountains, Chisongeli Forest, Muluzi catchment, alt. 1650 m, fl. 30 September 1988, *Chapman & Chapman 9339* (K!, K000049397; E!, E00330775; MO); Mulanje, Ruo Gorge, fl. and fr. 26 August 1983, *Dowsett-Lemaire 942* (K!, K000049400; BR!, BR0000019420677); Mulanje District, Ruo Gorge, alt. 900 m, fl. and fr. 1 September 1970, *Müller 1463* (K!, holotype, K000049396; SRGH, isotype; P); Mulanje Plateau, st. 24 September 1929, *Burtt Davy 22131* (BR!, BR0000019420684; FHO). **MOZAMBIQUE.** Nampula Province: Ribáuè, Serra de Mepáluè, alt. c. 1600 m, fr. 9 December 1967, *Torre & Correia 16403* (LISC!, paratype, LISC002849; COI; WAG!, paratype, WAG.1530185); Ribáuè, serra de Ribáuè (Mepáluè), alt. c. 1500 m, fr. 28 January 1964, *Torre & Paiva 10301* (K!, K001236782; LISC!, paratype, LISC002850; LMU). Zambézia Province: Encosta da serra do Gúruè, via fábrica Junqueiro a Oeste dos Picos Namuli, confluência dos rios Malema e Cocossi, alt. c. 1650 m, fl. and fr. (immature) 6 November 1967, *Torre & Correia 15921* (LISC!, paratype, LISC002848); Mt Namuli, Uivelo area, Manho forest, E Namuli, 15°24.683'S, 37°2.267'E, alt. 1590

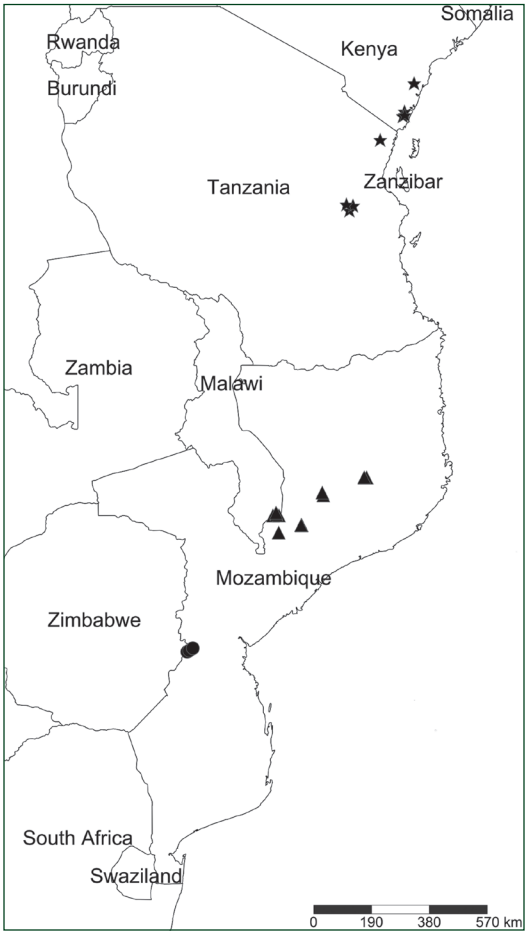

Figure 3. Geographical distribution map of *S. chimanimani*, *S. kaessneri*, and *S. muelleri*. Circles – *S. chimanimani*; triangles – *S. muelleri*; stars – *S. kaessneri*.

m, st. 23 November 2007, *Timberlake et al. 5283* (K!, K000614012); Mount Chiperone, 16°30.283'S, 35°43.333'E, alt. 1155 m, fr. 29 November 2006, *Harris et al. 69* (K!, K000545061); Mount Chiperone, 28 November 2006, *Patel HP7152* (K!, K000545123); Mount Mabu, 16°17.017'S, 36°23.567'E, alt. 1252 m, fl. and fr. 16 October 2008, *Mphamba et al. 50* (K!, K000614270); Mt Mabu, Mabu forest on SE side, 16°17.067'S, 36°23.483'E, alt. 1260 m, st. 15 October 2008, *Timberlake et al. 5402* (K!, K000614394); Mt Mabu, 16°17.167'S, 36°24.083'E, alt. 960 m, st. 26 October 2008, *Timberlake et al. 5461* (K!, K000614442) [cf. muelleri]; Mt Mabu, veg plot 012, 16°17.500'S, 36°23.550'E, alt. 1389 m, st. 20 October 2008, *Timberlake s.n.* (K!, K000614472); Mt Mabu, veg plot 022, 16°17.033'S, 36°23.100'E, alt. 1320 m, st. 22 October 2008, *Timberlake s.n.* (K!, K000614490).

Habitat and ecology. In the understorey of *Newtonia buchananii*-dominated moist forest, *Garcinia kingaensis* Engl. dominated moist forest and dense humid riverine forest at elevations of 900–1920 m.

Phenology. Flowering August to November. Fruiting August to January. There is a distinct rainy season in Mabu, Namuli, Ribáuè, Chiperone and Mulanje with the main rainfall months being November to April with a dry season from May to October. Flowering occurs at the end of the dry season and beginning of the rainy season with fruiting following.

Discussion

Taxonomy and conservation

We have only one flowering specimen of *S. chimanimani* sp. nov. and it has rarely been collected in fruit. It would be useful to have more flowering specimens for a more thorough comparison with *S. kaessneri*, which may reveal additional diagnostic characters. However, the two taxa are very clearly separated geographically by nearly 1,500 km and there are sufficient morphological differences for separation at the species level. A molecular phylogenetic study that includes the three taxa in this paper would also be useful to better understand relationships within *Synsepalum* and between *S. chimanimani*, *and S. kaessneri*. and *S. muelleri*. Whilst the molecular study by Borg et al. (2019) did not sample any of these species, it did include the type species of *Afrosersalisia*, *A. afzelii* (Engl.) A.Chev. (=*S. afzelii* (Engl.) T.D.Penn.) and one representative of *Vincentella*, *V. passargei* (Engl.) Aubrév. (= *S. passargei* (Engl.) T.D.Penn.), the segregate genus in which *S. muelleri* has previously been placed. They found that the clade containing *Afrosersalisia* is not closely related to the clades containing *Vincentella* or *Synsepalum* sensu stricto. This may support the morphological evidence that *S. chimanimani* and *S. muelleri* are not closely allied. However, it should be noted that *S. muelleri* (corolla lobes much shorter than tube) has a very different corolla morphology to *S. passargei* (corolla lobes much longer than tube; Kupicha 1983) and so the relationship between those species also requires confirmation.

Both *S. chimanimani* sp. nov. and *S. kaessneri* are rare species with restricted ranges and of conservation concern because of ongoing threats to the known populations. There are no known *ex situ* collections of either species (BGCI 2019) and it would be desirable to collect seeds for both banking and growing in botanic gardens.

The botanical importance of the Chimanimani foothills: an Important Plant Area

The high Chimanimani Mountains have long been renowned for their high botanical endemism, particularly associated with the extensive outcrops of nutrient-deficient quartzites (Wild 1964; van Wyk and Smith 2001; Timberlake et al. 2016b; Wursten et al. 2017; Cheek et al. 2018). Much less well known is the botanical importance of the low elevation foothills of these mountains (c. 300–1200 m elevation, mainly below 1000 m), particularly to the south and east of the massif. This area has extensive stands of low altitude moist evergreen and semi-deciduous forest that, whilst now

much fragmented, still represent the largest extent of this highly threatened habitat type in Mozambique.

The area of particular interest stretches from the lower valleys of the Rusitu and Haroni Rivers of Zimbabwe, the Makurupini area on the Zimbabwe-Mozambique border and the Maronga, Zomba and Mpunga communities of Mozambique. The botanical diversity of the Haroni-Rusitu-Makurupini region has been documented in an unpublished checklist of 787 species, compiled from a range of expeditions made between 1955 and 1998 (Timberlake 1999). Recent survey and inventory work in the Mozambican portion of this area, excluding Makurupini, documented 532 plant species (Timberlake et al. 2016a).

The forests vary in species composition and in the relative extent of evergreen versus deciduous components; the species composition in the Mozambican portion of these forests is discussed in detail by Timberlake et al. (2016a). Of particular interest botanically are the mostly evergreen forests and riverine fringes of Haroni-Makurupini, Maronga and the southwestern-most part of Zomba (Thekeza Forest). Amongst the dominant trees, these areas support what is potentially the largest population globally of *Maranthes goetzeniana* (Engl.) Prance. This species is often locally dominant in Maronga and also extends to Thekeza (Timberlake et al. 2016a).

Although of relatively low species richness compared to lowland forests in other parts of tropical Africa, the Chimanimani forests support a number of rare and threatened plant species. For example, the spectacular herb *Streptocarpus acicularis* I.Darbysh. & Massingue is so far known only from a single collection from along the Mevumozi River near Maronga (Darbyshire and Massingue 2014). *Vepris drummondii* Mendonça is largely restricted to the Haroni-Makurupini-Maronga forests except for an outlier population on nearby Mt Pene in Zimbabwe; it was encountered at low abundance in forests at Maronga in 2015 (I.D., pers. obs.). There is also a population of the globally Endangered wild coffee *Coffea salvatrix* Swynn. & Phillipson, or "mukofi" coffee, in the Maraumi Forest of Zomba and this species may occur more widely in this forest belt. Other range-restricted forest species include *Afrocanthium ngonii* (Bridson) Lantz and *Englerina swynnertonii* (Sprague) Polhill & Wiens.

These forests also support species that are nationally rare for Zimbabwe and/or Mozambique, including some interesting outlier populations. For example, *Ficus mucuso* Welw. ex Ficalho and *Raphidiocystis chrysocoma* (Schumach.) C.Jeffrey, West African species that are known in the Flora Zambesiaca region only from these forests, and *Dianella ensifolia* (L.) DC., a species of horticultural importance with an Indian Ocean distribution, on the African continent known in the wild only from the Chimanimani, Mabu and Ribáuè mountains of Mozambique. It is locally frequent at Maronga (Timberlake et al. 2016a). Also of interest is a dwarf, small-leaved species of *Podocarpus* (Podocarpaceae) that grows frequently along the rocky margins of forest rivers and streams at low elevations and also extending up into the higher mountains. This species has previously been placed within one of the two South African species *P. elongatus* (Aiton) L'Hér. ex Pers. (Farjon 2017) or *P. latifolius* (Thunb.) R.Br. ex Mirb. (Burrows et al. 2018) but it is quite possibly a distinct taxon – further taxonomic and molecular phylogenetic studies are required to confirm its placement. It is apparently also known

from the Mafinga Mountains of Northeast Zambia which are also partially quartzitic (J. Timberlake, pers. comm.).

The forests are interspersed with extensive areas of miombo woodland, dominated by *Brachystegia* (most frequently *B. spiciformis* Benth.) and *Uapaca* species. Whilst important ecologically, the miombo does not contain high numbers of rare or threatened plant species. Of greater botanical significance is the presence of three other vegetation types within this mosaic:

1. Low elevation outcrops of nutrient-deficient quartzites, usually associated with light woodland dominated by *Brachystegia microphylla* Harms. These outcrops are most frequent in the Makurupini-Maronga area but also extend further east. They support an interesting rock flora including the endemic *Ficus muelleriana* C.C.Berg, a tiny fig that climbs on the rock faces, and *Otiophora lanceolata* Verdc., a locally abundant endemic shrublet. *Aloe ballii* Reynolds, including its two varieties var. *ballii* and var. *makurupiniensis* Ellert (both Vulnerable), is a delicate grass aloe restricted to quartzite slopes along the Zimbabwe-Mozambique border. Other range-restricted and/or scarce species of this habitat include *Sclerochiton coeruleus* (Lindau) S.Moore, *Gutenbergia westii* (Wild) Wild & G.V.Pope and *Sericanthe chimanimaniensis* Wursten & de Block ined. (see Burrows et al. 2018). Where quartzite outcrops along rivers and streams, the endemic grass *Danthoniopsis chimanimaniensis* (J.B.Phipps) Clayton can be locally frequent.
2. Seasonally wet grasslands, which occur in small scattered areas within the forest-woodland mosaic. These support an interesting, though not diverse, herb flora including the recently resurrected species *Crepidorhopalon flavus* (S.Moore) I.Darbysh. & Eb.Fisch. whose range is centred on the southern Chimanimani foothills (Darbyshire et al. 2019), and *Mesanthemum africanum* Moldenke, a Chimanimani endemic mainly found in the high mountains but which occurs at much lower abundance in these lowland wet grasslands (Timberlake et al. 2016a).
3. Swamps and lowland watercourses that are fringed by large stands of the striking tree *Pandanus livingstonianus* Rendle. Whilst fairly widespread, this tree has very isolated and localised populations and is thought to be threatened by habitat loss (Beentje 2009). The Zomba Centro Swamp is particularly important for this species.

The entirety of this area falls within the Chimanimani Trans-Frontier Conservation Area (TFCA), in part within the core TFCA, i.e. the Chimanimani National Park of Zimbabwe and Chimanimani National Reserve of Mozambique, and in part within the TFCA buffer zone. This buffer zone includes the Maronga, Zomba and Moribane Forest Reserves in Mozambique (see Müller et al. 2005). Lowland habitats within the core TFCA are largely intact, with only small areas of human encroachment at present. However, threats are severe within the buffer zone including within the Forest Reserves. Large areas of forest have either been cleared or degraded for subsistence agriculture, using fire to clear the undergrowth once the large trees have been felled. Excessive burning prevents forest regrowth and impacts other key habitats. Regular burning also encourages the continuing spread of the invasive South

American shrub *Vernonanthura polyanthes* (Spreng.) A.J. Vega & Dematt. (syn. *V. phosphorica* (Vell.) H.Rob.; see Timberlake et al. 2016a; Sukhorukov et al. 2017) and this species is now mono-dominant over many hectares of disturbed, former forest habitats in the Chimanimani foothills, out-competing native species and preventing regeneration of natural habitats and encroaching into forest margins (Timberlake et al. 2016a). A further threat is the impact of mining for gold along some of the major rivers that flow from the massif, which pollutes the watercourses and denudes vegetation along their margins, as is clearly visible on satellite imagery on Google Earth. Conservation action is urgently needed in the TFCA buffer zone. Ongoing work with communities to attempt to better balance livelihoods with biodiversity conservation is ongoing, led by the Micaia Foundation (http://www.micaia.org), and this has led to the establishment of community conservation areas in the Maronga, Zomba and Mpunga communities of Mozambique (Timberlake et al. 2016a). However, there is still much work to be done to secure the future of the biodiversity within the TFCA buffer zone.

Applying the Important Plant Areas (IPA) criteria as revised by Darbyshire et al. (2017), the Chimanimani foothills qualify as an IPA under criterion A – presence of threatened species – with 17 criterion A taxa, of which 12 currently meet the threshold

Table 2. Taxa that qualify the Chimanimani foothills as an Important Plant Area under criterion A: threatened species.

Family	Taxon	IUCN Red List assessment	IPA sub-criteria met	Notes
Asphodelaceae	*Aloe ballii* Reynolds	VU D2	A(i)	Two varieties, var. *ballii* and var. *makurupiniensis*
Asteraceae	*Gutenbergia westii* (Wild) Wild & G.V.Pope	VU B1ab(iii)+2ab(iii)	A(i)	
Commelinaceae	*Cyanotis chimanimaniensis* Faden ined.	Not Evaluated	A(iv)	Species currently under description
Fabaceae	*Tephrosia longipes* Meisn. var. *swynnertonii* (Baker f.) Brummitt	Not Evaluated	A(iv)	
Gesneriaceae	*Streptocarpus acicularis* I.Darbysh. & Massingue	CR B2ab(iii)	A(i)	
Linderniaceae	*Crepidorhopalon flavus* (S.Moore) I.Darbysh. & Eb.Fisch.	Not Evaluated	A(iv)	Provisionally assessed as Vulnerable – VU B1ab(iii) – by Darbyshire et al. (2019)
Loranthaceae	*Englerina swynnertonii* (Sprague) Polhill & Wiens	Not Evaluated	A(iii)	
Moraceae	*Ficus muelleriana* C.C.Berg	EN B1ab(iii)+2ab(iii)	A(i)	
Phyllanthaceae	*Phyllanthus bernierianus* Baill. ex Müll. Arg. var. *glaber* Radcl.-Sm.	Not Evaluated	A(iv)	
Poaceae	*Danthoniopsis chimanimaniensis* (J.B.Phipps) Clayton	EN B1ab(iii)+2ab(iii)	A(i)	
Rubiaceae	*Afrocanthium ngonii* (Bridson) Lantz	VU B1ab(iii)+2ab(iii)*	A(i)	
	Coffea salvatrix Swynn. & Phillipson	EN B2ab(i,ii,iii)	A(i)	
	Otiophora lanceolata Verdc.	VU B1ab(iii)+2ab(iii)	A(i)	
	Sericanthe chimanimaniensis Wursten & De Block ined.	VU B1ab(iii)+2ab(iii)*	A(i)	Species currently under description
Rutaceae	*Vepris drummondii* Mendonça	VU B1ab(iii)+2ab(iii)	A(i)	
Sapotaceae	*Synsepalum chimanimani* S.Rokni & I.Darbysh.	EN B1ab(iii)+2ab(iii)	A(i)	
Zamiaceae	*Encephalartos chimanimaniensis* R.A.Dyer & I.Verd.	EN B1ab(i,ii,iv,v)+2ab(i,ii,iv,v); C1	A(i) – see note	Requires confirmation that this species is still extant within proposed IPA

* publication pending

for criterion A(i) – presence of globally threatened species (see Table 2). This site will also qualify under IPA criteria B(ii) – exceptional number of species of high conservation importance, and C(iii) – presence of nationally threatened or range restricted habitat, due to the large extent of threatened lowland moist forest. The lowland forest and the high massif are combined together in the two Important Bird and Biodiversity Areas for Chimanimani, which are divided along the international boundary (BirdLife International 2019a, 2019b). However, in botanical terms, the species assemblages are markedly different between the Chimanimani foothills and the high massif (albeit with a mid-elevation transition zone) and the threats and conservation issues that the two areas face are also markedly different. With this in mind, we consider it most useful to recognise the Chimanimani foothills as an IPA in their own right, with the high massif recognised as a separate IPA. In doing so, this also helps to draw more attention to the importance of the Chimanimani foothills as a site of global importance for biodiversity and in urgent need of conservation action.

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Supplementary material 1

Examined characters of *S. kaessneri* and the newly described species

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Data type: species data

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