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THE GENUS *FISSIDENS* IN RUSSIA, II: *FISSIDENS NEOMAGOFUKUI* AND RELATED SPECIES

РОД *FISSIDENS* В РОССИИ, II: *FISSIDENS NEOMAGOFUKUI* И БЛИЗКИЕ ВИДЫ

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Abstract

A recently described from Japan *Fissidens neomagofukui* Z. Iwats. & Tad. Suzuki differs from most species of the genus in Russia by having a reduced peristome, which teeth are triangular and not divided into two filiform branches. It also has elimbate leaves and therefore has been placed by Suzuki in subgenus *Fissidens* sect. *Aloma*, i.e. unrelated to subgenus *Fissidens* sect. *Fissidens* that includes *F. bryoides* and related species. Molecular phylogenetic analysis found *F. neomagofukui* in a sister position with specimens which are quite similar to species of *F. bryoides*-group, having almost complete limbidium in all parts of leaf, a typical *bryoides*-type peristome, and a *bryoides*-type costa. This species differs from other morphotypes of *F. bryoides* in smaller, smooth laminal cells and almost obligatory epiphytic growth on hardwood trunks; it occurs in the southern part of Primorsky Territory of Russia. Finding no appropriate existing name, we describe it as *F. extremiorientalis* sp. nov. *Fissidens neomagofukui* is confirmed in Russia only for southern part of Primorsky Territory, where it is rare and also grows exclusively on tree trunks, sometimes mixed with *F. extremiorientalis*.

Резюме

Недавно описанный из Японии *Fissidens neomagofukui* Z. Iwats. & Tad. Suzuki отличается от большинства видов рода сильно редуцированным перистомом с треугольными зубцами, не разделенными на две узко линейные доли. Он также имеет не окаймленные листья, и поэтому Сузуки поместил его в подрод *Fissidens* sect. *Aloma*, виды которой не родственны таковым подрода *Fissidens* sect. *Fissidens,* которая включает *F. bryoides* и близкие к нему виды. Однако, согласно результатам молекулярно-филогенетического анализа, он образует кладу, сестринскую образцам, очень похожим на виды группы *F. bryoides*, поскольку они имеют кайму из узких клеток почти по всей длине и во всех частях листа, перистом *bryoides*-типа и жилку *bryoides*-типа. Этот вид отличается от других морфотипов *F. bryoides* более мелкими, гладкими клетками пластинки листа и почти облигатным ростом на стволах дубов и других лиственных деревьев; он встречается на юге Приморского края в России. Поскольку не удалось найти подходящее название для этого растения, мы описываем его как новый для науки вид *Fissidens extremiorientalis*. Произрастание в России *F. neomagofukui* было подтверждено только для юга Приморского края, где он очень редок и растет только на стволах деревьев, иногда вместе с *F. extremiorientalis*.

KEYWORDS: mosses, taxonomy, new species, nr ITS, Russia

Introduction

This paper continues an overview of the genus *Fissidens* in Russia, which diversity appeared to be underestimated in previous taxonomic treatments of this genus for its territory. A molecular phylogenetic analysis revealed a number of more or less defined clades; some of them represent morphologically distinct species, whereas other lack characters useful for species delimitation, or they have characters too difficult to apply for identification of most specimens. First publication considered *F. monguillonii*-group, which has not been reported from Russia earlier at all (Ignatov *et al*., 2023). The present paper is aimed to discuss another clade, which species where found to be related to each other, despite of rather contrastingly different morphology.

First of these species, *F. neomagofukui* Z. Iwats. & Tad. Suzuki, a small moss growing on tree trunks, has been described from Japan quite recently (Iwatsuki & Suzuki, 2002). It was reported for Russia by Bakalin *et al*. (2012) from Sakhalin, but this report was based on an erroneous identification of depauperate plants of *F. osmundoides* Hedw. In fact, *F. neomagofukui* was collected by Suzuki in Primorsky Territory in 2007, as a single small shoot (see below), but it remained unpub-

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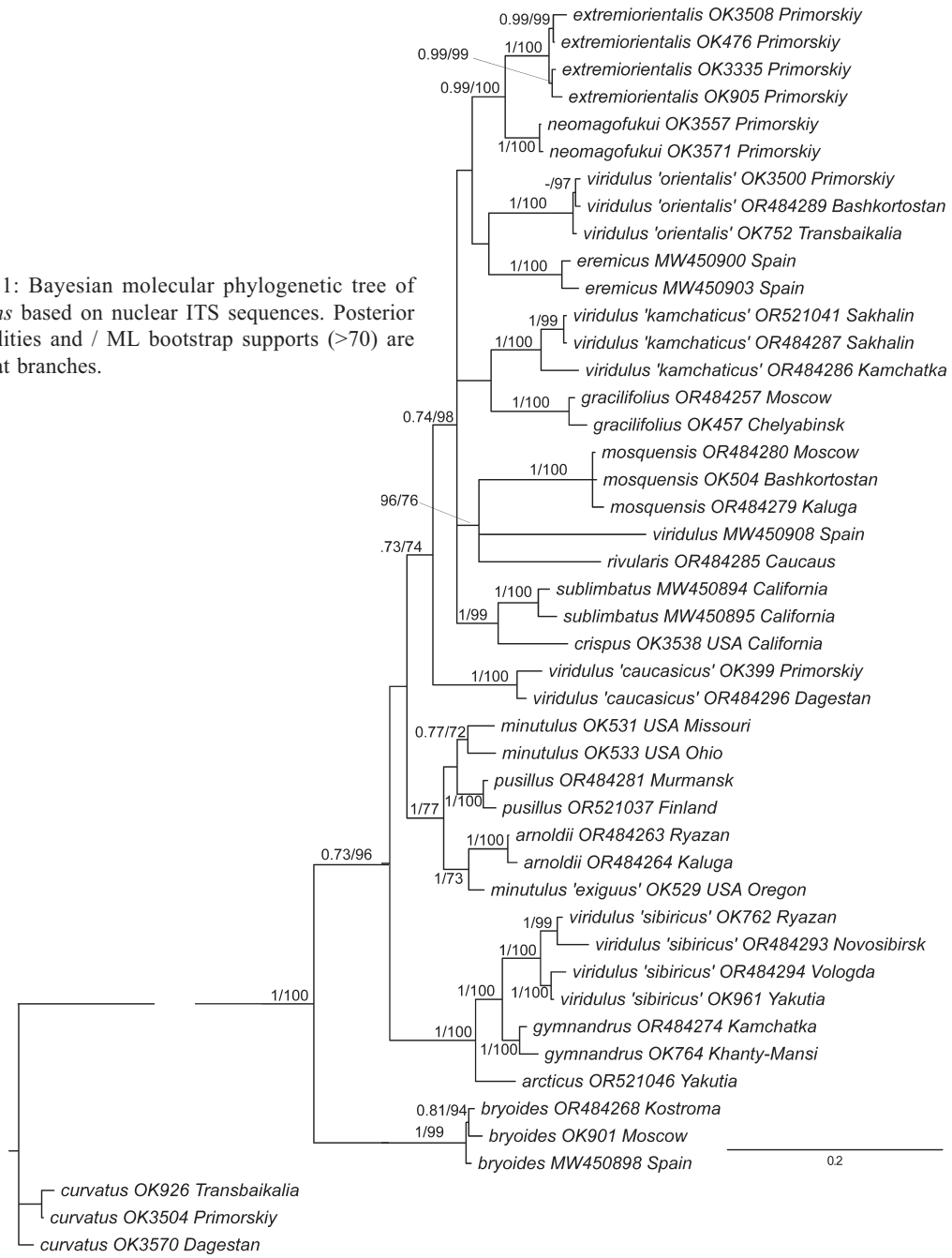

Fig. 1: Bayesian molecular phylogenetic tree of *Fissidens* based on nuclear ITS sequences. Posterior probabilities and / ML bootstrap supports (>70) are shown at branches.

lished and kept among questionable material, and thus overlooked in the checklist of the bryophytes of the Russian Far East (Cherdantseva *et al*., 2018).

The specimens resolved in a clade sister to *F. neomagofukui* are also epiphytic plants, but they have morphology similar to that of *F. bryoides* Hedw., *i.e.*, almost complete limbidium in all parts of leaves, typical *bryoides*-type peristome, and *bryoides*-type costa. The aim of the present study is to provide a taxonomic treatment for these two species.

MATERIAL AND METHODS

The molecular and morphological studies were conducted by the same methods and using the same facilities as in our previous study of the genus (Ignatov *et al.*, 2023).

Our large dataset of nr ITS sequences gathered for the sake to resolve the taxonomy of *Fissidens bryoides* complex in Russia was used so to delimit the smaller group and concentrate on its study. Similarly to a mentioned previous paper, we use here some informal names in quotes after *F. viridulus*. Their status will be discussed in details in further publications, while in the first part of the present series we gave a brief descriptions and illustrations for most of them (Ignatov *et al.*, 2023).

RESULTS

The molecular phylogenetic tree is shown in Fig. 1. It comprises a grade of clades with high to moderate support. The monospecific clades are mostly maximally or highly supported. Among the highly supported clades

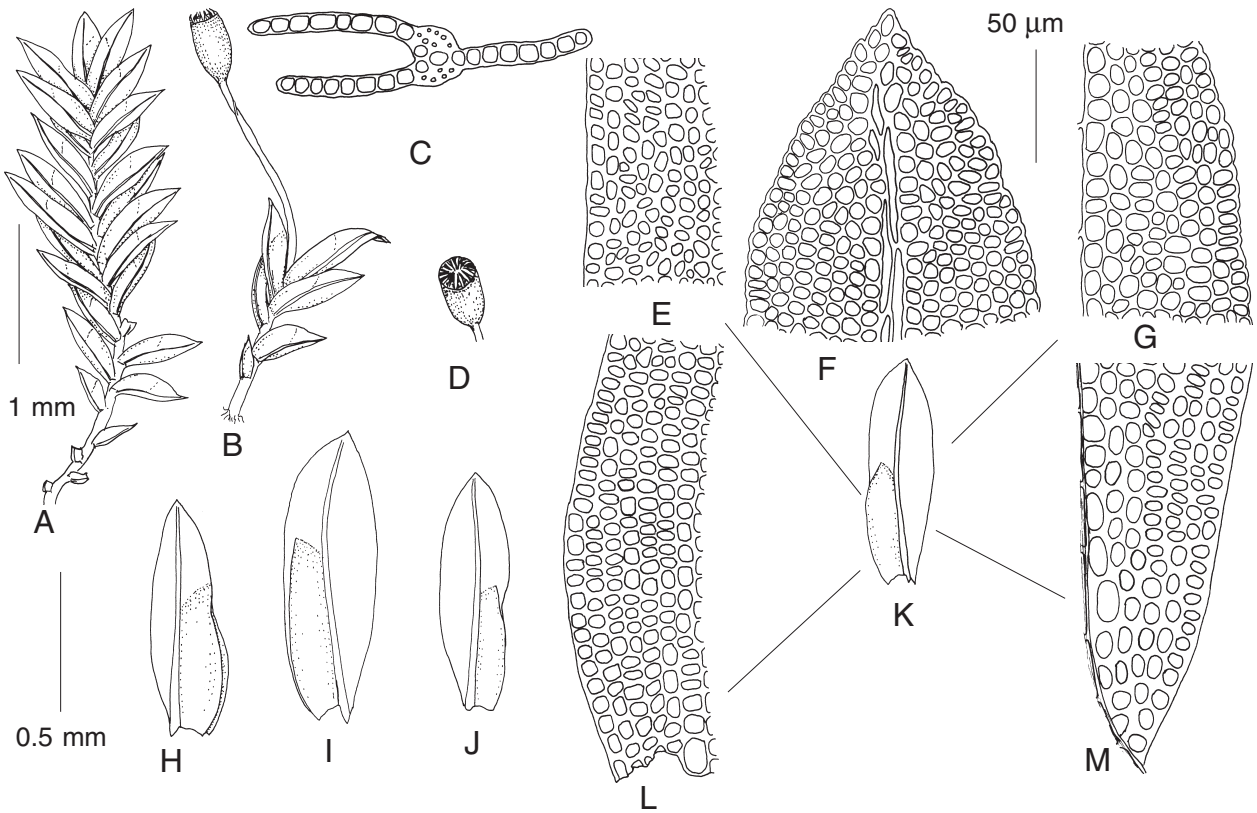

Рис. 2. *Fissidens neomagofukui* (from Russia, Primorsky Territory, *Malashkina & Ivanov Pr-8-10-13*, MHA). A: sterile plant, wet; B: plant with sporophyte, dry; C: leaf transverse section; D: capsule; E: median cells of vaginant lamina; F: cells of apical lamina; G: median cells of dorsal lamina; H–K: stem leaves; K: basal cells of vaginant lamina; M: lower cells of dorsal lamina. Scale bars: 1 mm for A–B, D; 0.5 mm H–K; 50 µm for C, E–G, L–M.

with more than two species are: 1) *F. arcticus+F. gymnandrus+F. viridulus* '*sibiricus*' (PP=1, BS=100); 2) *F. arnoldii+F. minutulis* '*exiguus*'*+F. minutulis* '*minutulis*'*+F. pusillus* (PP=0.99, BS=83); 3) *F. neomagofukui* + another species, which will be described below (PP=0.97, BS=95).

Since further discussion requires the names of these species, the taxonomy section preceeds here the discussion based on the obtained results.

Taxonomy

Fissidens neomagofukui Z. Iwats. & Tad. Suzuki, J. Hattori Bot. Lab. 92: 165, figs. 1 & 5a, b. 2002. Figs. 2–3.

Type: Japan, Honshu, Mie-ken, Iinan-gun, Iidaka-cho, Miyamae, Hanaoka Shrine, ca. 180 malt., on trunk of *Ginkgo,* base to 1 m above the ground, growing with *Fabronia matsumurae,* 18 July 1975, *T. Magohuku 16240* (NICH 149143, not seen).

Description (based on collections from Russia). *Plants* minute, growing on tree bark by separate shoots, green to yellow-green. *Stems* 0.5–1.5 mm long, not branched, with 4–10 pairs of overlapping or somewhat remote leaves; central strand not differentiated; axillary hyaline nodules inconspicuous. *Leaves* slightly curved to contorted when dry, erect-spreading when wet, angle with stem 40–50°, ovate to oblong, weakly asymmetrical, to 0.4–1.0 mm long and 0.1–0.3 mm wide, L/W 3.0–4.3, apex acute, angle 45–80°; dorsal lamina wedge-shaped, almost reaching the leaf base; margin of apical lamina crenulate, near leaf apex few cells serrulate; vaginant laminae 1/2–3/5 of the leaf length; costa in transverse section *bryoides*-type, ending few cells below leaf apex; cells of apical lamina quadrate to hexagonal, 5–10 µm, smooth; cells of vaginant lamina similar, cells near costa sometimes conspicuously enlarged; limbidium lacking. *Rhizoautoicous*. Archegonia terminal. *Perichaetial leaves* lanceolate, slightly narrower than stem leaves. *Setae* ca. l.5 mm. *Capsules* pale, ovoid, erect, symmetrical, 0.4–0.6 mm long. *Peristome* teeth red-orange, slightly recurved when dry, entire, without any apparent subdivision into branches, triangular, ca. 60–70 µm long, 20–25 µm wide at base, looking blunt due to fallen off uppermost fragile part, trabeculae on dorsal side prominent, low, dorsal surface of lamellae papillose above, with smaller low papillae below, almost smooth on venrtal side; exothecial cells rectangular, the number of exothecial cells around the capsule circumference ca. 40. *Spores* 17–20 µm [18–22 µm in Japanese collections], finely papillose. Opercula and calyptrae not seen.

Specimens examined: Russia, Primorsky Territory, Olga Distr., waterfall on Milogradovka Creek, 43°27.5'N, 134°19.3' E, 515 m alt., 21 Aug 2007 *T. Suzuki 31328* (NICH, dupl. MHA); Russia, Primorsky Territory, Partizansk Distr., Chandolaz, 43°01'N, 131°01' E, 100 m alt., on oak trunk, 9 Sept 2013 E.

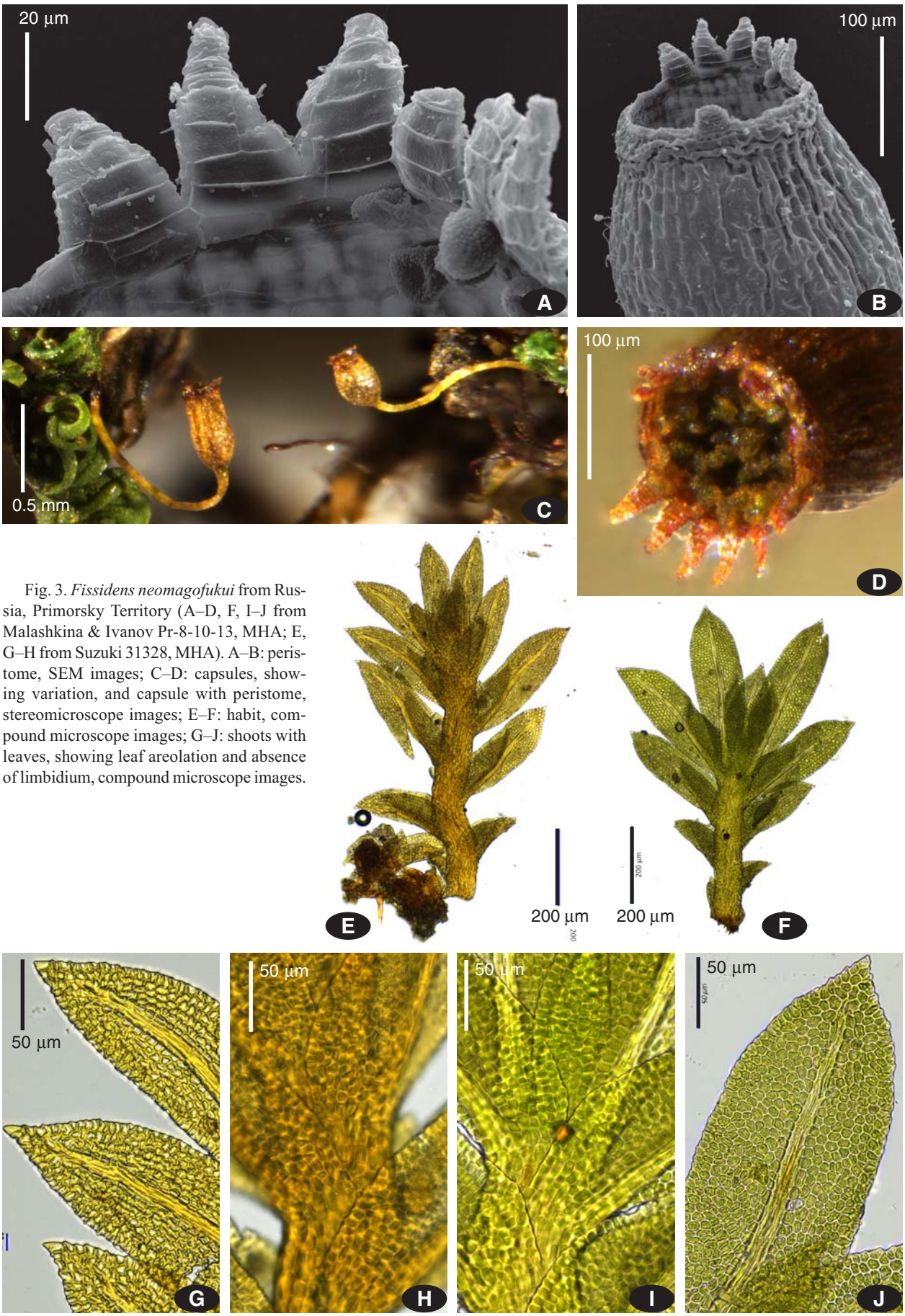

Fig. 3. *Fissidens neomagofukui* from Russia, Primorsky Territory (A–D, F, I–J from Malashkina & Ivanov Pr-8-10-13, MHA; E, G–H from Suzuki 31328, MHA). A–B: peristome, SEM images; C–D: capsules, showing variation, and capsule with peristome, stereomicroscope images; E–F: habit, compound microscope images; G–J: shoots with leaves, showing leaf areolation and absence of limbidium, compound microscope images.

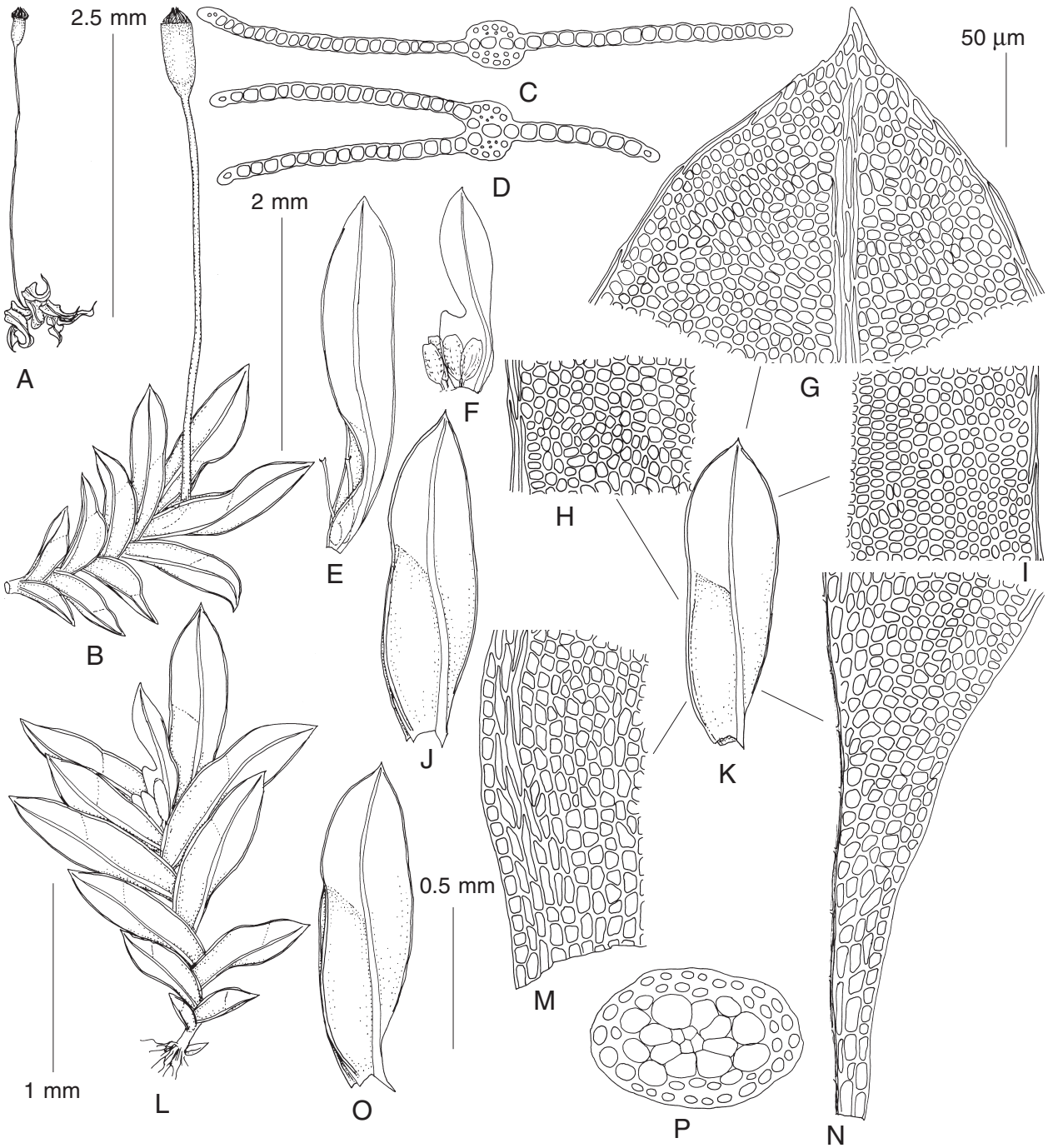

Рис. 4. *Fissidens extremiorientalis* (A–K, O–P: from holotype; L: from Primorsky Territory, *Ishchenko s.n.*, MHA). A, B: female plants with sporophytes; C: leaf transverse section in apical part; D: leaf transverse section through vaginant and dorsal laminae; E: perichaetial leaf with archegonia; F: perigonial leaf with antheridia; G: cells of apical lamina; H: median cells of vaginant lamina; I: median cells of dorsal lamina; J, K. O: leaves; L: male plant; M: lower cells of vaginant lamina; N: lower cells of dorsal lamina; P: stem transverse section. Scale bars: 2.5 mm for A; 2 mm for B; 1 mm for L; 0.5 mm for E, F, J, K, O; 50 µm for C–D, G–I, M–N, P.

Malashkina & O. Ivanov Pr-8-10-13 (MHA); isolates OK3557 & OK3571.

Distribution and ecology. All Russian collections were gathered from *Quercus* and *Tilia* trunks, where *F. neomagofukui* grew together with species of the genera *Anomodon, Herpetineuton, Frullania*, etc. It was collected at low elevation in the southern part of Primorsky Territory.

Distinction. A combination of strongly modified peristome with undivied teeth and elimbate leaf margins is unknown in any other species of the genus known in Russia, and the comparison with any of them would be totally superfluous.

There is a difference between Russian and Japanese plants in size: the former are smaller, with leaves being sometimes only 0.1 mm wide (Fig. 3E, F), whereas the

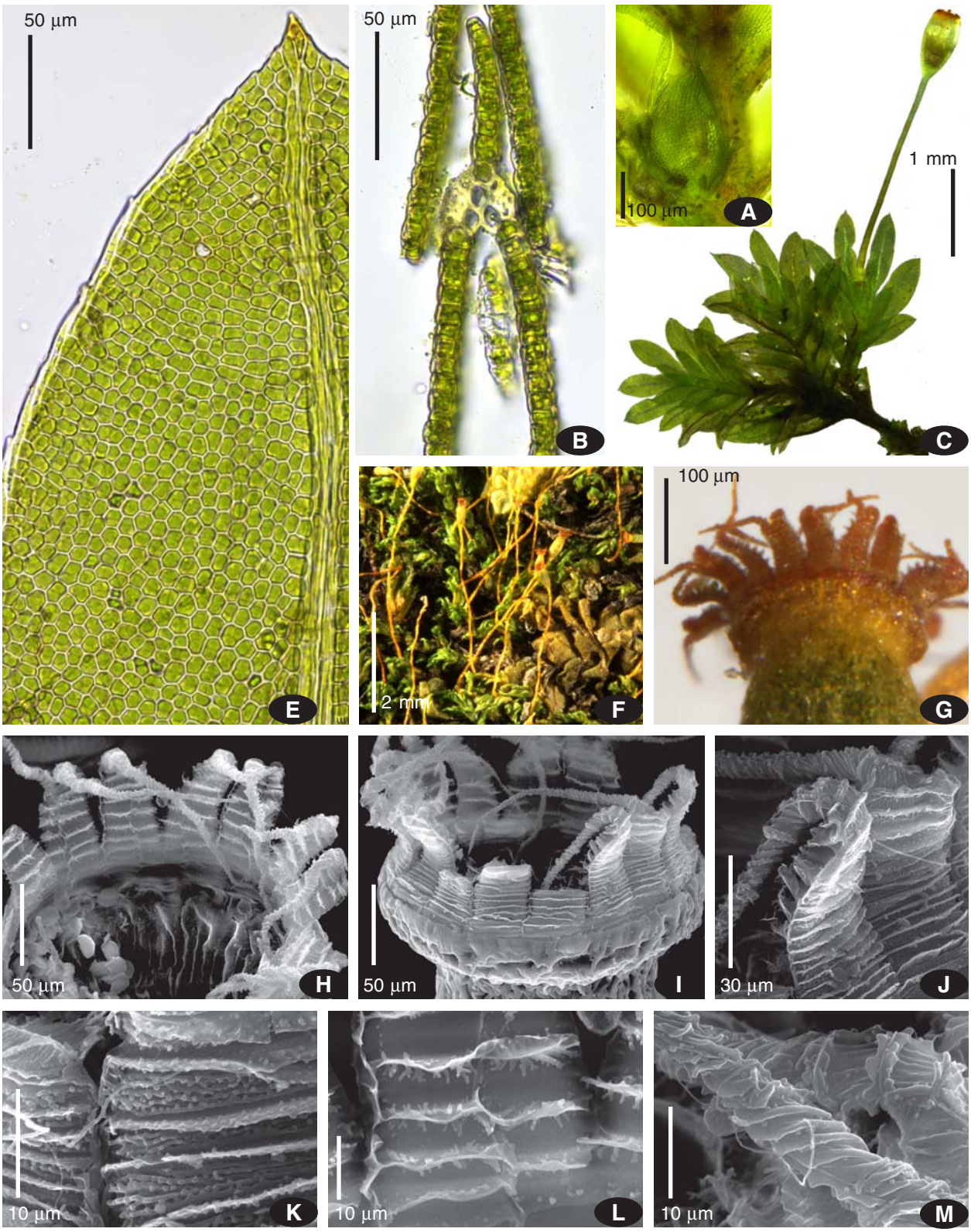

Fig. 5. *Fissidens extremiorientalis* (from Russia, Primorsky Territory, *Kolesnikova 19-27*, MHA). A: dwarf male plant; B: leaf transverse sections showing *bryoides*-type costa; C: plant with sporophyte; E: upper leaf portion; F: habit of plants, dry; G:–I: perisrome; J: side view of peristome teeth; K: lower portion of peristome teeth, dorsal view; L: lower portion of peristome tooth, ventral view; M: divided portion of peristome, dorsal side of branches. A–B, E: compound microscope images; C, F, G: stereomicroscope images; H–M: SEM images.

protologue describes them as 0.2–0.3 mm wide; however, leaves of such size occur in some specimens from Russia, too (e.g., Fig. 2H). Peristome teeth in collections from Russia are also shorter. They are entire in collections from Russia and Japan, but split to the base in Indian plants recently referred to *F. neomagofukui* (Daniels *et al.*, 2017). The identity of Indian specimens with Japanese plants needs in confirmation; moreover, the spores in Indian plants are reported as 24–28 μm, i.e., larger than in Japanese and Russian specimens.

When the sequence data revealed the closest relationship between *F. neomagofukui* from the Russian Far East and another epiphytic plant of more or less typical *Fissidens bryoides* morphology, we suspected an error and re-extracted and re-sequenced the material three times, finally understanding that this is not an error. We failed to find a proper existing name for the species resolved as sister to *F. neomagofukui*, so it is described below as a new species.

Fissidens extremiorientalis Ignatov & Ignatova, sp. nov. Figs. 4–5.

Type: Russia, Primorsky Krai, Botanical Garden Institute, Far Eastern Branch of the RAS, 43°12'N – 131°59'E, on *Tilia* trunk. 25.IX.2019 coll. M.A. Kolesnikova 19-27. Holotype MHA. DNA isolate OK3508.

Description. *Plants* small, growing as separate shoots or in loose tufts, intense light green to yellowish-green. *Stems* 0.5–1.5 mm long, simple to copiosely branched, with 5–12 pairs of overlapping leaves; central strand differentiated; axillary hyaline nodules moderately conspicuous. *Leaves* slightly curved to contorted when dry, erect-spreading when wet, angle with stem 30–50°, ovate to oblong, usually asymmetrical, to 0.9–1.4 mm long and 0.3–0.4 mm wide, L/W 2.8–4.5, apex acute, angle 60–95°; dorsal lamina wedge-shaped, almost reaching the leaf base; margins serrulate near apex, entire below; vaginant laminae 1/2–3/5 of the leaf length; costa in transverse section of *bryoides*-type, ending few cells below leaf apex; cells of apical lamina 6–10(–12)×7–10 μm, quadrate, hexagonal or transversely rectangular, irregular in shape, smooth; cells of vaginant lamina irregular in shape, 5–15×8–11 μm; limbidium apparent in all leaf parts excepting ca. 5 distalmost cells, uniseriate, 1–2-stratose, at base of vaginant lamina separated from margin by 1–2 rows of subquadrate cells (intramarginal). *Dioicous or phyllodioicous*. Male plants similar in size to female ones or dwarf at female plants, perigonial leaves constricted above its broadened basal portion. Archegonia terminal and occasionally lateral in axils of 1–2 leaves below perichaetial leaves, to 320 μm long. *Perichaetial leaves* lanceolate, slightly narrower than stem leaves, up to 1.4 mm long. *Setae* 2.5–3.5 μm. *Capsules* brownish, ovoid-cylindric, erect, symmetrical, urns 0.4–0.5 mm long, constricted below mouth. *Opercula* conic or rostrate. *Peristome bryoides*-type, teeth red-orange, incurved when wet, straight when dry at their basal parts, in the middle divided into two alsmost equal filiform branches, ca. 180 μm long, 35 μm wide at base, on dorsal side striolate-papillose below, dorsal trabeculae prominent, high; on the ventral side with spiculose papillae only on high ventral trabeculae and smooth between trabeculae; filiform distal branches with dense spiral crisrae. *Spores* 12–16 μm, finely papillose. *Calyptrae* not seen.

Specimens examined: Russia, Primorsky Territory, Partizansk Distr., Chandolaz, 43°01'N, 131°01' E, 100 m alt., on oak trunk, 9 Sept 2013 *Malashkina & Ivanov Pr-8-10-13a* [mixed with *F. neomagofukui*] (MHA); isolate OK905; Vladivostok, Botanical Garden-Institute, tree base, coll. Malashkina 8 May 2013 (MHA), isolate OK476; Ussurijsky Nature Reserve, Komarovka Creek, *Ishchenko 33*, 2022 (MHA), isolate OK3335.

Distinctions. *Fissidens extemiorientalis* can be distinguished from very variable *F. viridulus* by a combination of small cells (in sympatric morphs of *F. viridulus* cells are usually over 10 μm in apical and dorsal laminae) and well developed, constantly present limbidium. *F. viridulus* 'orientalis', the most common morph of *F. viridulus* in that area, has poorer developed limbidium, which often disappears in proximal part of distal lamina excepting 2–3 upper leaf pairs; it has autoicous, synoicous or rhizoautoicous sexual condition, and grows on rocks and soil, not on tree trunks, as *F. extremiorientalis*.

Small cells are characteristic feature of *Fissidens schmidtii* Müll. Hal. (*Fissidens bryoides* var. *schmidii* (Müll. Hal.) Chopra & Kumar). However, this species has even smaller cells, which are distinctly convex, and its leaves are in 10–28 pairs. Moreover, this is a tropical plant, growing on wet calcareous rocks. The fact, that this taxon was reported from Japan only from limestones and never has sporophytes, makes its conspecifity with *F. extremiorientalis* highly unlikely.

Fissidens bryoides var. *ramosissimum* (Ther.) Z. Iwats. & Tad. Suzuki has a similarity with *F. extremiorientalis* in occasionally copiose branching (Fig. 5C), but it is synoicous or polyoicous, cells in apical lamina are somewhat larger, 5–12(–14) μm vs. 6–10(–12) μm, and this is mainly an epilithic species.

Discussion

Suzuki & Iwatsuki (2007) assigned *F. neomagofukui* to the section *Semilimbidium* Müll. Hal. based on its Moenkemeyera-type peristome. Suzuki (2015) placed it in the subgen. *Fissidens* sect. *Aloma* (Kindb.) Müll. Hal. because of non-*bryoides* peristome type and absence of limbidium [subgenus *Polypodiopsis* (Müll. Hal.) Broth. according to Bruggeman-Nannenga, 2022]. However, the analysis of two chloroplast loci, rbcL and rps4 provided by Suzuki *et al.* (2018) resolved it among the species of subgen. *Fissidens* sect. *Fissidens*. Plastid marker rbcL (LC271989) appeared to be most similar to *F. monguillonii* Thér., *F. coacervatus* Brugg.-Nann., and *F. bryoides*; rps4 region (LC272043) showed an equal distance to the

most closely related *F. schmidii, F. incurvus* Starke ex Röhl., *F. diversifolius* Mitt., *F. coacervatus,* and *F. bryoides*. Our results support the conclusion of Suzuki *et al.* (2018) and also point a most closely related species, which, however, has a drastically different morphology and, first of all, different peristome structure.

Moss peristomes are responsible for efficient spore release and therefore they are usually fairly stable within moss taxa, being maintained by natural selection. Their importance for moss classification is comparable with that of flower for Angiosperms. Most taxa at the level of families, orders and classes were recognized based on peristome structure (Brotherus, 1924, 1925; Vitt, 1983).

At the same time, in pleurocarpous mosses perisome structure was strongly overestimated. The subdivision of Pleurocarps into two big groups, the Isobryales (Leucodontales) and the Hypnobryales (Hypnales), which was widely accepted in 20th century, was overturned by molecular systematics (Buck *et al.*, 2001; Tsubota *et al*., 2004). It became clear that the transition to epiphytic growth causes peristome simplicication, or reduction. Only in the Brachytheciaceae the molecular data revealed as many as 13 cases of such transitions (Huttunen *et al*., 2004).

Pursell & Bruggeman-Nannenga (2004) noted that anomalous peristomes are fairly common in corticolous species. Bruggeman-Nannenga (2022) also mentioned that corticolous species with reduced peristomes are mostly concentrated in subgen. *Polypodiopsis* sect. *Antennidens* (Müll. Hal.) Paris and subgen. *Neoamblyothallia* Tad. Suzuki & Z. Iwatsuki, whereas aquatic species with reduced peristomes usually belong to the subgen. *Fissidens*. However, *F. neomagofukui*, a corticolous species with reduced peristome, appeared to be most closely related to a species from subgen. *Fissidens* sect. *Fissidens*, having morphological characters of *F. bryoides*-group. Apparently the origin of such species has not been so far a subject of special consideration because of a deficiency of molecular data. It seems quite likely that the pair of *Fissidens extemiorientales* and *F. neomagofukui* comprises a case of a relatively rapid specialization to epiphytic growth, which consequences in the latter species proceeded much deeper than in the former one. The paucity of observations precludes an extended discussion on this matter. However, we would like to highlight this possibility, which might be better described by examples of other groups in the genus *Fissidens*.

Interestingly, in case of *F. neomagofukui* the changes in peristome structure are associated with the complete reduction of limbidium. The latter is more commonly observed in hydrophilous species, e.g. in *F. arnoldii*.

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Appendix 1. Voucher data and GenBank accession numbers for newly sequenced specimens of *Fissidens*.

Species	Isolate	Locality	Voucher data	ITS, GenBank acc. number
F. extremiorientalis	OK 476	Russia: Primorsky Territory	Malashkina, s.n. 8 May 2013, MHA	OR961017
F. extremiorientalis	OK 905	Russia: Primorsky Territory	Malashkina Pr-8-10-13, MHA	OR961018
F. extremiorientalis	OK 3335	Russia: Primorsky Territory	Ishchenko 3.3 MHA	OR961019

F. extremiorientalis	OK 3508	Russia: Primorsky Territory	Kolesnikova 19-27, MHA	OR961020
F. neomagofukui	OK 3557	Russia: Primorsky Territory	Malashkina Pr-8-10-13a, MHA	OR961021
F. neomagofukui	OK 3571	Russia: Primorsky Territory	Malashkina Pr-8-10-13b, MHA	OR961022
F. viridulus 'orientalis'	OK 3500	Russia: Primorsky Territory	Malashkina et al. Pr-01-1-13, MHA	OR961023
F. viridulus 'orientalis'	OK752	Russia: Zabaikalsky Territory	Afonina 7706, MHA (dupl. from LE)	OR961024
F. gracilifolius	OK457	Russia: Chelyabinsk Province	Ibatullin 004, 28 July 2011, MHA	OR961025
F. mosquensis	OK 504	Russia: Bashkortostan	Zolotov 10-85, MHA	OR961026
F. crispus	OK 3538	U.S.A.: California	Shevock 24537, NY00171880	OR961027
F. viridulus 'caucasicus'	OK 399	Russia: Primorsky Territory	Ignatov s.n., 7 Sept 2006, MHA	OR961028
F. minutulus	OK 531	U.S.A.: Missouri	Buck 18110, NY00304490	OR961029
F. minutulus	OK 533	U.S.A.: Ohio	Buck 50357, NY00829680	OR961030
F. exiguus	OK 529	U.S.A.: Pennsylvania	Buck 49268, NY06729646	OR961031
F. viridulus 'sibiricus'	OK 762	Russia: Ryazan Province	Volosnova s.n., 10 July 2013, MHA	OR961032
F. viridulus 'sibiricus'	OK 961	Russia: Yakutia	Ignatov s.n. 8 Sept 2000, MHA	OR961033
F. gymnandrus	OK 764	Russia: Khanty-Mansi Autonomous District	Pisarenko, op01903, MHA (dupl. from NSK)	OR961034
F. bryoides	OK 901	Russia: Moscow Province	Ignatov s.n. 23 July 1986, MHA	OR961035
F. curvatus	OK 926	Russia: Zabaikalsky Territory	Czernyadjeva s.n. 16 July 2012, MHA (dupl. from LE)	OR961036

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