Fissidens (Fissidentaceae, Bryophyta) species newly recorded in Korea

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ABSTRACT: Here, 15 taxa of genus *Fissidens* Hedw. are reported as new to the moss flora of Korea: *F. bryoides* var. *esquirolii*, *F. closteri* subsp. *kiusiuensis*, *F. crispus*, *F. curvatus*, *F. enervis*, *F. flabellulus*, *F. ganguleei*, *F. gracilifolius*, *F. gymnandrus*, *F. incurvus*, *F. longisetus*, *F. pusillus*, *F. takayukii*, *F. viridulus*, and *F. wichurae*. The list of *Fissidens* in Korea, consisting of 26 taxa previously, is updated to 38 taxa by adding 15 taxa and excluding three taxa. Descriptions, taxonomic notes with diagnoses, in situ and microscopic photographs of the unrecorded species, and taxonomic keys of four sections belonging to the subgen. *Fissidens* are provided.

Keywords: *Fissidens*, mosses, bryophyte, unrecorded species

Genus *Fissidens* Hedw. is the largest genus among all moss genera in the world. For a while, there were two largest moss genera, *Fissidens* and *Bryum* Hedw., which consisted of approximately 440 species, respectively (Crosby et al., 2000). Meanwhile, even after the genus *Bryum* was split into several genera (Spence, 2005, 2007), the genus *Fissidens* is still recognized as a single genus (Syazwana et al., 2018).

Genus *Fissidens* indicates highly complicated diversity with numerous species. Certain species of *Fissidens*, such as *F. bryoides* Hedw., *F. grandifrons* Bridel, and *F. curvatus* Hornsch. are broadly distributed or cosmopolitan (Bruggeman-Nannenga et al., 1994; Bruggeman-Nannenga and Pursell, 1995; Pursell and Allen, 2017). However, most species of *Fissidens* have relatively limited distributions. For instance, *F. geppii* M. Fleisch., *F. tosaensis* Broth., and *F. ganguleei* Nork. are only found in Asia (Li et al., 2001), *F. celticus* Paton is distributed in Europe (Vanderpoorten and Sotiaux, 2002), and *F. appalachensis* R. H. Zander is endemic to eastern North America (Pursell and Allen, 1996). On the other hand, there are some species treated differently in several respective countries, e.g. *F. bryoides* complex: *F. viridulus* (Sw.) Wahlenb., *F. gymnandrus* Buse, *F. incurvus* Starke ex Röhl., *F. pusillus* (Wilson) Milde (Huttunen et al., 2018). In several European countries, these taxa are recognized as distinct species or varieties of *F. bryoides* (Huttunen et al., 2018). By

contrast, in North America, most of these taxa are regarded as synonyms of *F. bryoides* (Pursell, 2007). After the 2010s, Japanese authors recorded *F. viridulus*, *F. incurvus*, and *F. pusillus* in Japan (Suzuki and Iwatsuki, 2012a), thus the distributions of the species were expanded from Europe to Asia. Considering that these taxa were described as ‘expressions’ in North America (Pursell and Allen, 2017), the members of *F. bryoides* complex seem to be widely distributed in the Northern Hemisphere.

In Asia, the five varieties of *F. bryoides*, var. *bryoides*, var. *lateralis*, var. *ramosissimus*, var. *esquirolii*, and var. *schmidii*, were classified into *F. bryoides* complex (Noguchi, 1987; Li et al., 2001). While the variety *schmidii* was treated as a synonym of *Fissidens crispus* Mont. (Shevock et al., 2013), the remaining three varieties except var. *bryoides* are still recognized only in Asia. The descriptions of *F. bryoides* var. *esquirolii* and *F. bryoides* var. *ramosissimus* were similar to those of European species, *F. exiguus* Sull. and *F. bambergeri* Schimp., respectively. Thus, comparative analysis between the Asian varieties and other species of *F. bryoides* complex should be considered.

To investigate the taxonomically controversial taxa, molecular phylogenetic approaches are necessary for understanding the relationship among similar taxonomic groups. Also, the investigation of *F. bryoides* complex had

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demanding systematic studies, but previous research was not sufficient to examine the species complex (Huttunen et al., 2018). Meanwhile, Kwon et al. (2019a) reported the first chloroplast genome sequence of *Fissidens*, and it is expected that high-resolution sequences such as the organelle genome will be the key for unraveling the species complex. Before the molecular phylogenetic studies based on organelle genome sequences of *Fissidens* species, 15 taxa of collected *Fissidens* including five taxa of *F. bryoides* complex were newly recorded in Korea from the voucher specimens of *Fissidens* collected during floristic surveys of Korean moss flora.

Since the first report of *Fissidens* from the Korean Peninsula (Cardot, 1904), several researchers contributed to the gradual accumulation of the *Fissidens* flora of Korea (Kim et al., 2020a) during the comprehensive bryofloristic surveys on the Korean Peninsula (Lee and Choi, 2012). After Park and Choi (2007) published a new list of Korean bryophytes including 16 taxa of *Fissidens*, Korean authors reported various unrecorded species of *Fissidens* in South Korea (Yoon and Sun, 2010; Yoon et al., 2015a, b; Kwon et al., 2019b; Kim et al., 2020b). Recently, Kim et al. (2020a) organized the list of mosses of the Korean Peninsula and listed 26 taxa of *Fissidens* as recognized in Korea, including three newly recorded *Fissidens* species. However, three taxa from the list had to be excluded for the following reasons: (1) *F. pellucidus* var. *asterodontius* (Müll. Hal.) Pursell is not recognized in Asia, and the taxon is endemic to Brazil (Pursell, 1994; Bordin et al., 2011), and (2) *F. pseudolateralis* Cardot and *F. borealis* C. Gao are recognized as synonyms of *F. geppii* and *F. bryoides*, respectively (Noguchi, 1987; Li et al., 2001). In this study, I also updated the list of *Fissidens* in Korea consisting of a total of 38 taxa of *Fissidens*, covering three subgenera and five sections (Appendix 1).

Materials and Methods

All specimens of *Fissidens* were collected in Korea during the field surveys from 2018 to 2020. The voucher specimens of unrecorded species were deposited in the InfoBoss Cyber Herbarium (IN). The infrageneric classification and key to sections of the genus followed the recent molecular phylogenetic study (Suzuki et al., 2018). The keys to species were revised from those of previous studies in several countries (Li et al., 2001, Smith, 2004; Suzuki, 2015; Erzberger, 2016).

Taxonomic Treatment

I. subgen. *Fissidens* sect. *Fissidens*

1. *Fissidens bryoides* var. *esquirolii* (Thér.) Z. Iwats. & T.

Suzuki, J. Hattori Bot. Lab. 51: 361, 1982 (Figs. 1A, 2A).

Fissidens esquirolii Thér., Bull. Acad. Int. Géogr. Bot. 18: 251, 1908.

Fissidens yamamotoi Sakurai, Bot. Mag. (Tokyo) 56: 218, 1952.

Korean name: Jom-kko-ma-bong-hwang-i-kki (좁꼬마봉황이끼).

Plants yellowish green to brownish green, 0.8–1.2 mm long and 0.5–0.8 mm wide with leaves. Stems unbranched; axillary hyaline nodules not differentiated. Leaves in 3–4 pairs, upper leaves oblong-lanceolate to ovate-lanceolate, $0.4\text{--}0.8 \times 0.15\text{--}0.20$ mm, acute at apex; base of dorsal laminae wedge-shaped; costae ending few cells below apex; margins finely serrulate to crenulate throughout by projecting cells; vaginant laminae ca. $3/5\text{--}2/3$ the leaf length, almost equal; limbidia absent or rarely developed, unistratose, 1–2 rows of elongate cells on the vaginant laminae of perichaetial leaves; laminal cells unistratose, smooth; cells in the middle of apical and dorsal laminae quadrate to hexagonal, $(8\text{--})10\text{--}15\text{--}(18)$ μm long; cells in the vaginant laminae similar to those of apical and dorsal laminae, elongated to rectangular near the base, up to 25 μm long. Sporophytes not seen.

Specimens examined: KOREA. Gangwon-do: Samcheok-si, Gapbongsan Mountain, elev. 70 m, 21 Dec 2019, W. Kwon KBDS02616 (IN); Yeongwol-gun, Balbonsan Mountain, elev. 300 m, 26 Apr 2020, W. Kwon KBDS03180 (IN).

Habitats: on moist calcareous rocks near the stream.

Distribution: China, Japan, Taiwan, Thailand; new to Korea.

The East Asian variety, *F. bryoides* var. *esquirolii*, is characterized by its markedly reduced limbidia. Its limbidia are only found on the vaginant laminae of perichaetial leaves (Li et al., 2001), while other members of sect. *Fissidens* commonly have at least rather differentiated limbidia on their cauline leaves. It was originally described in China as the basionym *F. esquirolii* Thériot (1908) and described in Japan as a synonym *F. yamamotoi* Sakurai (1942). After the taxon was treated as a variety of *F. bryoides* (Iwatsuki and Suzuki, 1982), it was also recognized in Taiwan and Thailand additionally (Tan et al., 2006). Two European taxa of sect. *Fissidens*, *F. arnoldii* R. Ruthe and *F. exiguus* Sull. are also characterized by their limbidia limited to the vaginant laminae of perichaetial leaves (Erzberger, 2016). However, leaf margins of those two species were described as slightly crenulate and entire respectively, contrary to *F. bryoides* var. *esquirolii* having serrulate margins.

The Korean name was given as ‘Jom-kko-ma-bong-hwang-i-kki’, based on its minute plants size.

Fig. 1. Photographs of the 15 unrecorded *Fissidens* in Korea. **A.** *F. bryoides* var. *esquirolii* (Thér.) Z. Iwats. & T. Suzuki. **B.** *F. closteri* subsp. *kiusiuensis* (Sakurai) Z. Iwats. **C.** *F. crispus* Mont. **D.** *F. curvatus* Hornsch. **E.** *F. enervis* Sim. **F.** *F. flabellulus* Thwait. & Mitt. **G.** *F. ganguleei* Nork. **H.** *F. gracilifolius* Brugg.-Nann. & Nyholm. **I.** *F. gymandrus* Buse. **J.** *F. incurvus* Starke ex Röhl. **K.** *F. longisetus* Griff. **L.** *F. pusillus* (Wilson) Milde. **M.** *F. takayukii* Tad. Suzuki. **N.** *F. viridulus* (Sw.) Wahlenb. **O.** *F. wichurae* Broth. & Fleisch.

Fig. 2. Microscopic photographs of the 15 unrecorded *Fissidens* in Korea. **A.** *F. bryoides* var. *esquirolii* (Thér.) Z. Iwats. & T. Suzuki. **B.** *F. closteri* subsp. *kiusiuensis* (Sakurai) Z. Iwats. **C.** *F. crispus* Mont. **D.** *F. curvatus* Hornsch. **E.** *F. enervis* Sim. **F.** *F. flabellulus* Thwait. & Mitt. **G.** *F. ganguleei* Nork. **H.** *F. gracilifolius* Brugg.-Nann. & Nyholm. **I.** *F. gymnandrus* Buse. **J.** *F. incurvus* Starke ex Röhl. **K.** *F. longisetus* Griff. **L.** *F. pusillus* (Wilson) Milde. **M.** *F. takayukii* Tad. Suzuki. **N.** *F. viridulus* (Sw.) Wahlenb. **O.** *F. wichuræ* Broth. & Fleisch.

2. *Fissidens crispus* Mont., Ann. Sci. Nat., Bot., sér. 2., 9: 57, 1838 (Figs. 1C, 2C).

Fissidens schmidii Müll. Hal., Bot. Zeit. (Berlin) 11: 18, 1853; *Fissidens bryoides* var. *schmidii* (Müll. Hal.) R.S. Chopra & S.S. Kumar, Ann. Cryptog. Phytopathol. (New Delhi) 5: 43, 1981.

Fissidens limbatus Sull., Expl. Railroad Mississippi Pacific, Descr. Moss. Liverw. 4: 185, 1856.

Korean name: San-kko-ma-bong-hwang-i-kki (산꼬마봉황이끼).

Plants green to vivid green, 2.0–3.5 mm long and 0.8–2.0 mm wide with leaves. Stems unbranched; axillary hyaline nodules $\pm$ weakly differentiated. Leaves in 4–8 pairs, upper leaves elliptical-lanceolate to linear lanceolate, $0.8\text{--}1.8 \times 0.2\text{--}0.4$ mm, acute at apex; perichaetial leaves differentiated, much longer than cauline leaves; base of dorsal laminae wedge-shaped; costae nearly percurrent to shortly excurrent; margins entire; vaginant laminae ca. 1/2 the leaf length, equal; limbidia usually uni- to bistratose, nearly extending to the apex; laminal cells unistratose, smooth; cells in the middle of apical and dorsal laminae quadrate to hexagonal, $4\text{--}10 \times 4\text{--}7$ μm , strongly bulging (twice as high as wide in cross-section); cells in the vaginant laminae less bulging than those of apical and dorsal laminae, elongated toward base; basal juxtacostal cells of vaginant laminae rectangular, gradually enlarged, up to 30 μm long. Rhizautoicous or synoicous. Archegonia terminal on stems, 230–290 μm long. Antheridia terminal on minute bud-like or normal-sized male shoots, ca. 180 μm long. Setae 2.0–2.5 mm long. Capsules symmetrical, erect, urns $0.33\text{--}0.45 \times 0.22\text{--}0.25$ mm; peristome teeth 0.14–0.20 mm long, 27–33 μm wide at base. Spores 12–15 μm in diameter. opercula and calyptrae not seen.

Specimens examined: KOREA. Gangwon-do: Samcheok-si, Galmaegisan Mountain, elev. 240 m, 20 Aug 2019, *W. Kwon* KBDS02346 (IN); Jeongseon-gun, Unbongsan Mountain, elev. 270 m, 16 Jul 2020, *W. Kwon* KBDS03370 (IN).

Habitats: on dry limestone rocks in the small valley.

Distribution: widely distributed in tropics to temperate regions; new to Korea.

Fissidens crispus is characterized by its small protuberant laminal cells mostly twice as deep as wide in cross-section, of which trait is shared with *F. ovatifolius* R. Ruthe and *F. sublimatus* Grout (Corley, 1980; Ros et al., 2001). This species is also well known as its synonym, *F. limbatus* Sull. in North America (Pursell, 2007) and *F. schmidii* or *F. bryoides* var. *schmidii* in Asia (Tan et al., 2006). *F. schmidii* was treated as a synonym of *F. crispus* (Bruggeman-Nannenga, 2013;

Shevock et al., 2013), while the synonymy of *F. minutulus* Sull. and *F. crispus* was not clearly determined (Hill et al., 2006). *F. minutulus* was recognized as a synonym of *F. crispus* in Europe while the two taxa were regarded as distinct species in North America (Erzberger, 2016).

The Korean name was given as ‘San-kko-ma-bong-hwang-i-kki’, based on its habitats.

3. *Fissidens curvatus* Hornsch., Linnaea. 15: 148, 1841 (Figs. 1D, 2D).

Fissidens strictulus Müll. Hal., Nuov. Giorn. Bot. Ital., n.s. 5: 159, 1898.

Korean name: Beo-deul-bong-hwang-i-kki (머들봉황이끼).

Plants pale green to yellowish green, 1.5–3.0 mm long and 0.5–0.7 mm wide with leaves. Stems unbranched; axillary hyaline nodules differentiated; fertile and sterile stems dimorphic; fertile stems short, variable, with much longer leaves than sterile stems, or with somewhat reduced, scale-like leaves. Leaves in 5–9 pairs, upper leaves linear-lanceolate, $0.7\text{--}0.8 \times 0.15\text{--}0.17$ mm, acuminate at apex; perichaetial leaves differentiated, much longer than cauline leaves, or shorter with somewhat reduced apical and dorsal laminae; base of dorsal laminae wedge-shaped; costae percurrent to shortly excurrent; margins entire; vaginant laminae ca. 3/5–2/3 the leaf length, almost equal; limbidia uni- to bistratose, thin-walled, confluent with the costa; laminal cells unistratose, smooth; cells in the middle of apical and dorsal laminae narrowly hexagonal, 7–17 μm long and 5–8 μm wide; cells in the vaginant laminae similar to those of apical and dorsal laminae but somewhat regularly arranged, elongated to rectangular near the base, up to 25 μm long. Rhizautoicous. Archegonia terminal, 180–210 μm long. Antheridia terminal on minute bud-like male shoots, 110–170 μm long. Setae 3.0–3.5 mm long. Capsules symmetrical, erect to slightly inclined, urns $0.50\text{--}0.65 \times 0.35\text{--}0.40$ mm; opercula conic-rostellate, 0.27–0.33 mm long; calyptrae cucullate, ca. 0.4 mm long; peristome teeth 0.27–0.30 mm long, 36–40 μm wide at base. Spores 16–21 μm in diameter.

Specimens examined: KOREA. Jeju-do: Seogwipo-si, Changgocheon Stream, elev. 190 m, 19 Jan 2020, *W. Kwon* KBDS02652 (IN); Seogwipo-si, Jungmuncheon Stream, elev. 140 m, 19 Jan 2020, *W. Kwon* KBDS02714 (IN); Seogwipo-si, Dosuncheon Stream, elev. 100 m, 20 Jan 2020, *W. Kwon* KBDS02738 (IN).

Habitats: on clayey soil and moist rocks on the banks of the ephemeral streams.

Distribution: Africa, Asia, Australasia, Europe, North and

South America; new to Korea.

Fissidens curvatus is a cosmopolitan species, widely distributed in all continent except Antarctica (Bruggeman-Nannenga and Pursell, 1995). This species is characterized by (1) stout limbidia that are confluent with costa, (2) large, slightly elongated laminal cells, and (3) dimorphic sterile and fertile stems (Pursell 2007; Bruggeman-Nannenga, 2013). Its longly tapering leaves with well-developed limbidia are quite distinct from other limbate species (Atherton et al., 2010).

The Korean name was given as ‘Beo-deul-bong-hwang-i-kki’, based on its leaf shape.

4. *Fissidens gracilifolius* Brugg.-Nann. & Nyholm, Ill. Fl. Nord. Mosses 1: 10, 1986 (Figs. 1H, 2H).

Korean name: Ga-neun-dol-kko-ma-bong-hwang-i-kki (가네돌꼬마봉황이끼).

Plants green to pale green, 1.8–2.5 mm and 1.0–1.5 mm wide with leaves. Stems unbranched; axillary hyaline nodules not differentiated; fertile stems dimorphic, female shoots are smaller with fewer leaves or somewhat larger than sterile shoots. Leaves in 2–6 pairs, upper leaves oblong-lanceolate to linear lanceolate, $0.9\text{--}1.5 \times 0.10\text{--}0.25$ mm, acuminate at apex; perichaetial leaves differentiated, much longer than cauline leaves, ca. 7 times as long as wide; base of dorsal laminae wedge-shaped; costae percurrent to shortly excurrent; margins entire; vaginant laminae ca. 1/2 the leaf length, equal; limbidia usually unistratose, ending below apex; laminal cells unistratose, smooth; cells in the middle of apical and dorsal laminae quadrate to hexagonal, $9\text{--}15 \times 6\text{--}9$ μm ; cells in the vaginant laminae similar to those of apical and dorsal laminae, $\pm$ elongated toward base; basal juxtacostal cells of vaginant laminae rectangular, somewhat enlarged, up to 25 μm long. Rhizautoicous. Archegonia terminal, 200–250 μm long. Antheridia terminal, 120–180 μm long. Setae 1.3–3.0 mm long. Capsules symmetrical, erect, urns $0.30\text{--}0.62 \times 0.20\text{--}0.33$ mm; opercula rostellate, 0.20–0.33 mm long; calyptrae cucullate, 0.35–0.50 mm long; peristome teeth 0.14–0.20 mm long, 25–34 μm wide at base. Spores 10–14 μm in diameter.

Specimens examined: KOREA. Gyeongsangbuk-do: Gimcheon-si, Sudosan Mountain, elev. 950 m, 5 Sep 2020, *W. Kwon* KBDS03742 (IN).

Habitats: on rocks near the stream.

Distribution: Europe, China, Japan; new to Korea.

Fissidens gracilifolius is a small saxicolous species, characterized by (1) narrowly lanceolate leaves with unistratose limbidia ending below the acuminate apex, and (2) elongated perichaetial leaves approximately 7 times as long as wide

(Erzberger, 2016). These two characteristics separate *F. gracilifolius* from the confusable species, *F. pusillus*, which has perichaetial leaves 4–6 times as long as wide (Smith, 2004; Erzberger, 2016). Though features of costa and leaf apex of both species are variable, the perichaetial leaves of *F. gracilifolius* have acuminate apex with excurrent costa, while those of *F. pusillus* have acute to obtuse apex and costa usually ending below the apex (Smith, 2004; Erzberger, 2016). *F. gracilifolius* is also known as having shorter fertile stems with fewer cauline leaves compared to sterile stems (Suzuki and Iwatsuki, 2012a), and the dimorphism of the stems may separate *F. gracilifolius* from *F. pusillus*. Meanwhile, Korean materials had another type of fertile stems, undifferentiated from sterile stems but having somewhat larger leaves, co-existing with typical short fertile stems.

The Korean name was given as ‘Ga-neun-dol-kko-ma-bong-hwang-i-kki’, based on its narrow leaves and saxicolous habitats.

5. *Fissidens gymnandrus* Buse, Hedwigia 8: 55, 1869 (Figs. 1I, 2I).

Korean name: Min-kko-ma-bong-hwang-i-kki (민꼬마봉황이끼).

Plants pale green to vivid green, 3.0–5.0 mm long and 1.5–2.5 mm wide with leaves. Stems unbranched; axillary hyaline nodules not differentiated. Leaves in 4–7 pairs, upper leaves elliptical-lanceolate to oblong-lanceolate, $1.4\text{--}1.7 \times 0.4\text{--}0.5$ mm, obtuse to acute or mucronate at apex; perichaetial leaves not differentiated; base of dorsal laminae wedge-shaped; costae nearly percurrent; margins entire; vaginant laminae ca. 1/2–3/5 the leaf length, almost equal; limbidia usually unistratose, nearly extending to the apex; laminal cells unistratose, smooth; cells in the middle of apical and dorsal laminae quadrate to hexagonal, $7\text{--}17 \times 6\text{--}11$ μm ; cells in the vaginant laminae similar to those of apical and dorsal laminae; basal juxtacostal cells of vaginant laminae rectangular, gradually enlarged, up to 30 μm long. Autoicous, paroicous, or synoicous. Archegonia terminal, 240–290 μm long. Antheridia usually in leaf axils of fertile shoots, without perigonial leaves, 180–200 μm long. Setae 2.0–4.0 mm long. Capsules symmetrical, erect, urns $0.53\text{--}0.68 \times 0.23\text{--}0.28$ mm; opercula conic-rostellate, ca. 0.3 mm long; calyptrae cucullate, ca. 0.5 mm long; peristome teeth 0.14–0.20 mm long, 33–39 μm wide at base. Spores 11–16 μm in diameter.

Specimens examined: KOREA. Gangwon-do: Jeongseong-gun, Gariwangsan Mountain, elev. 1,120 m, 17 Jul 2020, *W. Kwon* KBDS03442 (IN).

Habitats: on decaying woods and soil of mountains (elev. 900–1,300 m).

Distribution: Europe, North America, Japan, Russia; new to Korea.

Fissidens gymnanthus is characterized by its naked axillary antheridia, contrary to *F. bryoides* having antheridia in axillary bud-like perigonia. In the distal part of ovate to elliptical leaves, *F. gymnanthus* has wider leaf apex than that of *F. bryoides*, forming obtuse apex with short apiculus (Erzberger, 2016). *F. gymnanthus* is widely distributed in Europe and also reported in Russia, Japan, and North America (Guerra et al., 2012). Although there were a lot of controversies over the taxonomy of *F. gymnanthus* and *F. bryoides* (Huttunen et al., 2018), I adopted the basionym of the taxon since phylogenetics of these taxa have not been studied yet.

The Korean name was given as ‘Min-kko-ma-bong-hwang-i-kki’, based on its naked axillary antheridia.

6. *Fissidens incurvus* Starke ex Röhl. *Deutschl. Fl.* (ed. 2), Kryptog. Gew. 3: 76, 1813 (Figs. 1J, 2J).

Korean name: Gub-eun-kko-ma-bong-hwang-i-kki (굽은꼬마봉황이끼).

Plants green to yellowish green, 2.5–4.0 mm long and 1.3–2.2 mm wide with leaves. Stems unbranched; axillary hyaline nodules not differentiated; fertile shoots are smaller than sterile shoots. Leaves in 5–9 pairs, upper leaves ovate-lanceolate to narrowly elliptical, 1.2–1.7 × 0.3–0.5 mm, acute at apex; perichaetial leaves differentiated, more or less longer and narrower than cauline leaves; base of dorsal laminae wedge-shaped; costae percurrent to excurrent; margins entire; vaginant laminae ca. 3/5–2/3 the leaf length, equal; limbidia well-developed, 1–2(–3)-stratose, extending to the apex; laminal cells unistratose, smooth; cells in the middle of apical and dorsal laminae quadrate to hexagonal, 8–15 × 6–10 µm; cells in the vaginant laminae similar to those of apical and dorsal laminae; basal juxtacostal cells of vaginant laminae rectangular, gradually enlarged, up to 25 µm long. Rhizautoicous. Archegonia terminal, 210–280 µm long. Antheridia terminal on small bud-like male shoots near the base of female shoots, ca. 180 µm long. Setae 4.0–6.5(–10.0) mm long. Capsules asymmetrical, inclined, urns 0.58–0.65 × 0.33–0.38 mm; opercula rostrate, 0.40–0.45 mm long; calyptrae cucullate, ca. 0.6 mm long; peristome teeth 0.27–0.33 mm long, 38–44 µm wide at base. Spores 12–15 µm in diameter.

Specimens examined: KOREA. Jeollanam-do: Wando-gun, Jeongjusan Mountain, elev. 10 m, 20 Apr 2018, *W. Kwon* KBDS00520 (IN). Gyeongsangnam-do: Geoje-si, Bukbyeongsan

Mountain, elev. 80 m, 8 Feb 2019, *W. Kwon* KBDS01324 (IN). Gyeongsangbuk-do: Chilgok-gun, Dongmugol valley, elev. 200 m, 13 Sep 2019, *W. Kwon* KBDS02573 (IN). Jeju-do: Seogwipo-si, Dosuncheon Stream, elev. 90 m, 20 Jan 2020, *W. Kwon* KBDS02718 (IN).

Habitats: on soil; rarely on rocks near the streams.

Distribution: Africa, Asia, Australia, Europe, and North America; new to Korea.

Fissidens incurvus is characterized by (1) inclined asymmetric capsules, and (2) short male shoots on the base of female shoots, not axillary (Smith, 2004; Erzberger, 2016). The East Asian species *F. tosaensis* is closely related to *F. incurvus*, also recognized by its inclined asymmetric capsules. However, *F. tosaensis* has axillary male inflorescences, as referred to the original description (Brotherus, 1921). In addition, there is a difference on the female shoots of these species. *F. incurvus* only has terminal setae while the setae of *F. tosaensis* were described as terminal or lateral (Noguchi, 1987; Li et al., 2001). The Korean materials had small bud-like male shoots on the base of other shoots, and had female shoots somewhat smaller than sterile shoots.

The Korean name was given as ‘Gub-eun-kko-ma-bong-hwang-i-kki’, based on its reduced limbidia.

7. *Fissidens longisetus* Griff., *Calcutta J. Nat. Hist.* 2: 503, 1842 (Figs. 1K, 2K).

Korean name: Keun-kko-ma-bong-hwang-i-kki (큰꼬마봉황이끼).

Plants green to brownish green, 5.0–13.0 mm long and 2.2–3.5 mm wide with leaves. Stems branched at middle parts of older stems; axillary hyaline nodules not differentiated. Leaves in 7–13 pairs, upper leaves narrowly elliptic to oblong-lanceolate, 1.5–2.4 × 0.2–0.5 mm, mucronate to acuminate at apex; perichaetial leaves ± differentiated, much narrower than cauline leaves; base of dorsal laminae wedge-shaped; costae excurrent; margins entire; vaginant laminae ca. 3/5–2/3 the leaf length, equal; limbidia usually stoat, confluent with the costa, 2–4-stratose on vaginant laminae, yellowish in older parts; laminal cells unistratose, smooth; cells in the middle of apical and dorsal laminae quadrate to hexagonal, 8–15 × 6–9 µm; cells of vaginant laminae similar to those of apical and dorsal laminae; basal juxtacostal cells of vaginant laminae rectangular, conspicuously enlarged, up to 40 µm long. Gonioautoicous or synoicous. Archegonia terminal on fertile shoots or short axillary branches, 230–250 µm long. Antheridia terminal on fertile shoots or in axillary bud-like perigonia, ca. 170 µm long. Setae 4.0–6.0 mm long. Capsules symmetrical, erect, urns

0.65–0.90 × 0.32–0.40 mm; opercula rostellate, ca. 0.4 mm long; calyptrae cucullate, ca. 0.8 mm long; peristome teeth 0.36–0.40 mm long, 44–52 µm wide at base. Spores 14–16 µm in diameter.

Specimens examined: KOREA. Gangwon-do: Samcheok-si, Gapbongsan Mountain, elev. 60 m, 21 Dec 2019, *W. Kwon KBDS02606* (IN); Yeongwol-gun, Balbonsan Mountain, elev. 300 m, 26 Apr 2020, *W. Kwon KBDS03182* (IN). Chungcheongbuk-do: Chungju-si, Indeungsan Mountain, elev. 290 m, 15 Mar 2020, *W. Kwon KBDS03078* (IN).

Habitats: on moist soil and rocks.

Distribution: Europe, North America, Japan; new to Korea.

Fissidens longisetus, a member of sect. *Fissidens*, has relatively large plants that grow up to 1.5 cm high. This species is characterized by its long setae that are terminal, or lateral growing on short axillary branches. There are two species with lateral setae, *F. tosaensis* and *F. bryoides* var. *lateralis*, similar to *F. longisetus*. However, *F. tosaensis* has asymmetric capsules and *F. bryoides* var. *lateralis* has shorter (0.8–2.5 mm) setae, while *F. longisetus* has symmetric capsules and longer (5.0–11.0 mm) setae (Suzuki and Iwatsuki, 2008).

The Korean name was given as ‘Keun-kko-ma-bong-hwang-i-kki’, based on its large plant size.

8. *Fissidens pusillus* (Wilson) Milde, Bryol. Siles. 82, 1869 (Figs. 1L, 2L).

Fissidens viridulus var. *pusillus* Wilson, Bryol. Brit.: 303, 1855.

Korean name: Dol-kko-ma-bong-hwang-i-kki (돌꼬마봉황이끼).

Plants green to light green, 1.5–2.5 mm long and 1.0–1.3 mm wide with leaves. Stems unbranched; axillary hyaline nodules not differentiated. Leaves in 3–7 pairs, upper leaves much larger than lower leaves, oblong-lanceolate to lingulate-lanceolate, 0.50–1.50 mm × 0.20–0.35 mm, in upper part suddenly narrowed, acute to obtuse at apex; base of dorsal laminae wedge-shaped; vaginant laminae ca. 1/2 to 3/5 the leaf length, almost equal; perichaetial leaves differentiated, much longer than cauline leaves, 4–6(–7) times as long as wide; margin entire to slightly denticulate at apex; costae ending few cells below apex or percurrent; limbidia usually uni- to bistratose, ending below apex; laminal cells unistratose, smooth; cells in the middle of apical and dorsal laminae quadrate to hexagonal, (6–)8–16(–18) × 4–8(–12) µm; cells in the vaginant laminae similar to those of apical and dorsal laminae; basal juxtacostal cells of vaginant laminae rectangular, conspicuously enlarged, up to 40 µm long. Rhizautoicous.

Archegonia terminal, 240–280 µm long. Antheridia terminal on minute bud-like or normal-sized male shoots, 180–220 µm long. Setae 2.5–3.0 mm long. Capsules symmetrical, erect, urns 0.45–0.58 × 0.24–0.30 mm; opercula conic-rostellate, 0.30–0.33 mm long; calyptrae cucullate, ca. 0.6 mm long; peristome teeth 0.20–0.23 mm long, 27–32 µm wide at base. Spores 12–14 µm in diameter.

Specimens examined: KOREA. Gangwon-do: Pyeongchang-gun, Cheongoksan Mountain, elev. 990 m, 21 Aug 2019, *W. Kwon KBDS02493* (IN); Jeongseon-gun, Gariwangsan Mountain, elev. 600 m, 17 Jul 2020, *W. Kwon KBDS03410* (IN).

Habitats: on moist rocks in trails and slopes.

Distribution: Europe, North America, Japan; new to Korea.

This species is characterized by (1) plants usually growing on moist siliceous rocks, up to 5 mm high, (2) limbidia and costae ending below leaf apex, and (3) leaf margins at apex more or less straight, and (4) perichaetial leaves 4–6 times as long as wide (Erzberger, 2016). This species was described as a hydrophilous species by some authors, contrary to the non-hydrophilous species, *F. gracilifolius* (Smith, 2004; Erzberger, 2016). In Korea, the species was also found in non-hydrophilous habitats like trails, slopes, and on the top point of the mountain.

The Korean name was given as ‘Dol-kko-ma-bong-hwang-i-kki’, based on its saxicolous habitats.

9. *Fissidens viridulus* (Sw.) Wahlenb., Fl. Lapp. 334, 1812 (Figs. 1N, 2N).

Dicranum viridulum Sw., Monthly Rev. 34: 538, 1801.

Korean name: Eo-ri-kko-ma-bong-hwang-i-kki (어리꼬마봉황이끼).

Plants pale green to vivid green, 1.5–4.0 mm long and 1.0–1.6 mm wide with leaves. Stems unbranched; axillary hyaline nodules not differentiated. Leaves in 3–5 pairs, upper leaves elliptical-lanceolate to oblong-lanceolate, 0.7–1.3 × 0.20–0.35 mm, acute to obtuse-apiculate at apex; perichaetial leaves not differentiated but somewhat larger than cauline leaves; base of dorsal laminae wedge-shaped; costae ending below the apex; margins entire, often finely serrulate at apex with bluntly projected cells; vaginant laminae ca. 3/5 the leaf length, almost equal; limbidia unistratose, ending below apex; laminal cells unistratose, smooth; cells in the middle of apical and dorsal laminae quadrate to hexagonal, 7–15 × 6–10 µm; cells in the vaginant laminae similar to those of apical and dorsal laminae; basal juxtacostal cells of vaginant laminae rectangular, gradually enlarged, up to 30 µm long. Rhizautoicous. Archegonia terminal, 230–260 µm long. Antheridia terminal

on minute bud-like or normal-sized male shoots, 150–180 µm long. Setae 1.8–3.5(–5.0) mm long. Capsules symmetrical, erect, urns 0.52–0.64 × 0.26–0.31 mm; opercula conic-rostellate, ca. 0.3 mm long; calyptrae cucullate, ca. 0.4 mm long; peristome teeth 0.12–0.18 mm long, 30–37 µm wide at base. Spores 12–17 µm in diameter.

Specimens examined: KOREA. Gangwon-do: Samcheok-si, Galmaegisan Mountain, elev. 220 m, 20 Aug 2019, *W. Kwon* KBDS02342 (IN).

Habitats: on soil in the side of trails.

Distribution: Africa, Australia, Europe, North and Central America, and Japan; new to Korea.

Fissidens viridulus is a small terricolous species, characterized by (1) rhizautoicous plants usually with small bud-like male shoots, (2) unistratose limbidia not confluent with costa that ending below leaf apex, (3) leaf margins at apex concave with acuminate or cuspidate apex, and (4) perichaetial leaves not differentiated but somewhat larger than cauline leaves (Smith, 2004; Erzberger, 2016). Like the case of *F. gymnandrus*, this species is also regarded as a expression of *F. bryoides* (Pursell and Allen, 2017). Phylogenetic analysis based on marker sequences was not enough to support the taxon as a distinct species (Hassel et al., 2013), further studies are required.

The Korean name was given as ‘Eo-ri-kko-ma-bong-hwang-i-kki’, based on its relatively reduced limbidia and costae.

Key to the species of subgen. *Fissidens* sect. *Fissidens* in Korea

1. Leaves of sterile stems usually elmbate, limbidia restricted to the vaginant laminae of perichaetial leaves
..... *F. bryoides* var. *esquirolii*
1. Limbidia on all laminae of fully developed cauline leaves
 2. Leaves narrowly lanceolate with acute apex; limbidia stoat, confluent at the apex *F. curvatus*
 2. Leaves not as above
 3. Cells in the middle of dorsal laminae 4–10 µm long, strongly bulging (twice as high as wide in cross-section) *F. crispus*
 3. Cells in the middle of dorsal laminae 6–15 µm long, not or scarcely bulging
 4. Capsules inclined, asymmetrical
 5. Setae terminal; male inflorescences mostly at the base of fertile shoots; archegonia 210–350 µm long *F. incurvus*
 5. Setae mostly lateral; male inflorescences bud-like, often axillary; archegonia 160–220 µm

- long *F. tosaensis*
4. Capsules erect, symmetrical
 6. Limbidia usually stoat on vaginant laminae, yellowish in older leaves; plants often > 5 mm long
 7. Plants autoicous; setae terminal or on short axillary branches; antheridia usually in axillary bud-like perigonia *F. longisetus*
 7. Plants synoicous; setae terminal; antheridia mixed with archegonia *F. geppii*
 6. Limbidia not as above; plants usually < 5 mm long
 8. Setae usually lateral
..... *F. bryoides* var. *lateralis*
 8. Setae always terminal
 9. Antheridia usually axillary
 10. Antheridia in bud-like perigonia
..... *F. bryoides* var. *bryoides*
 10. Antheridia naked in the leaf axils ..
..... *F. gymnandrus*
 9. Antheridia not axillary
 11. Plants synoicous or polyoicous
..... *F. bryoides* var. *ramosissimus*
 11. Plants rhizautoicous
 12. Plants usually terricolous; perichaetial leaves not differentiated *F. viridulus*
 12. Plants usually saxicolous; perichaetial leaves differentiated, much longer than cauline leaves
 13. Perichaetial leaves 4–6(–7) times as long as wide, acute to obtuse at apex, costa usually ending below apex *F. pusillus*
 13. Perichaetial leaves up to 9 times as long as wide, acuminate at apex, costa percurrent to excurrent
..... *F. gracilifolius*

II. subgen. *Fissidens* sect. *Polypodiopsis*

10. *Fissidens enervis* Sim, Trans. Roy. Soc. South Africa 15: 187, 1926 (Figs. 1E, 2E).

Korean name: I-seul-bong-hwang-i-kki (이슬봉황이끼).

Plants pale green, 0.8–1.4 mm long and 0.5–0.7 mm wide with leaves. Stems unbranched; axillary hyaline nodules not differentiated. Leaves in 3–5 pairs, ecostae, upper leaves

elliptical to ovate, $0.45\text{--}0.60 \times 0.14\text{--}0.20$ mm, acuminate to cuspidate at apex; base of dorsal laminae more or less rounded; margins entire; vaginant laminae ca. $1/2\text{--}3/5$ the leaf length, equal; limbidia usually bistratose, thick-walled, extending to the apex; laminal cells large, unistratose, smooth, slightly protuberant, thin-walled; cells in the middle of apical and dorsal laminae hexagonal, $20\text{--}45 \times 12\text{--}28$ μm ; cells in the vaginant laminae narrower, $24\text{--}50 \times 10\text{--}17$ μm ; rhizoids often originating from laminal cells. Sporophytes not seen.

Specimens examined: KOREA. Gangwon-do: Jeongseon-gun, Gariwangsan Mountain, elev. 440 m, 21 Aug 2019, *W. Kwon KBDS02442* (IN); Jeongseon-gun, Joyangsan Mountain, elev. 380 m, 15 Jul 2020, *W. Kwon KBDS03322* (IN).

Habitats: on moist soil in the trails.

Distribution: Southern Africa, India; new to Korea.

Fissidens enervis is a rare species of *Fissidens* in Asia. It was known to be distributed only in South Africa, however, the recent study reported the species in India for the first time in Asia (Bruggeman-Nannenga et al., 2016). This species is characterized by its ecostae leaves with cuspidate apex and remarkable rhizoids originating from laminal cells (Bruggeman-Nannenga et al., 2016). It also has uni- to bistratose limbidia, contrary to *F. hyalinus* that only has unistratose limbidia (Bruggeman-Nannenga, 2017). Some expressions of *F. hyalinus* had small leaves with cuspidate apex, but neither bistratose limbidia nor rhizoids from laminae were present. Meanwhile, in Korea, *F. enervis* was currently found only in Jeongseon-gun, while *F. hyalinus* was in Jeju Island, Wando-gun, Geoje-si, Hapcheon-gun, Jeongseon-gun, and Yanggu-gun.

The Korean name was given as ‘I-seul-bong-hwang-i-kki’, based on its large, protuberant laminal cells.

Key to the species of subgen. *Fissidens* sect. *Polypodiopsis* in Korea

1. Protonemata persistent; plants bud-like ··· *F. protonemaecola*
1. Protonemata not persistent; plants not bud-like
 2. Limbidia usually bistratose, rhizoids often originating from laminal cells ··········· *F. enervis*
 2. Limbidia unistratose, rhizoids not as above ··· *F. hyalinus*

III. subgen. *Fissidens* sect. *Aloma*

11. *Fissidens closteri* subsp. *kiusiuensis* (Sakurai) Z. Iwats., J. Jap. Bot. 33: 249, 1958 (Figs. 1B, 2B).

Fissidens kiusiuensis Sakurai, Bot. Mag. (Tokyo) 47: 740, 1933.

Korean name: To-kki-bong-hwang-i-kki (토끼봉황이끼).

Plants vivid green to yellowish green, 0.6–1.2 mm long and 0.4–0.6 mm wide with leaves. Stems unbranched; axillary hyaline nodules not differentiated. Leaves in 2–3(–4) pairs, upper leaves elliptical-lanceolate to narrowly lanceolate, $0.5\text{--}1.2 \times 0.13\text{--}0.22$ mm, acute at apex; base of dorsal laminae wedge-shaped; costa ending below the apex; margins entire to finely serrulate by projecting cells in upper laminae; vaginant laminae ca. $1/2\text{--}2/3$ the leaf length, barely equal; elimbate; laminal cells unistratose, smooth; cells in the middle of apical and dorsal laminae irregularly, quadrate to narrowly hexagonal, $7\text{--}20(27) \times 6\text{--}11$ μm ; cells in the vaginant laminae rectangular, enlarged, conspicuously elongated toward base, up to $40(55)$ μm long; marginal cells of upper laminae smaller than the others, $7\text{--}15 \times 5\text{--}8$ μm . Rhizautoicous. Archegonia terminal, 100–130 μm long. Antheridia in minute bud-like male shoots, ca. 100 μm long. Setae 1.3–2.3 mm long. Capsules symmetrical, erect, urns $0.23\text{--}0.32 \times 0.16\text{--}0.21$ mm; opercula rostellate, 0.16–0.18 mm long; calyptrae cucullate, distinctly papillose by cells projecting at each upper end, ca. 0.3 mm long; peristome teeth 0.10–0.12 mm long, 20–28 μm wide at base. Spores 8–13 μm in diameter.

Specimens examined: KOREA. Busan-si, Geumjeongsan Mountain, elev. 350 m, 19 Jul 2019, *W. Kwon KBDS01865* (IN). Gangwon-do: Jeongseon-gun, Yujideungsan Mountain, elev. 400 m, 16 Jul 2020, *W. Kwon KBDS03350* (IN); Yanggu-gun Dosolsan Mountain, elev. 660 m, 20 Aug 2020, *W. Kwon KBDS03705* (IN). Jeollanam-do: Gwangyang-si, Baegunsan Mountain, elev. 1,090 m, 5 Sep 2020, *W. Kwon KBDS03729* (IN). Gyeongsangnam-do: Hamyang-gun, Geumwonsan Mountain, elev. 1,160 m, 5 Sep 2020, *W. Kwon KBDS03737* (IN).

Habitats: on rocks on trails, ridges, and side of streams.

Distribution: China, Japan; new to Korea.

Fissidens closteri Austin is a minute species characterized by its markedly short stems with well-differentiated leaves. The characteristic of stem is shared with other minute species, *F. protonemaecola* Sakurai and *F. takayukii* Tad. Suzuki, which have bud-like plants. However, *F. closteri* has the typical leaf structure of *Fissidens*, while *F. protonemaecola* and *F. takayukii* have somewhat reduced leaf structures. *F. closteri* subsp. *kiusiuensis* is an Asian subspecies recognized in China and Japan. It differs from the typical subspecies in having distinctly scabrous calyptrae with unipapillose surface cells projecting at each upper end.

The Korean name was given as ‘To-kki-bong-hwang-i-kki’, based on its leaf shape.

12. *Fissidens flabellulus* Thwait. & Mitt., J. Linn. Soc., Bot. 13: 324, 1873 (Figs. 1F, 2F).

Korean name: Bal-tob-bong-hwang-i-kki (발톱봉황이끼).

Plants pale green to yellowish green, 1.4–2.0 mm long and 0.8–1.2 mm wide with leaves. Stems unbranched; axillary hyaline nodules well-differentiated. Leaves in 3–6 pairs, upper leaves linear-lanceolate to lanceolate, $0.8\text{--}1.5 \times 0.12\text{--}0.27$ mm, acute at apex; base of dorsal laminae wedge-shaped; costae stout, percurrent; margins finely crenulate to denticulate throughout by projecting cells; vaginant laminae ca. $2/5\text{--}1/2$ the leaf length, unequal, minor lamina $\pm$ ending on the costa; elimbate; laminal cells unistratose, smooth, slightly protuberant; cells in the middle of apical and dorsal laminae usually hexagonal, $12\text{--}22(30) \times 10\text{--}16$ μm ; cells in the vaginant laminae similar to those of apical and dorsal laminae, conspicuously elongated toward base, up to 45 μm long. Sporophytes not seen.

Specimens examined: KOREA. Jeju-do: Seogwipo-si, Changgocheon Stream, elev. 190 m, 19 Jan 2020, *W. Kwon* KBDS02663 (IN).

Habitats: on muddy soil on the bank of the ephemeral stream.

Distribution: China, Fiji, India, Japan, Malaysia, Sri Lanka, Thailand, Vanuatu; new to Korea.

Fissidens flabellulus is a tropical Asian species, distributed in Southern and Eastern Asia (Tan et al., 2006). It is characterized by (1) minute plants with narrow leaves, (2) percurrent to shortly excurrent costae that often divide laminae unequally, and (3) crenulate to serrulate leaf margins with projecting cells (Li et al., 2001). The species is separated from the related species, *F. serratus* C. Müll., which has smaller (8–11 μm) and unipapillose laminal cells, by its larger (10–19 μm) and almost smooth laminal cells (Li et al., 2001).

The Korean name was given as ‘Bal-tob-bong-hwang-i-kki’, based on its leaf shape.

13. *Fissidens takayukii* Tad. Suzuki, Hattoria 6: 8, 2015 (Figs. 1M, 2M).

Korean name: Sae-ssak-bong-hwang-i-kki (새싹봉황이끼).

Plants yellowish green to brownish green, 0.5–0.7 mm long and 0.4–0.6 mm wide with leaves. Stems unbranched; axillary hyaline nodules not differentiated. Leaves in 1–2 pairs, upper leaves lanceolate, $0.5\text{--}0.6 \times 0.18\text{--}0.20$ mm, acute to caudate at apex, upper ends often slightly reflexed; apical and dorsal laminae not developed; costa percurrent to nearly percurrent, usually starting in the middle part of leaves; margins slightly denticulate throughout by projecting cells; elimbate; laminal cells unistratose, smooth; upper laminal cells irregularly

quadrate, $12\text{--}15 \times 10\text{--}13$ μm ; middle laminal cells rectangular, conspicuously elongated toward base, up to 50 μm long; marginal cells of leaves smaller than the others, $10\text{--}15 \times 5\text{--}8$ μm . Rhizautoicous. Archegonia terminal, 130–160 μm long. Antheridia in minute bud-like male shoots near the base of female shoots, ca. 100 μm long. Setae 1.5–2.0 mm long. Capsules symmetrical, erect, urns $0.35\text{--}0.48 \times 0.23\text{--}0.36$ mm; opercula conic-rostellate, 0.23–0.26 mm long; calyptrae cucullate, smooth to nearly smooth, ca. 0.4 mm long; peristome teeth 0.20–0.23 mm long, 26–35 μm wide at base. Spores 9–12 μm in diameter.

Specimens examined: KOREA. Jeju-do: Jeju-si, Cheonmicheon Stream, elev. 310 m, 21 Jan 2020, *W. Kwon* KBDS02885 (IN).

Habitats: on muddy soil on the bank of the ephemeral stream.

Distribution: Japan; new to Korea.

Fissidens takayukii is characterized by its peculiar scale-like leaf structure without differentiated apical and dorsal laminae. The costae of *F. takayukii* are percurrent, usually starting in the middle part of leaves (Suzuki, 2015). Its plants have minute bud-like appearances, similar to those of *F. protonemaecola* and *F. closteri* subsp. *kiusiuensis*. However, *F. protonemaecola* has persistent protonemata, and *F. closteri* subsp. *kiusiuensis* has leaves with well-differentiated laminae structure. The closely related species, *Fissidens pseudoclosteri* Z. Iwats. & S. S. Kumar, has undifferentiated leaf structure significantly similar to *F. takayukii* (Tang et al., 2020). However, though the characteristic of calyptrae was not described in the original description (Iwatsuki and Kumar, 1992), *F. pseudoclosteri* has papillose calyptrae (Suzuki and Iwatsuki, 2012a) contrary to smooth calyptrae of *F. takayukii* (Suzuki, 2015). Korean materials of *F. takayukii* had smooth to nearly smooth calyptrae, not papillose. Meanwhile, the leaf structures of those two species were quite variable, comparative analyses through a multifarious approach should be required.

The Korean name was given as ‘Sae-ssak-bong-hwang-i-kki’, based on its bud-like appearance.

Key to the species of subgen. *Fissidens* sect. *Aloma* in Korea

1. Plants not bud-like, elongated stems with distinctly pinnately arranged leaves *F. flabellulus*
1. Plants bud-like, markedly short stems with $\pm$ scale-like leaves
 2. Leaves with well-differentiated apical and dorsal laminae *F. closteri* subsp. *kiusiuensis*

2. Leaves without well-differentiated apical and dorsal laminae *F. takayukii*

IV. subgen. *Fissidens* sect. *Semilimbidium*

14. *Fissidens ganguleei* Nork., Mosses E. India 2: 527, 1971 (Figs. 1G, 2G).

Korean name: Nal-gae-bong-hwang-i-kki (날개봉황이끼).

Plants pale green to yellowish green, 2.0–4.0 mm long and 1.2–1.6 mm wide with leaves. Stems unbranched; axillary hyaline nodules not differentiated. Leaves in 5–12 pairs, upper leaves oblong-lanceolate, $0.6\text{--}1.3 \times 0.20\text{--}0.35$ mm, acute to mucronate at apex; base of dorsal laminae rounded to wedge-shaped; costae stout, often bent angularly in cauline leaves, nearly percurrent to shortly excurrent; margins finely denticulate to crenulate throughout by projecting cells; vaginant laminae ca. $1/2\text{--}3/5$ the leaf length, unequal, the upper part of minor lamina often ending on the costa; limbidia unistratose, 1–3 rows of elongate cells on the vaginant laminae of perichaetial leaves; laminal cells unistratose, smooth; cells in the middle of apical and dorsal laminae quadrate to hexagonal, $10\text{--}20 \times 6\text{--}14$ μm ; cells in the vaginant laminae similar to those of apical and dorsal laminae; marginal cells $\pm$ differentiated, somewhat smaller than the others, $8\text{--}12 \times 6\text{--}12$ μm in upper laminae; a conspicuous central oil globule found in each laminal cell. Dioicous? Archegonia terminal, 360–400 μm long. Antheridia terminal, 190–220 μm long. Sporophytes not seen.

Specimens examined: KOREA. Jeju-do: Seogwipo-si, Akgeunnae Stream, elev. 310 m, 20 Jan 2020, *W. Kwon KBDS02759* (IN). Jeollanam-do: Gwangyang-si, Baegunsan Mountain, elev. 1,030 m, 5 Sep 2020, *W. Kwon KBDS03720* (IN).

Habitats: on moist soil and rocks, usually in shaded backslopes or trails of mountains (elev. 1,000–1,400 m); rarely on hard earth banks of the ephemeral stream.

Distribution: Bangladesh, China, India, Indonesia, Japan, Laos, Nepal, Vietnam; new to Korea.

Fissidens ganguleei, the Asian species, was originally described in India and recorded in several Asian countries (Zhang et al., 2016). This species is characterized by its leaves with (1) often bent costa, (2) the upper part of minor vaginant lamina ending on the costa, (3) tapered dorsal lamina that slightly decurrent, and (4) more or less thin-walled laminal cells (Noguchi, 1987; Li et al., 2001). These characteristics are also shared in the European species, *F. celticus* Paton, which is recognized as a West-European endemic moss (Vanderpoorten and Sotiaux, 2002; Guerra et al., 2012). This species has well-

marked leaves characterized by (1) distinctly bent costa, (2) unequal vaginant laminae the upper part of which is ending on the costa, and (3) laminal cells that 8–12 μm wide in the marginal row and 12–20 μm wide in the rest (Paton, 1965). Japanese and Chinese authors described *F. ganguleei* as having broader (0.2–0.3 mm wide) leaves with smaller (7–15 μm long) laminal cells (Noguchi, 1987; Li et al., 2001), while *F. celticus* having narrower (0.16–0.23 mm wide) leaves with somewhat larger ($8\text{--}16 \times 12\text{--}20$ μm) laminal cells (Paton, 1965). Meanwhile, Korean materials had 0.20–0.35 mm wide leaves, with $10\text{--}20 \times 6\text{--}14$ μm laminal cells.

Though Pursell and Bruggeman-Nannenga (2004) did not divide the subgen. *Aloma* into sections, the two species were generally regarded as belonging to the sect. *Aloma* (Vanderpoorten and Sotiaux, 2002; Suzuki and Iwatsuki, 2012b). However, the recent study of the infrageneric classification of *Fissidens* based on molecular phylogeny treated *F. ganguleei* as a member of the sect. *Semilimbidium* (Suzuki et al., 2018). As with the members of the sect. *Semilimbidium*, *F. celticus* also has the weakly differentiated limbidia with elongate cells on the vaginant laminae of perichaetial leaves, as referred to the original description of *F. celticus* (Paton, 1965). In consequence, I expected that *F. ganguleei* and *F. celticus* are close relative in the aspect of phylogeny because both species share the particular morphological features. Meticulous studies are essential for clarifying the species delimitation.

The Korean name was given as ‘Nal-gae-bong-hwang-i-kki’, based on its leaf shape.

15. *Fissidens wichurae* Broth. & Fleisch., Hedwigia 38: 127, 1899 (Figs. 1O, 2O).

Korean name: Kal-ip-bong-hwang-i-kki (칼잎봉황이끼).

Plants yellowish green to dark green, 2.0–3.0 mm long, 1.5–1.8 mm wide with leaves. Stems unbranched; axillary hyaline nodules weakly differentiated. Leaves in 4–7 pairs, upper leaves narrowly lanceolate, $1.4\text{--}1.8 \times 0.16\text{--}0.23$ mm, acuminate at apex; base of dorsal laminae wedge-shaped; costa shortly excurrent; margins finely crenulate throughout by projecting cells; vaginant laminae ca. $1/2\text{--}3/5$ the leaf length, equal; limbidia unistratose, (0–)2–4 rows of elongate cells on the lower parts of vaginant laminae; laminal cells unistratose, pluripapillose, obscure; cells in the middle of apical and dorsal laminae quadrate to hexagonal, $5\text{--}10 \times 5\text{--}7$ μm ; cells in the vaginant laminae similar to those of apical and dorsal laminae; basal juxtacostal cells of vaginant laminae smooth, rectangular, conspicuously enlarged, up to 30 μm long. Sporophytes not seen.

Specimens examined: KOREA. Gyeongsangnam-do: Geoje-si, Bukbyeongsan Mountain, elev. 80 m, 08 Feb. 2019, W. Kwon KBDS01330 (IN).

Habitats: on soil of slopes on the mountain.

Distribution: China, Indonesia, Japan, Malaysia, New Guinea, Philippines, Thailand; new to Korea.

Fissidens wichurae is characterized by its weakly differentiated axillary hyaline nodules, which are not differentiated in *F. linearis* var. *obscurirete* (Broth. & Par.) Stone (Li et al., 2001). In addition, *F. wichurae* has narrower leaves with distinct limbidial cells in most leaves, while those of *F. linearis* var. *obscurirete* are restricted to perichaetial leaves (Suzuki and Iwatsuki, 2012a).

The Korean name was given as ‘Kal-ip-bong-hwang-i-kki’, based on its leaf shape.

Key to the species of subgen. *Fissidens* sect. *Semilimbium* in Korea

1. Laminal cells smooth *F. ganguleei*
1. Laminal cells mamilllose or papillose
 2. Laminal cells highly mamilllose or with 1(–2) indistinct papillae *F. crenulatus*
 2. Laminal cells with 4–6 papillae
 3. Costae ending below the apex
 4. Vaginant laminae unequal; peristome teeth undivided or incompletely divided ... *F. gardneri*
 4. Vaginant laminae more or less equal; peristome teeth clearly divided *F. pallidinervis*
 3. Costae percurrent to excurrent
 5. Upper leaves narrowly lanceolate, axillary hyaline nodules indistinct *F. linearis* var. *obscurirete*
 5. Upper leaves linear-lanceolate, axillary hyaline nodules weakly differentiated *F. wichurae*

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Conflict of Interest

The author declares that there are no conflicts of interest.

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Appendix 1. The list of *Fissidens* in Korea (*new to Korea).

No.	Taxa
Subgen. <i>Fissidens</i>	
Sect. <i>Fissidens</i>	
1	<i>Fissidens bryoides</i> Hedw.
2	<i>Fissidens bryoides</i> var. <i>esquirolii</i> (Thér.) Z. Iwats. & T. Suzuki*
3	<i>Fissidens bryoides</i> var. <i>lateralis</i> (Broth.) Z. Iwats. & Tad. Suzuki
4	<i>Fissidens bryoides</i> var. <i>ramosissimus</i> Thér.
5	<i>Fissidens crispus</i> Mont.*
6	<i>Fissidens curvatus</i> Hornsch.*
7	<i>Fissidens geppii</i> M. Fleisch.
8	<i>Fissidens gymnandrus</i> Buse*
9	<i>Fissidens incurvus</i> Starke ex Röhl*
10	<i>Fissidens longisetus</i> Griff.*
11	<i>Fissidens pusillus</i> (Wilson) Milde*
12	<i>Fissidens tosaensis</i> Broth.
13	<i>Fissidens viridulus</i> (Sw.) Wahlenb.*
Sect. <i>Polypodiopsis</i>	
14	<i>Fissidens enervis</i> Sim*
15	<i>Fissidens hyalinus</i> Wilson & Hook.
16	<i>Fissidens protonemaecola</i> Sakurai
Sect. <i>Aloma</i>	
17	<i>Fissidens closteri</i> subsp. <i>kiusiuensis</i> (Sakurai) Z. Iwats.*
18	<i>Fissidens flabellulus</i> Thwait. & Mitt.*
19	<i>Fissidens takayukii</i> Tad. Suzuki*
Sect. <i>Semilimbidium</i>	
20	<i>Fissidens cremulatus</i> Mitt.
21	<i>Fissidens ganguleei</i> Nork.*
22	<i>Fissidens gardneri</i> Mitt.
23	<i>Fissidens linearis</i> var. <i>obscurirete</i> (Broth. & Paris) I. G. Stone
24	<i>Fissidens pallidinervis</i> Mitt.
25	<i>Fissidens wichurae</i> Broth. & Fleisch.*
Subgen. <i>Neoamblyothallia</i>	
Sect. <i>Crispidium</i>	
26	<i>Fissidens crispulus</i> Brid.
27	<i>Fissidens crispulus</i> var. <i>robinsonii</i> (Broth.) Z. Iwats. & Z. H. Li
Subgen. <i>Pachyfissidens</i>	
28	<i>Fissidens adianthoides</i> Hedw.
29	<i>Fissidens anomalus</i> Mont.
30	<i>Fissidens dubius</i> P. Beauv.
31	<i>Fissidens geminiflorus</i> Dozy & Molk.
32	<i>Fissidens grandifrons</i> Brid.
33	<i>Fissidens gymnogynus</i> Besch.
34	<i>Fissidens involutus</i> var. <i>jejuensis</i> Y. J. Yoon, B. C. Tan & B. Y. Sun
35	<i>Fissidens nobilis</i> Griff.
36	<i>Fissidens osmundoides</i> Hedw.
37	<i>Fissidens taxifolius</i> Hedw.
38	<i>Fissidens teysmannianus</i> Dozy & Molk.