

日本新産となる地衣生菌Skyttella mulleriについて

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Note (資料)

Skyttella mulleri, a lichenicolous fungus new to Japan

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日本新産となる地衣生菌 *Skyttella mulleri* について

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Here we report morphological observations and phylogenetic analysis of *Skyttella mulleri*, a lichenicolous fungus newly recorded from Japan. It forms white to pale yellow apothecia abundantly on the thallus of *Peltigera* sp. The apothecia are formed on the upper cortex of the host thallus, become translucent when wet, and lack an exciple. Phylogenetic analysis of the large subunit of the nuclear ribosomal RNA gene suggested that this fungus belongs to *Cordieritidaceae* (*Helotiales*).

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Key Words—*Ascomycota*, *Cordieritidaceae*, *Helotiales*, *Peltigera*, Taxonomy

The genus *Skyttella* D. Hawksw. & R. Sant. includes two lichenicolous fungi, *S. mulleri* and *S. stictae*. The former has been reported to occur on the thallus of *Peltigera* spp., and the latter on that of *Sticta* sp. (Etayo 2017; Lawrey and Diederich 2018), and neither species has been recorded from Japan. *Skyttella* has been assigned to *Cordieritidaceae* without evidence for its phylogenetic position (Jaklitsch et al. 2016). In this paper, we report morphological characteristics and the result of our molecular phylogenetic analysis of sequences of the large subunit rRNA gene of *Skyttella mulleri* collected from Japan.

Microscopic structures were studied in squashed as-

comata (for asci, ascospores, and paraphyses) or hand sections (for hymenium and subhymenium). The photos of the fresh materials in the field were taken with an iPhone 8 (Apple Inc. USA). The size of ascomata was measured under a stereo microscope (SMZ 1500, Nikon, Japan). The paraphyses were mounted in 3% KOH solution to soften the tissue and facilitate clear observation of the basal part, and the length was measured. The other dimensions were measured mounted in water. An amyloid reaction of asci was studied using Lugol's solution after pretreatment in 3% KOH. Microscopic images were taken using a microscope (Olympus BHS) with an iPhone 8, or a microscope (Leica DMLB) equipped with a digital camera (EOS Kiss X5, Canon, Japan). NPlan objectives (with

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Leica DMLB) or DPlan objectives (with Olympus BHS) (40× for hymenium and subhymenium; 100× for asci, ascospores, and paraphyses) were used for observation and documentation. Dimensions were measured using ImageJ software (<http://rsbweb.nih.gov/ij/>). All specimens examined were deposited in the Osaka Museum of Natural History (OSA; Osaka, Japan).

Genomic DNA was extracted from fresh materials according to the protocol of Izumitsu et al. (2012). Polymerase chain reaction (PCR) was performed using KOD FX Neo DNA polymerase (Toyobo, Osaka, Japan). The primer pair ITS1F (Gardes and Bruns 1993) and LR5 (Vilgalys and Hester 1990) was used to amplify sequences of the internal transcribed spacer (ITS) and the large subunit (LSU) of the nuclear ribosomal RNA gene (nrDNA). PCR cycling conditions were 95°C for 5 min; 10 cycles of 98°C for 10 s, 55–50°C (decreasing 0.5°C per cycle) for 30 s, and 68°C for 1 min 30 s; 30 cycles of 98°C for 10 s, 50°C for 30 s, and 68°C for 1 min 30 s; and held at 4°C. The PCR products were purified by polyethylene glycol (PEG) precipitation and sequenced by the Fasmac sequencing service (Kanagawa, Japan) using the primers LR0R (Rehner and Samuels 1994) and LR5 for the D1/D2 region of LSU. The newly obtained sequences were deposited with the International Nucleotide Sequence Database Collaboration (INSDC) through the DNA Data Bank of Japan (DDBJ).

For phylogenetic analysis, 43 LSU sequences of *Helotiales* (including 35 taxa in *Cordieritidaceae*, three in *Cenangiaceae*, three in *Sclerotiniaceae/Rutstroemiaceae*, and two in *Dermateaceae* as outgroup according to Johnston et al. (2019)) were retrieved from the NCBI databases (<https://www.ncbi.nlm.nih.gov/>) and included in the phylogenetic analysis (Table 1). DNA sequences were aligned using MAFFT v.7 online service (Katoh et al. 2019; Kuraku et al. 2013) using default parameters. The aligned sequences were manually refined using SeaView v.5.0.4 (Gouy et al. 2010). The optimum substitution models were estimated using ModelTest-NG (Darrriba et al. 2020) and TrN+I+G 4 model was selected based on the lowest BIC (Bayesian Information Criterion) score. Phylogenetic analysis was performed for LSU sequence under maximum likelihood (ML) criteria, using RAxML-NG v1.0.3 (Kozlov et al. 2019). Bootstrap support was calculated based on 1,000 replicates.

Skyttella mulleri (Willey) D. Hawksw. & R. Sant., *Graphis Scripta* 2: 34, 1988.

Mycobank no.: MB 134443.

Fig. 1

Basionym: *Phacopsis mulleri* Willey, *Enum. Lich. New Bedford*: 34, 1892.

Ascomata apothecia, sessile, convex, superficial, circular to lenticular, occasionally confluent, waxy, translucent when moist, white to pale yellow, (0.1–)0.2–0.5(–1.0) mm diam., immarginate. **Exciple** absent. **Hymenium** (47–)54–72(–79) μm thick. **Subhymenium** (15–)18–29 μm thick, composed of irregularly shaped cells, (2.9–)3.8–7.4(–10) × (2.1–)2.5–4.3(–5.7) μm. **Paraphyses** hyaline, septate, simple or sympodially branched at the base, (36–)46–64(–73) × (2.6–)3.0–4.0(–4.4) μm, cell wall thickened, embedded in gelatinous matrix. **Asci** clavate, 8-spored, (30–)31–38(–43) × (7.8–)8.7–11(–12) μm, thin-walled, pore-like indentation present at the apex, contents of mature asci occasionally stained reddish orange in Lugol's solution after pretreatment with 3% KOH. **Ascospores** irregularly arranged in the asci, hyaline, narrowly ellipsoid, the apices rounded, aseptate, smooth-walled, often guttulate, (8.0–)9.9–13(–15) × (1.7–)2.4–3.2(–3.6) μm. **Specimens examined**: Japan, Kyoto, Kuramakibunouchou, on thalli of *Peltigera* sp. growing on bryophytes over rock or timber, 10 Jan 2023, T. Moriyama TM 057 [OSA-MY-9549]; ditto, 19 Jan 2023, T. Moriyama TM065 [OSA-MY-9550], INSDC accession number: LSU = LC 779668; ditto, on a thallus of *Peltigera* sp. growing on bryophytes on rock surface, 19 Apr 2023, T. Moriyama TM145 [OSA-MY-9551].

Habit and Habitat: Ascomata occur on the upper side of the thallus of *Peltigera* sp. growing on bryophytes over rock or timber of a conifer near a river in a forest.

Japanese name: Hadare-yuki-yadori (“*hadare-yuki*” = Snow piled up in speckles, referring to the whitish and translucent ascomata, “*yadori*” = a parasite, for the lichicolous habit of this species).

Distribution: Europe and North America (Hawksworth and Santesson 1988), Asia (Zhurbenko et al. 2019).

Notes: Morphological characters from our specimens agreed with the original description, although the following point is worth mentioning. In the original report by Hawksworth and Santesson (1988), the authors merely described apothecia of this species as erumpent from

Table 1. Taxa used in the phylogenetic analysis and their GenBank accession numbers

Species	Family	Voucher	LSU	Reference
<i>Ameghiniella australis</i>	<i>Cordieritidaceae</i>	KL391	KX090841	Pärtel et al. (2017)
<i>Annabella australiensis</i>	<i>Cordieritidaceae</i>	AD283531	MK328476	Fryar et al. (2019)
<i>Cordierites frondosa</i>	<i>Cordieritidaceae</i>	HKAS41508	AY789354	Wang et al. (2005)
<i>Cordierites guianensis</i>	<i>Cordieritidaceae</i>	192	EU107270	Peterson and Pfister (2010)
<i>Cordieritidaceae</i> sp.	<i>Cordieritidaceae</i>	G.M. 2014-12-06.2	MZ052130	Marson unpub.
<i>Diplocarpa bloxami</i>	<i>Cordieritidaceae</i>	KL317	KX090834	Pärtel et al. (2017)
<i>Diplocarpa constans</i>	<i>Cordieritidaceae</i>	HKAS 124025	ON668100	Su et al. (2022)
<i>Diplocarpa irregularis</i>	<i>Cordieritidaceae</i>	KL154	KX090804	Pärtel et al. (2017)
<i>Diplolaevopsis</i> cf. <i>ranula</i>	<i>Cordieritidaceae</i>	Diederich 16989	KJ559554	Suija et al. (2015)
<i>Diplolaevopsis ranula</i>	<i>Cordieritidaceae</i>	NBM FL-14388	KP984785	Etayo et al. (2015)
<i>Encoelia heteromera</i>	<i>Cordieritidaceae</i>	KL164	KX090809	Pärtel et al. (2017)
<i>Encoelia heteromera</i>	<i>Cordieritidaceae</i>	195	EU107233	Peterson and Pfister (2010)
<i>Hyphodiscus stereicola</i>	<i>Cordieritidaceae</i>	TU 104241	FN995636	Pärtel and Pöldmaa (2011)
<i>Hyphodiscus stereicola</i>	<i>Cordieritidaceae</i>	TU 107690	FR686966	Pärtel and Pöldmaa (2011)
<i>Ionomidotis fulvotingsens</i>	<i>Cordieritidaceae</i>	KL231	KX090819	Pärtel et al. (2017)
<i>Ionomidotis olivascens</i>	<i>Cordieritidaceae</i>	KL301	KX090833	Pärtel et al. (2017)
<i>Lawreyella lobariella</i>	<i>Cordieritidaceae</i>	KRAM: A.F. 25157	MT153979	Flakus et al. (2019)
<i>Llimoniella gregorellae</i>	<i>Cordieritidaceae</i>	Vondrák 8374	KJ559569	Suija et al. (2015)
<i>Llimoniella gregorellae</i>	<i>Cordieritidaceae</i>	CBFS JV9954	KJ559553	Suija et al. (2015)
<i>Llimoniella</i> sp.	<i>Cordieritidaceae</i>	Diederich 17525	KJ559555	Suija et al. (2015)
<i>Llimoniella terricola</i>	<i>Cordieritidaceae</i>	LL95	KX090842	Pärtel et al. (2017)
<i>Macroskyttea parmotremitis</i>	<i>Cordieritidaceae</i>	UGDA	KP984788	Etayo et al. (2015)
<i>Protounguicularia nephromatis</i>	<i>Cordieritidaceae</i>	A.F.26297	MT153988	Flakus et al. (2019)
<i>Rhizocladopodium argillaceum</i>	<i>Cordieritidaceae</i>	CBS 241.67	EU040240	Crous et al. (2007)
<i>Rhymbocarpus fuscoatrae</i>	<i>Cordieritidaceae</i>	Ertz 16200	KJ559571	Suija et al. (2015)
<i>Sabahriopsis eucalypti</i>	<i>Cordieritidaceae</i>	CBS 139906	MH878669	Vu et al. (2019)
<i>Skyttea gregaria</i>	<i>Cordieritidaceae</i>	NY0118113	KJ559559	Suija et al. (2015)
<i>Skyttea lecanorae</i>	<i>Cordieritidaceae</i>	Ertz 16099	KJ559574	Suija et al. (2015)
<i>Skyttea lecanorae</i>	<i>Cordieritidaceae</i>	NY1595972	KJ559561	Suija et al. (2015)
<i>Skyttea pyrenulae</i>	<i>Cordieritidaceae</i>	Ertz 16253	KJ559575	Suija et al. (2015)
<i>Skyttea radiatilis</i>	<i>Cordieritidaceae</i>	NY00977030	KJ559558	Suija et al. (2015)
<i>Skyttella mulleri</i>	<i>Cordieritidaceae</i>	OSA-MY-9550	LC779668	This study
<i>Thamnogalla crombiei</i>	<i>Cordieritidaceae</i>	Diederich 17553	KJ559557	Suija et al. (2015)
<i>Unguiculariopsis lettaui</i>	<i>Cordieritidaceae</i>	TU64867	KJ559566	Suija et al. (2015)
<i>Unguiculariopsis thallophila</i>	<i>Cordieritidaceae</i>	TU45703	KJ559565	Suija et al. (2015)
<i>Unguiculariopsis thallophila</i>	<i>Cordieritidaceae</i>	Diederich 16944	KJ559573	Suija et al. (2015)
<i>Sclerotinia sclerotiorum</i>	<i>Sclerotiniaceae</i>	NBRC 109858	LC429380	Johnston et al. (2019)
<i>Lambertella corni-marit</i>	<i>Rutstroemiaceae</i>	TNS:F-40083	AB926139	Hosoya et al. unpub.
<i>Rutstroemia firma</i>	<i>Rutstroemiaceae</i>	KL290	KX090830	Pärtel et al. (2017)
<i>Chlorencoelia versiformis</i>	<i>Cenangiaceae</i>	KL21	KX090795	Pärtel et al. (2017)
<i>Heyderia abietis</i>	<i>Cenangiaceae</i>	OSC60392	AY789289	Wang et al. (2005)
<i>Trochila craterium</i>	<i>Cenangiaceae</i>	CBS:146632	MT363246	Crous et al. (2020)
<i>Neofabraea malicorticis</i>	<i>Dermateaceae</i>	OSC 100036	AY544662	AFTOL unpub.
<i>Pezicula carpinea</i>	<i>Dermateaceae</i>	CBS 282.39	DQ470967	Spatafora et al. (2006)

the host thalli and did not provide anatomical information. In our observation, primordia of ascomata (Fig. 2 B) occurred on the surface of the host thallus. At the early stage of the ascomatal development, the upper cortex was not damaged compared to the intact one (Fig. 2 A). Hyphae intruding the upper cortex of the host thallus were observed only at the central part of the fully mature ascomata (Fig. 2C, D). Examination of more specimens from

different locations will be required to determine whether the site of ascomatal development in/on the host tissue is stable and whether this difference is affected by the genetic basis.

As the result of the phylogenetic analysis (Fig. 3), *S. mulleri* was suggested to belong to *Cordieritidaceae* with high bootstrap support (BS = 100%), although the relationship with other members of this family remains unre-

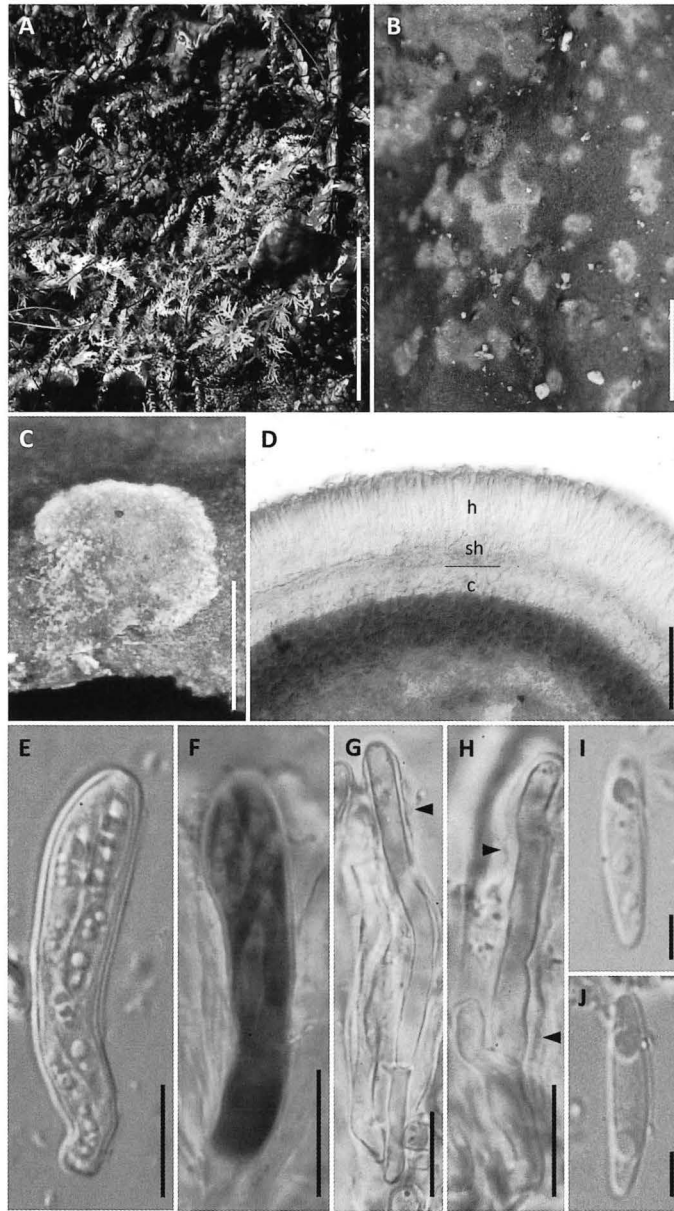


Fig. 1. *Skyttella mulleri*. A: Apothecia abundantly formed on the thallus of *Peltigera* sp. in the field. B: Air-dried apothecia on the host thallus. C: Wet apothecium. D: Cross section of apothecium (in water; h: hymenium, sh: subhymenium, c: the upper cortex of the host thallus). The line indicates the border between the apothecia and the upper cortex of the host thallus. E: Ascus (in water). F: Ascus in Lugol's solution after pretreatment with 3% KOH. G, H: Paraphyses (in 3% KOH). Arrowheads indicate the gelatinous matrix surrounding the paraphyses. I, J: Ascospores (in water). B, C, E, I, J: OSA-MY-9550; A, D, F–H: OSA-MY-9551. Bars: A 2 cm; B 1 mm; C 500 μ m; D 100 μ m; E–H 10 μ m; I, J 3 μ m.

solved. Besides *S. mulleri*, *Cordieritidaceae* includes many lichenicolous fungi, such as *Skyttea gregaria* and *Lawreyella lobariella* (Sherwood et al. 1980; Flakus et al. 2019).

This study newly added *S. mulleri* to the list of lichenicolous fungi of this family with phylogenetic data.

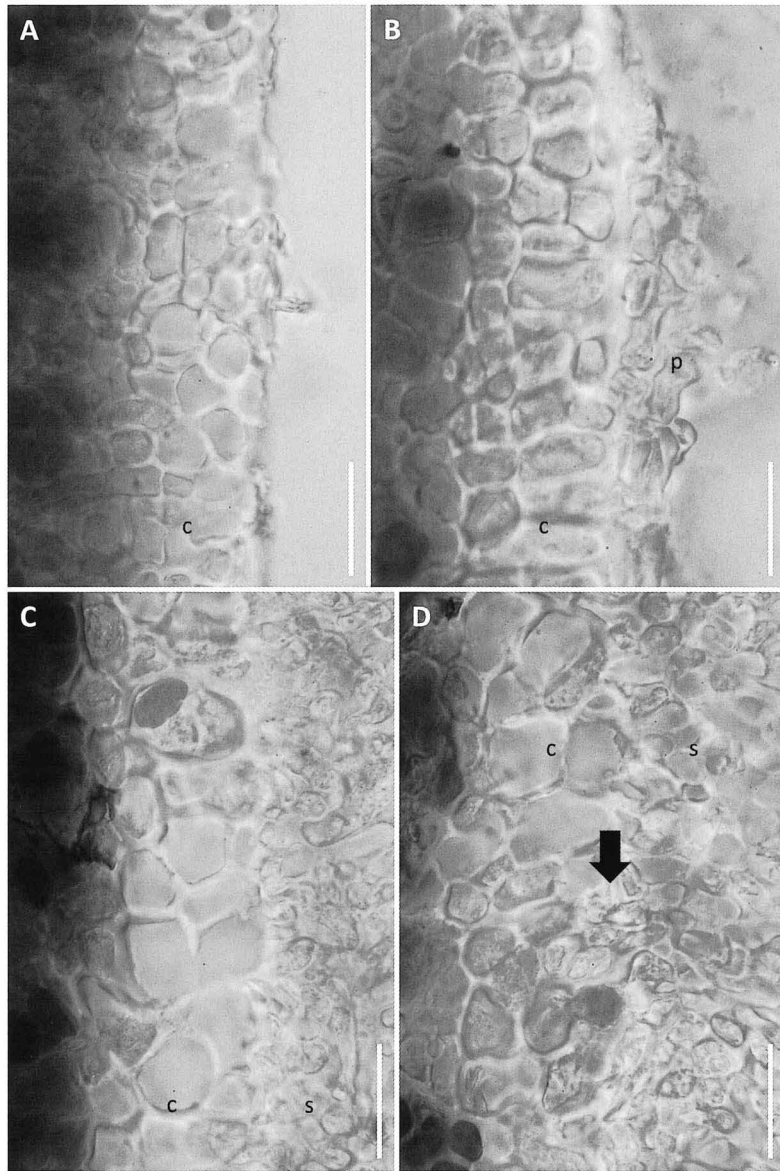


Fig. 2. Ascomatal development of *Skyttella mulleri* [OSA-MY-9551]. A: The upper cortex (c) of an intact thallus of *Peltigera* sp. B: The primordium of ascomata (p) of *S. mulleri* on the upper cortex of the host thallus. Note that the primordium occurs on the upper cortex of the host thallus. C, D: The border between the subhymenium (s) of the ascomata of *S. mulleri* and the upper cortex (c) of the host thallus. The arrow in D points to the part that the hyphae of *S. mulleri* intrude the upper cortex of the host thallus. Bars: 10 μ m.

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摘要

日本新産となる地衣生菌 *Skyttella mulleri* (ハダレユキヤドリ, 新称) について, その形態ならびに分子系統解析結果を報告する. 本種は宿主となるツメゴケ属菌 (*Peltigera* spp.) の地衣体上に無柄で円形からレンズ形, 白色から淡黄色の子嚢果を豊富に形成する. 子嚢果は宿

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