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New distribution record of northern lineage plant of *Stellaria filicaulis* (Caryophyllaceae) from South Korea

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A northern lineage plant, *Stellaria filicaulis* (Caryophyllaceae), was newly found in Yeoncheon-gun, Gyeonggi-do of South Korea. This species is distributed in China, Japan, Korea, Mongolia, and Russia. On the Korean Peninsula, *St. filicaulis*, however, has been known to grow in North Korea. Species identification was confirmed using morphological characteristics and DNA sequence data, while comparing with materials obtained from herbarium specimens. *Stellaria filicaulis* is distinguished from *St. longifolia* by having smooth surface of stem, petals about twice longer than sepals. On the neighbor-joining tree, *St. filicaulis* formed a clade, and the species is closely related to *St. longifolia* of the Parviflorae clade. Details of the morphological characters, the type specimens, voucher specimens data, and photographs of *St. filicaulis* in South Korea are presented. In addition, it is likely that a new habitat will be found by plant biodiversity field surveys through the middle part of the Korean Peninsula. Further research is needed to determine its population size, distribution, and threats, as well as identify appropriate locations for conservation collection of germplasm.

Keywords: Caryophyllaceae, northern lineage plant, *Stellaria*, *Stellaria filicaulis*

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Introduction

The Korean Peninsula exhibits a characteristic distribution, with northern (Manchurian flora) and southern (China, Japan, and Korea flora) lineage plants coexisting according to climatic and topographical characteristics (Kim *et al*., 2022). Northern lineage plants refer to a plant originating from the north (Gantsetseg *et al*., 2020). They defined the term "northern lineage plants" referring to plants whose southernmost limit of geographic distribution is the Korean Peninsula. Since the term "northern lineage plants" is relative to a given region (Gantsetseg *et al*., 2020), it is not globally applicable. With regard this, Gantsetseg *et al*. (2020) have reported 616 northern lineage plants in the Korean Peninsula.

Among 86 taxa belonging to Caryophyllaceae in the Korean Peninsula, 23 in *Cerastium* L. (*Cerastium fischerianum* Ser. and *C. pauciflorum* Stev. ex Ser. var. *amurense* (Regel) Mizush.), *Dianthus* L. (*Dianthus repens* Willd.), *Gypsophila* L. (*Gypsophila pacifica* Kom.), *Lychnis* L. (*Lychnis cognata* Maxim., *L. fulgens* Fisch., and *L. wilfordii* (Regel) Maxim.), *Minuartia* L. (*Minuartia arctica* (Steven ex Ser.) Graebn., *M. laricina* (L.) Mattf., and *M. macrocarpa* (Pursh) Ostenf. var. *koreana* (Nakai) H. Hara), *Moehringia* L. (*Moehringia lateriflora* (L.) Fenzl), *Pseudostellaria* Pax (*Pseudostellaria davidii* (Franch.) Pax ex Pax & Hoffm., *P. japonica* (Korsh.) Pax, and *P. sylvatica* (Maxim.) Pax), *Silene* L. (*Silene foliosa* Maxim., *Si. jenisseensis* Willd., *Si. koreana* Kom., *Si. macrostyla* Maxim., and *Si. repens* Patrin), and *Stellaria* L. (*St. bungeana* Fenzl, *St. filicaulis* Makino, *St. longifolia* Muhl. ex Willd., and *St. radians* L.) are enlisted as the northern lineage plants (Gantsetseg *et al*., 2020), and some of them have not been found in South Korea. To establish a conservation management system, it is important to recognize their exact distribution range and taxonomic position.

The genus *Stellaria* L. was described by Linnaeus and comprises ca. 190 species around the world (Chen and Rabeler, 2001; Xu and Ma, 2018; Wang *et al*., 2020). In the Korean Peninsula, *Stellaria* is composed of 8−11 species (Lee, 1996; Choi, 2007; 2018; So *et al*., 2015; Korea National Arboretum, 2017; National Institute of Biological Resources, 2019; Chang *et al*., 2020), with one alien species (Kang *et al*., 2020). More recently, the Checklist of Korean Plants (Korea National Arboretum, 2020; 2021) listed 10 taxa in *Stellaria*: *St. alsine* Hoffm. var. *undulata* (Thunb.) Ohwi, *St. aquatica* (L.) Scop., *St. bungeana*, *St. diversiflora* Maxim., *St. filicaulis*, *St. longifolia*, *St. media* (L.) Vill., *St. neglecta* (Lej.) Weihe., *St. radians*, and *St. sessiliflora* Y. Yabe. Of these, *St. bungeana*, *St. filicaulis*, *St. longifolia*, and *St. radians* have only been reported from North Korea (Lee, 1996; Choi, 2007; 2018; Chang *et al*., 2020), so far.

We are reporting new distribution record of one northern lineage plant, *St. filicaulis* based on a field survey in South Korea. The aims of this study are to evaluate the distribution of *St. filicaulis* in South Korea with careful morphological examination and molecular analysis based on the original description and type specimens, and to provide fundamental information for further studies assessing their conservation status.

Materials and Methods

The newly found *St. filicaulis* from South Korea was exhaustively compared with the type specimens [Japan, Tokyo, Koiwa-mura, 16 Jun 1895, *Watanabe s.n*., (lectotype, TNS!, TNS62378); Japan, Musashi Prov., Koiwa-mura, Yoda, 23 Jun 1895, *Makino s.n*., (syntype, MAK!, barcode MAK009391); Japan, Hitachi Prov., Itako, 19 May 1901, *Suzuki s.n*., (syntype, MAK!, barcode MAK 009392); Japan, Musashi Prov., Koiwa-mura, Yoda, 16 Jun 1895, *Watanabe s.n*., (isolectotype, MAK!, barcode MAK010156)], and with the original description of Makino (1901). Descriptions and taxonomic key of this species were checked (So *et al*., 2015; Choi, 2018). Photographs in the field were captured by using a digital camera (Body: Nikon D750, Tokyo, Japan; Lens: Nikon 60 mm f/2.8D, Tokyo, Japan). Measurements of the morphological characters were performed by using digital Vernier calipers (Mitutoyo, CD-20AX, Sakado, Japan) and data derived from field notes. Details of the seeds were examined and photographed under a stereo microscope (Olympus, SZX7, Tokyo, Japan). All voucher specimens were deposited at the herbarium of National Institute of Biological Resources (KB).

We reconstructed the phylogenetic tree of Korean *Stellaria* species based on the sequence of the internal transcribed spacer of nuclear ribosomal DNA (rITS; Jin *et al*., 2023). The neighbor-joining tree was constructed by applying Kimura 2-parameter (K2P) model, and bootstrap value of each node was calculated with 2,000 replications, using MEGA 11 (Tamura *et al*., 2021).

Results and Discussion

Taxonomic treatment

Stellaria filicaulis Makino, Bot. Mag. (Tokyo). 15: 113, 1901 (Figs. 1, 2, 3). - TYPE: JAPAN. Tokyo, Koiwa-mura, 16 Jun 1895, *Watanabe s.n*., (lectotype: TNS, photo!; designated by Wang *et al*., 2020: 75; isolectotype, MAK!, barcode MAK010156); Musashi Prov., Koiwa-mura, Yoda, 23 Jun 1895, *Makino s.n*., (syntype, MAK!, barcode MAK009391); Hitachi Prov., Itako, 19 May 1901, *Suzuki s.n*., (syntype, MAK!, barcode MAK009392).

Stellaria jaluana Nakai, Bot. Mag. (Tokyo). 28: 129, 1913; *Stellaria filicaulis* f. *jaluana* (Nakai) Kitag., Neolin. Fl. Manshur. 277, 1979.

Stellaria neopalustris Kitag., J. Jap. Bot. 24: 88, 1949.

Herbs, perennial, hermaphroditic, 30−50 cm tall, glabrous. Stems tufted, erect or ascending, quadrangular, slender, apically branched, smooth. Leaves opposite, estipulate, sessile; blade linear, 2−3 cm × 2−3 mm, apex acute or acuminate, base cuneate, margins basally ciliate, midvein abaxially raised. Inflorescences solitary or in axillary cymes; bracts lanceolate, 1−2 mm long, apex acuminate, base cuneate, margins scarious; pedicels filiform, 2−5 cm long, deflexed after fruiting. Flowers bisexual; sepals 5, lanceolate or narrowly lanceolate, 4−5 mm long, apex acuminate, margins scarious, 1-nerved; petals 5, white, linear-lanceolate or ovate, 1.5−2 times as long as sepals, deeply 2-fid; stamens 10, 3.5−4 mm long, shorter than sepals; anthers 0.5−0.7 mm long; ovary globose; styles 3. Fruit capsules, yellow, cylindric-ovoid or oblong, 4−5 mm long, 6-valved. Seeds numerous, brown, ellipsoid, 0.7−1 mm long, obscurely rugulose.

Korean name: Sil-byeol-kkot (실별꽃).
Flowering: June to July.
Fruiting: July to August.
Distribution: Korea, China, Japan, Mongolia, and Russia.
Specimens examined: KOREA. Gyeonggi-do: Yeoncheon-gun, Gunnam-myeon, Samgeo-ri, Imjingang River, 15 Jul 2020, *Jin Dong Lee*, *Inbae Lee* & *Kwuidong Jung Lee JD et al. 20488-2* (KB); same locality, 10 Jun 2021, *Jung-Hyun Kim KIMJH21113*, *KIMJH21114*, *KIMJH21115*, *KIMJH21116*, *KIMJH21117*, *KIMJH21118* (KB).

Fig. 1. Type specimen of *Stellaria filicaulis* Makino in National Museum of Nature and Science (TNS), Japan.

Surveys of habitat status and distribution

During a plant diversity field survey on the Korean Peninsula, a new *St. filicaulis* site was found from South Korea. *Stellaria filicaulis* is very rare in distribution, and only a few isolated populations were found from the Imjin-gang River, Yeoncheon-gun, Gyeonggi-do (Fig. 4). About

Fig. 2. Voucher specimen of *Stellaria filicaulis* Makino in National Institute of Biological Resources (KB), South Korea.

10 individuals of *St. filicaulis* were discovered in open habitat and riversides on lowlands. When considering a small number of individuals, it is possible that this population was originated from a population located in the upstream region of Imjingang River (North Korea) during a recent flood. The canopy vegetation includes *Salix grac-*

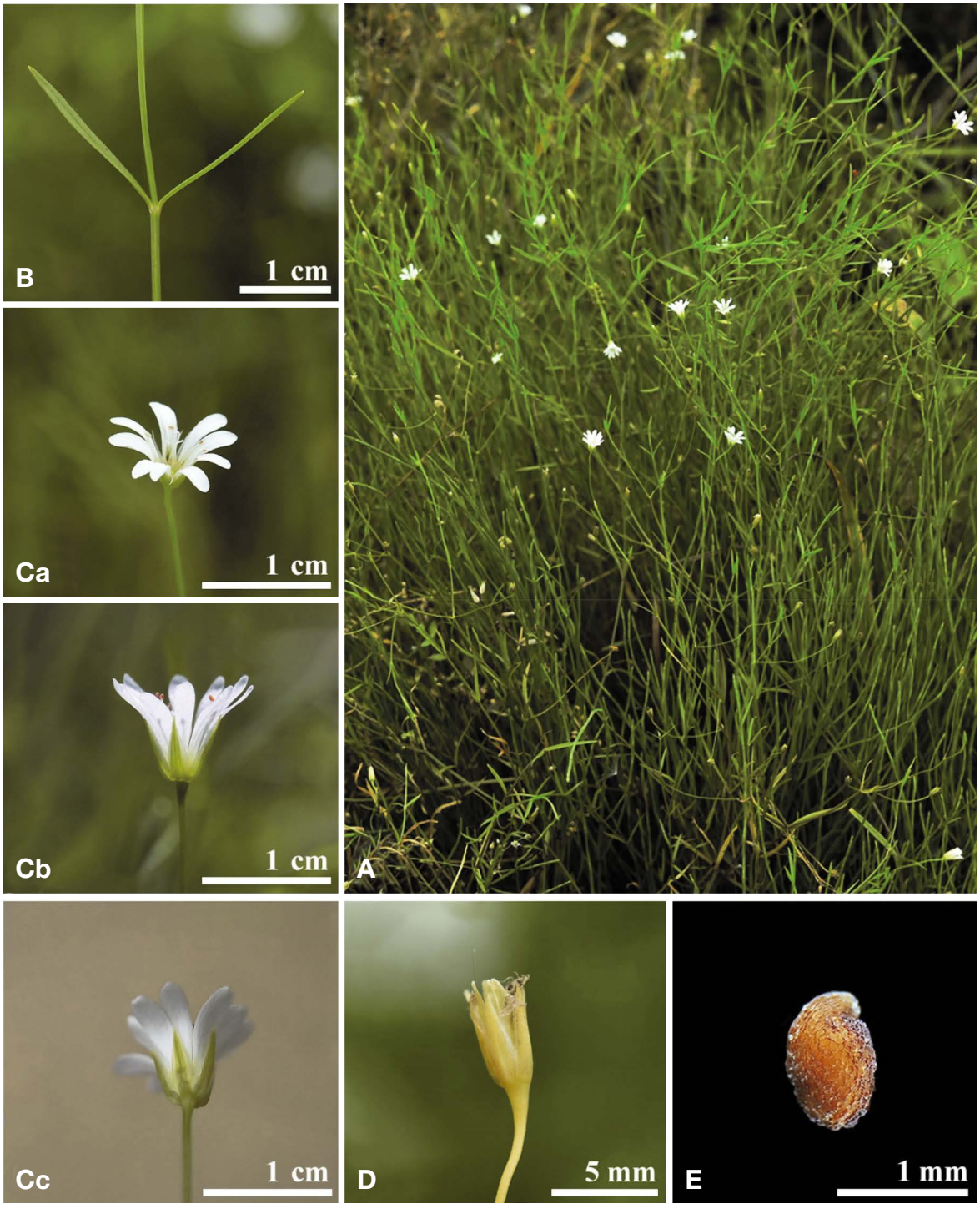

Fig. 3. Photographs of *Stellaria filicaulis* Makino. A. Habit. B. Stem with Leaf. C. Flowers (a, frontal view; b, lateral view; c, below view). D. Capsule with Sepal. E. Seed.

ilistyla Miq. and *S. koriyanagi* Kimura ex Goerz; the herbaceous vegetation is made up of *Equisetum arvense* L., *Ranunculus sceleratus* L., *St. alsine* var. *undulata*, *Persicaria thunbergii* (Siebold & Zucc.) H. Gross, *Rorippa globosa* (Turcz. ex Fisch. & C. A. Mey) Hayek, *R. palustris* (L.) Besser, *Androsace filiformis* Retz., *Potentilla supina* L., *Mazus pumilus* (Burm. f.) Steenis, *Veronica undulata* Wall., *Ambrosia trifida* L., *Artemisia capillaris*

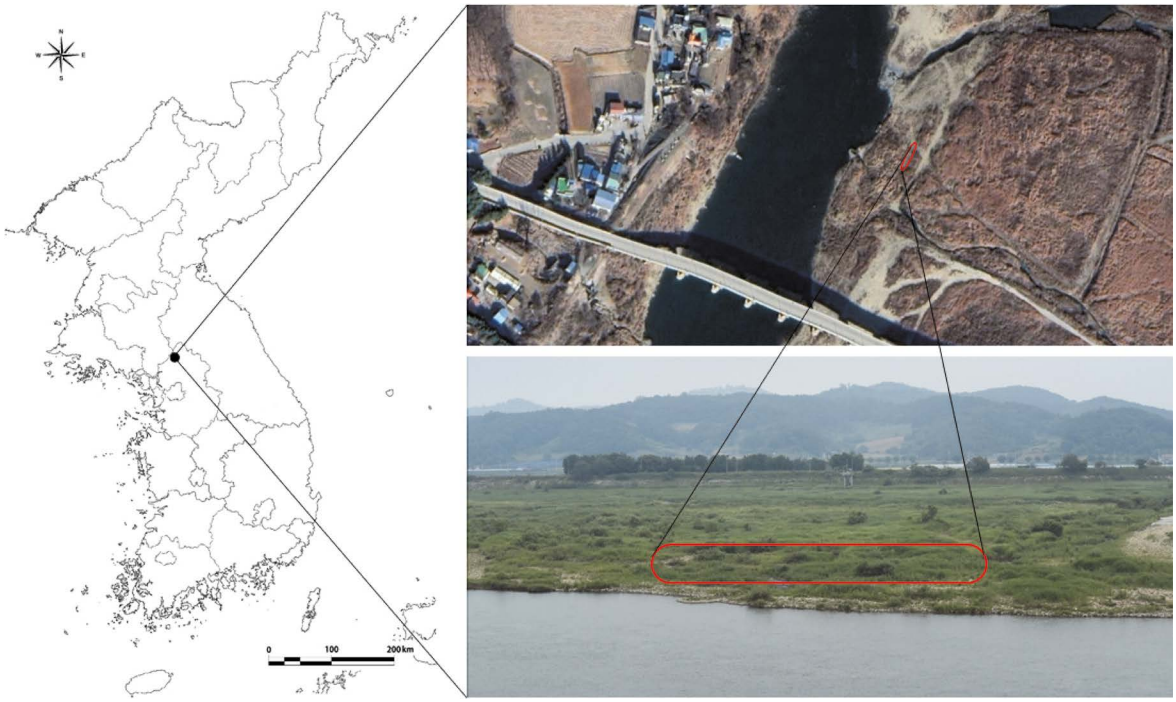

Fig. 4. Distribution of *Stellaria filicaulis* Makino in Yeoncheon-gun, Gyeonggi-do, South Korea.

Thunb., *A. selengensis* Turcz. ex Besser, *Bidens frondosa* L., *Hemistepta lyrata* Bunge, *Tripleurospermum limosum* (Maxim.) Pobed., *Juncus tenuis* Willd., *Carex tegulata* H. Lév. & Vaniot, *Eleocharis ussuriensis* G. Zinserl., *Alopecurus aequalis* Sobol., *Beckmannia syzigachne* (Steud.) Fernald, *Bromus japonicas* Thunb., *Elymus tsukushiensis* Honda, and *Phragmites australis* (Cav.) Trin ex Steud.

Molecular analysis

On the phylogenetic tree based on the rITS sequences, Korean *Stellaria* species are supported as a monophyletic group (Fig. 5). *Stellaria filicaulis* is the sister species of *St. longifolia*, both belonging to the Parviflorae clade of Tribe Larbreae, identical to the Sharples and Tripp's *Stellaria* phylogeny (2019). Morphologically, *St. filicaulis* and *St. longifolia* share leaf characteristics that their leaves are much longer than wide (Sharples, 2019). However, two species are clearly distinguished from each other with strong bootstrap values (98–99%).

Key to taxa of Korean *Stellaria* modified from So *et al.* (2015) and Choi (2018)

1. Leaves at least lower ones distinctly petiolate; ovate or deltoid-ovate; hairs, simple, unbranched.
 2. Styles 5····· *St. aquatica* 쇠별꽃
 2. Styles 3.
  3. Stems and pedicels glabrous; upper surface of leaves often with a few long multicellular appressed hairs·· ····· *St. diversiflora* 일월산별꽃
  3. Stems and pedicels with a longitudinal series of soft hairs; upper surface of leaves glabrous or nearly so.
   4. Leaves 4–8 cm long; nerves of sepals obsolete····· ····· *St. bungeana* 큰별꽃
   4. Leaves 1–4 cm long; nerves of sepals 1.
    5. Stamens 3–5(–7) ····· *St. media* 별꽃
    5. Stamens 8–10.
     6. Annual; leaves sessile at the upper part of stem· ····· *St. neglecta* 초록별꽃
     6. Perennial; leaves petiolate at the upper part of stem····· *St. sessiliflora* 그늘별꽃
1. Leaves sessile or subsessile; hairs branched.
 7. Stems and leaves silky pubescent; petals fimbriate····· ····· *St. radians* 왕별꽃
 7. Stems and leaves glabrous; petals bifid or absent.
  8. Leaves oblong-lanceolate, apex obtuse to subacute·· ····· *St. alsine* var. *undulata* 벼룩나물
  8. Leaves linear or broadly, apex acute.
   9. Stem surface smooth; petals about twice longer than sepals ····· ***St. filicaulis* 실별꽃**
   9. Stem surface slightly scabrous; petals equal to slightly longer than sepals····· ····· *St. longifolia* 긴잎별꽃

Note

Makino first described *St. filicaulis* without designating a specimen as holotype but mentioned four specimens

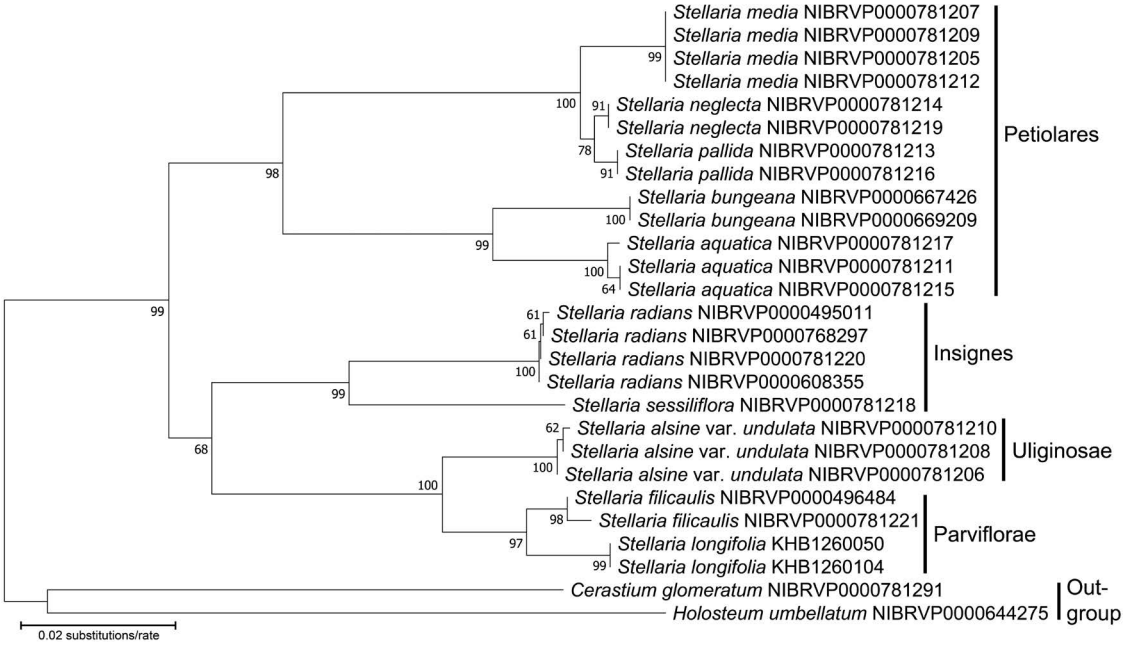

Fig. 5. The neighbor-joining phylogenetic tree of the Korean *Stellaria* species based on nuclear ribosomal internal transcribed spacer (rITS) sequences. The bootstrap values for each node are indicated in the tree. Voucher numbers corresponding to each species are shown next to scientific names.

"*Watanabe s.n*., 16 Jun, 1895; *Makino s.n*., 23 Jun, 1895; *Watanabe s.n*., 16 Jun, 1895; *Suzuki s.n*., 19 May, 1901" in the protologue (Makino, 1901; Wang *et al*., 2020). However, following Arts. 9.6 and 40 Note 1 of the ICN (Turland *et al*., 2018), these specimens should be treated as syntypes. According to Stafleu and Cowan (1981; 1988), the original specimens were traced in GH, TI, and MAK, but no specimens could be found in GH and TI mentioned in the protologue (Wang *et al*., 2020). Tropicos (Tropicos, 2020) cited "Type-Protologue: *K. Watanabe s.n*. in TI", but related specimens were not found in TI. Fortunately, original specimens in TNS (TNS62378) and MAK (MAK 009391, MAK009392, MAK010156) were traced, with a description of the collecting location and date agreeing with the protologue. They could be confirmed as original materials. Moreover, Makino might have described *St. filicaulis* based on one of these specimens because it has a label containing a message which means a new name (Wang *et al*., 2020). Therefore, *St. filicaulis* (TNS62378 specimen) is designated by Wang *et al*. (2020) as the lectotype for its good preservation and also greatly agreeing with the protologue according to Art. 9.3 and 9.4 of the ICN (Turland *et al*., 2018).

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