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Species Identification Based on DNA of Selected Mushrooms from Myanmar (1) *Lactarius austrotorminosus* and 17 Other Taxa Newly Reported from Myanmar

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Abstract A total of 33 specimens (22 species) of mushrooms collected from Myanmar were characterized and identified to species based on morphological observation and DNA barcoding using the internal transcribed spacer (ITS) region of nuclear ribosomal DNA newly generated for this study. The ITS sequences of many Myanmar materials showed significant similarity (99% or higher) to the existing data in GenBank, but some had much lower similarity, warranting further, more rigorous taxonomic studies. Results from the BLAST search indicated that the countries of origin of the top hits varied. Although the majority of Myanmar materials showed close affinities with materials from the adjacent areas, such as Thailand, India or China, some materials had significant similarity in ITS sequences with those from geographically distant areas, such as Argentina and French Guiana. A total of 18 species, including *Lactarius austrotorminosus*, are newly reported from Myanmar.

Keywords: Agaricomycota, Agaricomycetes, BLAST, biogeography, Dacrymycetes, distribution, fungi, internal transcribed spacer, inventory, Southeast Asia.

Introduction

To clarify fauna and flora (including fungi) of Myanmar and the surrounding areas, a joint research team of National Museum of Nature and Science, Japan, and Forest Research Institute, Myanmar has been conducting biological inventories in Myanmar since 2016. As a result, the first comprehensive field guidebook of flora and fauna (including fungi) has been published (Tanaka, 2021). The guidebook contains colored photographs and morphological descriptions of selected species, and a total of 25 species of mushrooms are illustrated.

Little is known for mushroom diversity in Myanmar. The most comprehensive list of mushrooms in Myanmar was published by Thaung (2007), listing ca. 180 species. Since then, no intensive surveys on mushrooms have been conducted until 2016. Since the beginning of the joint research project described above, more than 400 additional specimens of mushroom were collected, including some new records from Myanmar (Hosaka *et al.*, 2019, 2020). Mushroom inventory in Myanmar is still at very preliminary stage and many new records and species remain to be described.

While the publication of the first field guidebook containing fungi is a significant event, the book does not cover the molecular characterization of mushrooms from Myanmar. Because many mushroom species cannot easily be distin-

guished each other by morphological characters alone, comparing them by DNA sequence data is crucial. For example, Hosaka *et al.* (2020) demonstrated that materials of *Sphaerobolus* from Myanmar are morphologically indistinguishable from the existing species, but they clearly represent a new species in the genus by analyzing DNA sequences of mitochondrial and nuclear genes.

In this study, we characterized a total of 22 species of mushrooms covered in the field guidebook (Hosaka and Linn, 2021) based on newly generated DNA Hosaka and Linn of the internal transcribed spacer (ITS) region of nuclear ribosomal DNA.

Materials and Methods

Collecting and Curation of Specimens

A total of 33 specimens used in this study were collected during the years 2016–2017 from various locations in Myanmar. The samples were photographed under natural light in the field and then wrapped with aluminum foil for transport to the laboratory. In the laboratory, the samples were photographed again using artificial lighting and more in-depth macroscopic observation was conducted. The samples were dried with low heat and good air circulation using a food dehydrator for 24 hours.

In addition to dried materials, small fragments (ca. 3 cubic millimeters each) of clean, sterile tissue from freshly collected materials were cut using a clean razor blade. Contamination of visible soil particles and other materials was carefully avoided. The tissue fragments were soaked in dimethyl sulfoxide (DMSO) buffer (Seutin *et al.*, 1991) with an addition of 100 mM Tris-HCl (pH 8.0) and 0.1 M sodium sulfite (Na_2SO_3), and they were stored at room temperature until further molecular experiment became possible, following the procedures of Hosaka (2009) and Hosaka and Castellano (2008).

All specimens collected during the fieldwork were deposited at Forest Research Institute, Myanmar, and the duplicate at the herbarium of the National Museum of Nature and Science (TNS), Tsukuba, Japan. All tissue samples were stored in freezers (−80°C) at the Center for Molecular Biodiversity Research, National Museum of Nature and Science.

DNA Preparation, PCR, and Sequencing

DNA was extracted from the tissue fragments stored in DMSO buffer. Tissues were ground under liquid nitrogen using a mortar and pestle. DNA extractions used a modified cetyltrimethylammonium bromide (CTAB) extraction followed by glass milk purification methods as summarized by Hosaka (2009) and Hosaka and Castellano (2008).

DNA sequence data were obtained from the ITS region. The primer combination of ITS5 and ITS4 (White *et al.*, 1990) was used for PCR amplifications. PCR reactions were carried out using 20 µl reaction volumes each containing: 1 µl genomic DNA, 1 µl dNTPs (4 mM), 1 µl of each primer (8 µM), 0.5 units of Taq polymerase (TaKaRa, Tokyo, Japan), 2 µl MgCl2 (25 mM), 2 µl bovine serum albumin (BSA). PCR reactions were performed using the following parameters: 95°C for 3 min; 35 cycles of 95°C for 1 min, 51°C for 45 sec, 72°C for 1 min; and 72°C for 15 min.

PCR products were electrophoresed in 1% agarose gels stained with ethidium bromide and visualized under UV light. When amplification bands were confirmed, PCR products were then purified using the ExoSap-IT (Millipore, Molsheim, France) and directly sequenced using the Big Dye Terminator Cycle Sequencing Kit on ABI3500 (Applied Biosystems Inc., Foster City, CA, USA), following the manufacturer's instructions.

Molecular Analyses

The obtained raw sequences were edited using ATGC version 7.1.0 (GENETYX Corporation, Tokyo, Japan). All edited ITS sequences were first complied into a single FASTA file, and they were then analyzed using the GenBank basic local alignment search tool (BLAST) search

(Zhang *et al.*, 2000) to confirm their phylogenetic affinities with registered taxa. Default settings of blastn option, including "Standard databases (nr etc.)" with "Nucleotide collection (nr/nt)" optimized for "Highly similar sequences (megablast)," were used. All major scores resulted from the BLAST search, e.g., "Total Score", "Query Cover" and "Per. Ident," were recorded along with taxon names and the countries of origin of the top hits. When the top hits did not have information on specific epithet or the country of origin, data from the next highest hit were also recorded. BLAST search was conducted on February 2, 2021. After the BLAST results were obtained, the distribution records of each species (including synonyms) were searched using the Global Biodiversity Information Facility (GBIF) database (GBIF, 2021) and the occurrence data were downloaded to compare with literature.

Results and Discussion

Molecular Identification of Specimens

Results from the BLAST search using the blastn option with default settings mostly corroborated the validity of our field identification of the species (Tables 1 and 2). A total of 30 out of 33 sequences showed percent identities of 97% or higher with the registered data. The two sequences identified as *Craterellus atratus* (KH-MYA16-168) and *Fistulina hepatica* (KH-MYA16-057) showed percent identities of 96.26% and 96.98%, respectively. The lowest percent identity was 92.3% for the collection tentatively identified as *Turbinellus floccosus* (KH-MYA16-017).

For this study, we have applied the species names obtained from the top hits of the BLAST search (Table 1). However, many taxa are likely to contain multiple biological species. Furthermore, we have not confirmed taxonomic identity of the registered data based on voucher specimens. It is therefore advisable that taxon names used in this study are treated as tentative ones, and more rigorous taxonomic studies should be conducted in the future.

The countries of origin of the top BLAST hits indicated that many have close affinities with materials from Southeast Asia, South Asia and East Asia (Table 2). Thailand was represented by a total of 7 sequences, followed by China (5) and India (3). Some sequences from distantly located regions were also represented as the top hit, including *Geastrum schweinitzii* (Argentina), *Phallus merulinus* (French Guiana) and *Psathyrella candolleana* (Nigeria). No significant hits were observed from materials from Australia and North America. These results indicate a close affinity of the Myanmar mycoflora with that of Asia, especially Southeast Asia. However, the degree of taxon sampling is significantly different across species and countries, and therefore the results should be interpreted with caution.

Specimens Molecularly Identified in this Study

A total of 33 specimens were identified to species based on morphological observation and ITS sequences. Because morphological characters were described in detail by Hosaka and Linn (2021), we hereby provide the information on collection and molecular data along with the distribution records of each species.

Amanita ceciliae (Berk. & Broome) Bas

Material examined: Myanmar: Mandalay, Than Daung Village near Pyin Oo Lwin (21.851267, 96.374177), alt. 985 m, under *Quercus* spp., 31 Aug 2016, K. Hosaka (KH-MYA16-100).

Type locality: United Kingdom.

Remarks: The species is generally considered widely distributed in the Northern Hemisphere (Imazeki and Hongo, 1987; Hosaka and Linn, 2021), which is corroborated by the GBIF records (GBIF, 2021), showing specimen records from North America, Europe, Japan and Taiwan, but not from Southeast Asia. The ITS sequence of material from Myanmar (KH-MYA16-100) showed 99.62% identity with that of Japanese specimen (Table 2), and they can be considered conspecific. This is the first record of the species from Myanmar.

Table 1. Mushrooms of Myanmar molecularly identified to species

ID*1	Taxon names	Voucher nos.*2	Accession nos.*3
1	*Amanita ceciliae* (Berk. & Broome) Bas	KH-MYA16-100	MW577302
2	*Craterellus atratus* (Corner) Yomyart, Watling, Phosri, Piap. & Sihan.	KH-MYA16-168	MW577303
3	*Dacryopinax spathularia* (Schwein.) G.W. Martin	KH-MYA16-051	MW577304
4	*Favolaschia calocera* R. Heim	KH-MYA16-026	MW577305
5	*Fistulina hepatica* (Schaeff.) With.	KH-MYA16-057	MW577306
6	*Geastrum courtecuissei* P.-A. Moreau & C. Lécuru	KH-MYA16-040	MW577307
7	*Laccaria vinaceoavellanea* Hongo	KH-MYA16-063	MW577308
8	*Laccaria vinaceoavellanea* Hongo	KH-MYA16-101	MW577309
9	*Laccaria vinaceoavellanea* Hongo	KH-MYA16-106	MW577310
10	*Lactarius austrotorminosus* H.T. Le & Verbeken	KH-MYA16-023	MW577311
11	*Lactifluus piperatus* (L.) Roussel	KH-MYA16-048	MW577312
12	*Lactifluus volemus* (Fr.) Kuntze	KH-MYA16-117	MW577313
13	*Lentinus sajor-caju* (Fr.) Fr.	KH-MYA16-004	MW577314
14	*Lentinus sajor-caju* (Fr.) Fr.	KH-MYA17-046	MW577315
15	*Lentinus squarrosulus* Mont.	KH-MYA16-003	MW577316
16	*Lentinus squarrosulus* Mont.	KH-MYA16-077	MW577317
17	*Lentinus squarrosulus* Mont.	KH-MYA16-140	MW577318
18	*Leucocoprinus birnbaumii* (Corda) Singer	KH-MYA17-043	MW577319
19	*Leucocoprinus birnbaumii* (Corda) Singer	KH-MYA17-077	MW577320
20	*Neonothopanus nambi* (Speg.) R.H. Petersen & Krisai	KH-MYA17-031	MW577321
21	*Phallus merulinus* (Berk.) Cooke	KH-MYA17-064	MW577322
22	*Pisolithus albus* (Cooke & Massee) Priest	KH-MYA17-119	MW577323
23	*Psathyrella candolleana* (Fr.) Maire	KH-MYA16-012	MW577324
24	*Psathyrella candolleana* (Fr.) Maire	KH-MYA16-085	MW577325
25	*Psathyrella candolleana* (Fr.) Maire	KH-MYA16-121	MW577326
26	*Pycnoporus sanguineus* (L.) Murrill	KH-MYA16-053	MW577327
27	*Russula virescens* (Schaeff.) Fr.	KH-MYA16-045	MW577328
28	*Schizophyllum commune* Fr.	KH-MYA16-013	MW577329
29	*Schizophyllum commune* Fr.	KH-MYA16-094	MW577330
30	*Schizophyllum commune* Fr.	KH-MYA17-038	MW577331
31	*Schizophyllum commune* Fr.	KH-MYA17-112	MW577332
32	*Trogia infundibuliformis* Berk. & Broome	KH-MYA17-033	MW577333
33	*Turbinellus floccosus* (Schwein.) Earle ex Giachini & Castellano	KH-MYA16-017	MW577334

*1 The numbers are corresponding to those of Table 2.

*2 All specimens have been deposited under the same voucher numbers both in Japan (TNS) and Myanmar (Forest Research Institute).

*3 The GenBank accession numbers of the ITS sequences newly generated for this study are shown.

Craterellus atratus (Corner) Yomyart, Watling, Phosri, Piap. & Sihan.

Material examined: Myanmar: Mandalay, near Pyin Oo Lwin (21.954638, 96.384396), alt. 929 m, under *Quercus* spp., 1 Sept 2016, K. Hosaka (KH-MYA16-168).

Type locality: Brazil.

Remarks: The species has been reported from Brazil (Corner, 1966), Guyana (Wilson *et al.*, 2012; GBIF, 2021), and Thailand (Yomyart *et al.*, 2012). The ITS sequence of material from Myanmar (KH-MYA16-168) showed 96.26% identity with that of Thai specimen (Table 2), and they can be considered conspecific. However, due to their disjunct distribution pattern, the conspecificity of South American and Southeast Asian materials warrants further studies. This is the first record of the species from Myanmar. In addition, *Craterellus* was not reported by Thaung (2007), and therefore, it could be the first record of the genus from Myanmar.

Dacryopinax spathularia (Schwein.) G.W.Martin

Material examined: Myanmar: Mandalay, Baw Reserve Forest No. 85 near Pyin Oo Lwin (21.908162, 96.541085), alt. 969 m, on hardwood, 29 Aug 2016, K. Hosaka (KH-MYA16-051).

Type locality: United States of America.

Table 2. BLAST results of the ITS sequences generated from materials of Myanmar

ID*1	BLAST top hit*2	Total Score*3	QueryCover (%)*3	E Value*3	Per.Ident (%)*3	Accession nos. *4	Country of origin*5
1	Uncultured fungus/*Amanita ceciliae*	959/959	99/99	0/0	99.62/99.62	AB015694	Japan
2	*Craterellus atratus*	1122	100	0	96.26	AB445115	Thailand
3	*Dacryopinax spathularia*	883	97	0	98.6	AJ537397	Indonesia
4	*Favolaschia calocera*	1349	98	0	99.59	MW462898	India
5	*Fistulina hepatica*	1332	98	0	96.98	KY474052	n.s./China
6	*Geastrum courtecuissei*	1009	94	0	99.46	KF988437	Argentina
7	Uncultured *Laccaria*/*L. vinaceoavellanea*	1109/1109	100/100	0/0	99.83/99.83	AB777480/AB453023	Thailand
8	*Laccaria* sp./*L. vinaceoavellanea*	1245/1138	98/91	0/0	99.14/98.9	MN585661/KJ411955	China/India
9	*Laccaria* sp./*L. vinaceoavellanea*	1125/1050	100/96	0/0	100/98.98	MN585660/KJ411955	China/India
10	*Lactarius austrotorminosus*	1330	100	0	99.86	EF141533	Thailand
11	*Lactarius piperatus*	1166	100	0	97.12	KF220042	Belgium
12	*Lactarius volemus*	1197	99	0	99.85	HQ318260	Thailand
13	*Lentinus sajor-caju*	1223	100	0	99.55	KP283492	Malaysia
14	*Lentinus sajor-caju*	1234	100	0	99.7	KP283492	Malaysia
15	*Lentinus squarrosulus*	1254	100	0	100	KT273373	Nigeria
16	*Lentinus* sp./*L. squarrosulus*	1096/1092	100/100	0/0	100/99.83	KJ654561/MG719283	Indonesia/India
17	*Lentinus squarrosulus*	1212	99	0	99.55	JQ868749	India
18	*Leucocoprinus birnbaumii*	1279	100	0	99.15	MW191767	New Zealand
19	*Leucocoprinus birnbaumii*	1286	99	0	97.74	MH861267	Japan
20	*Neonothopanus nambi*	1327	100	0	99.19	JN571729	Vietnam
21	*Phallus merulinus*	935	100	0	99.61	MF372141	French Guiana
22	*Pisolithus albus*	1155	99	0	100	JQ365190	Thailand
23	*Psathyrella candolleana*	1103	100	0	99.18	KT273355	Nigeria
24	*Psathyrella candolleana*	1131	100	0	99.52	KY940508	China
25	*Psathyrella candolleana*	1199	99	0	99.85	KH940508	China
26	*Pycnoporus sanguineus*	1158	98	0	99.84	FJ372672	Thailand
27	*Russula* cf. *virescens*	1142	98	0	97.06	MT333231	China
28	*Schizophyllum commune*	1164	100	0	100	MK647986	South Africa
29	*Schizophyllum commune*	1170	99	0	100	MH857808	n.s./India
30	*Schizophyllum commune*	1166	100	0	100	MN341837	South Korea
31	*Schizophyllum commune*	1151	100	0	99.84	MH857808	n.s./India
32	*Trogia infundibuliformis*	1242	99	0	98.72	MW504969	Thailand
33	*Turbinellus floccosus*	1083	97	0	92.3	KJ411951	India

*1 The numbers are corresponding to those of Table 1.

*2 Taxon names of the BLAST top hits, followed by those of the next highest hits with specific epithet, if applicable, are shown.

*3 Values of the BLAST top hits, followed by those of the next highest hits with species level identification, if applicable, are shown.

*4 GenBank nucleotide accession numbers of the BLAST top hits, followed by those of the next highest hits with species level identification, if applicable, are shown.

*5 The countries of origin of the BLAST top hits, followed by those of the next highest hits, if applicable.

Remarks: The species is generally considered widespread (Hosaka and Linn, 2021), and the GBIF records (GBIF, 2021) showed its distribution in all major continents except for Antarctica. The ITS sequence of material from Myanmar (KH-MYA16-051) showed 98.6% identity with that of Indonesian specimen (Table 2). Higher diversity of *Dacryopinax* and related genera were recently discovered (Shirouzu *et al.*, 2009) and the taxonomic status of Myanmar material warrants further studies. The species has previously been recorded from Thailand (Chandrasrikul *et al.*, 2008) and Myanmar (Thaung, 2007).

Favolaschia calocera R.Heim

Material examined: Myanmar: Mandalay, Pyin Oo Lwin, National Kandawgyi Garden (21.992546, 96.471205), alt. 1114 m, on hardwood, 28 Aug 2016, K. Hosaka (KH-MYA16-026).

Type locality: Madagascar.

Remarks: Although it has not been proven yet, the species is thought to have originated in Madagascar (McMullan-Fisher *et al.*, 2014), and materials from Australia and New Zealand are generally considered exotic. The GBIF records (GBIF, 2021) showed its distribution in Europe, Taiwan, Southeast Asia (Laos) and widely in the Southern Hemisphere. The ITS sequence of material from Myanmar (KH-MYA16-026) showed 99.59% identity with that of Indian specimen (Table 2). This is the first record of the species from Myanmar.

Fistulina hepatica (Schaeff.) With.

Material examined: Myanmar: Mandalay, Baw Reserve Forest No. 85 near Pyin Oo Lwin (21.908162, 96.541085), alt. 969 m, on *Quercus* sp., 29 Aug 2016, K. Hosaka (KH-MYA16-057).

Type locality: Germany.

Remarks: The species is generally considered widespread (Imazeki and Hongo, 1989; Hosaka and Linn, 2021), and the GBIF records (GBIF, 2021) showed its worldwide distribution in all continents except for Antarctica. Although no records of the species from Southeast Asia except for the Philippines are available from the GBIF (GBIF, 2021), Chandrasrikul *et al.* (2008) reported it from Thailand. The ITS sequence of material from Myanmar (KH-MYA16-057) showed 96.98% identity with that of Chinese specimen (Table 2). This is the first record of the species from Myanmar.

Geastrum courtecuissei P.-A.Moreau & C.Lécuru

Material examined: Myanmar: Mandalay, Pyin Oo Lwin, National Kandawgyi Garden (21.992546, 96.471205), alt. 1114 m, under bamboo, 28 Aug 2016, K. Hosaka (KH-MYA16-040).

Type locality: Guadeloupe.

Remarks: The species has originally been described as *G. schweinitzii* (Hosaka and Linn, 2021), but its sequence corresponds to the paratype of *G. courtecuissei* (Accioly *et al.*, 2019). The ITS sequence of material from Myanmar (KH-MYA16-040) showed 99.46% identity with that of Argentinian specimen (Table 2), and they can be considered conspecific despite their long geographical distance from each other. This is the first record of the species from Myanmar and outside of Central and South America, i.e., Argentina and Guadeloupe (Accioly *et al.*, 2019).

Laccaria vinaceoavellanea Hongo

Materials examined: Myanmar: Mandalay, Baw Reserve Forest No. 85 near Pyin Oo Lwin (21.908162, 96.541085), alt. 969 m, under *Quercus* sp., 29 Aug 2016, K. Hosaka (KH-MYA16-063); Mandalay, Than Daung Village near Pyin Oo Lwin (21.851267, 96.374177), alt. 985 m, under *Quercus* sp., 31 Aug 2016, K. Hosaka (KH-MYA16-101); Mandalay, Than Daung Village near Pyin Oo Lwin (21.842197, 96.402772), alt. 963 m, under *Quercus* sp., 31 Aug 2016, K. Hosaka (KH-MYA16-106).

Type locality: Japan.

Remarks: The species has been reported from Japan, Korea, New Guinea (Imazeki and Hongo, 1987), China (Wang *et al.*, 2004), and Southeast Asia (Laos and Malaysia) (GBIF, 2021). The ITS sequences of materials from Myanmar showed at least 98.9% identity with those of Chinese, Indian or Thai materials (Table 2), and they can

be considered conspecific. This is the first record of the species from Myanmar. In addition, *Laccaria* was not reported by Thaung (2007), and therefore, it could be the first record of the genus and the family Hydnangiaceae from Myanmar.

Lactarius austrotorminosus H.T.Le & Verbeken

Material examined: Myanmar: Mandalay, Pyin Oo Lwin, National Kandawgyi Garden (21.992546, 96.471205), alt. 1114 m, under broadleaf trees, 28 Aug 2016, K. Hosaka (KH-MYA16-023).

Type locality: Thailand.

Remarks: The species was originally reported from Thailand (Le *et al.*, 2007; GBIF, 2021), but it has more recently been discovered from South Korea (Lee *et al.*, 2018). The ITS sequence of material from Myanmar (KH-MYA16-023) showed 99.86% identity with that of Thai specimen (Table 2), and they can be considered conspecific. The type materials were collected under *Castanopsis* (Le *et al.*, 2007), but the collection locality in Myanmar was dominated by a variety of broadleaf trees and *Pinus* spp., and the presence of *Castanopsis* was not confirmed (Hosaka *et al.*, 2019).

Lactifluus piperatus (L.) Roussel

Material examined: Myanmar: Mandalay, Baw Reserve Forest No. 85 near Pyin Oo Lwin (21.908162, 96.541085), alt. 969 m, under *Quercus* sp., 29 Aug 2016, K. Hosaka (KH-MYA16-048).

Type locality: Sweden [neotypified by De Crop *et al.* (2014)].

Remarks: The species is generally considered widespread in temperate regions of the Northern Hemisphere (Hosaka and Linn, 2021 as "*Lactarius piperatus* (L.) Pers."), but there are also some records from Australia (Imazeki and Hongo, 1989; GBIF, 2021) and Southeast Asia (Chandrasrikul *et al.*, 2008; GBIF, 2021). The ITS sequence of material from Myanmar (KH-MYA16-048) showed 97.12% identity with that of Belgium specimen (Table 2). This is the first record of the species from Myanmar.

Lactifluus volemus (Fr.) Kuntze

Material examined: Myanmar: Mandalay, Shwe Kyaung Village near Pyin Oo Lwin (21.801094, 96.419242), alt. 911 m, under *Quercus* sp., 31 Aug 2016, K. Hosaka (KH-MYA16-117).

Type locality: Sweden [epitypified by Van de Putte *et al.* (2016)].

Remarks: The species is generally considered widespread in temperate regions of the Northern Hemisphere [Imazeki and Hongo, 1989; Hosaka and Linn, 2021 as "*Lactarius volemus* (Fr.) Fr."], but there are also some scattered records from Australia (GBIF, 2021). The species has been reported from Thailand (Chandrasrikul *et al.*, 2008) and China (Wang *et al.*, 2004), and the ITS sequence of material from Myanmar (KH-MYA16-117) showed 99.85% identity with that of Thai specimen (Table 2). It is the first record of the species from Myanmar.

Lentinus sajor-caju (Fr.) Fr.

Materials examined: Myanmar: Yangon, Kan Daw Gyi Lake (16.798038, 96.164525), alt. 35 m, on hardwood, 27 Aug 2016, K. Hosaka (KH-MYA16-004); Bo Cho Island (10.673655, 98.246158), alt. 70 m, on hardwood, 19 May 2017, K. Hosaka (KH-MYA17-046).

Type locality: Old tropics but could not be identified with certainty.

Remarks: The species has been reported widely distributed in tropical and subtropical regions of the world, including Africa, Australia, and Southeast Asia, but it appears uncommon in South America (GBIF, 2021). The ITS sequences of materials from Myanmar showed at least 99.55% identity with those of Malaysian material (Table 2), and they can be considered conspecific. The species has previously been recorded from Thailand (Chandrasrikul *et al.*, 2008) and Myanmar (Thaung, 2007).

Lentinus squarrosulus Mont.

Materials examined: Myanmar: Yangon, Kan Daw Gyi Lake (16.798038, 96.164525), alt. 35 m, on hardwood, 27 Aug 2016, K. Hosaka (KH-MYA16-003); Mandalay, Baw Reserve For-

est No. 85 near Pyin Oo Lwin (21.905359, 96.533851), alt. 968 m, on hardwood, 29 Aug 2016, K. Hosaka (KH-MYA16-077); Myanmar: Mandalay, near Pyin Oo Lwin (21.767522, 96.415126), alt. 884 m, on sclerotia, 31 Aug 2016, K. Hosaka (KH-MYA16-140).

Type locality: Old tropics but could not be identified with certainty.

Remarks: The species has been reported widely mostly from tropical regions of the world (GBIF, 2021). The ITS sequences of materials from Myanmar showed at least 99.55% identity with those of Indonesian, Indian and Nigerian materials (Table 2), and they can be considered conspecific. The species has previously been recorded from Thailand (Chandrasrikul *et al.*, 2008) and Myanmar (Thaung, 2007).

Leucocoprinus birnbaumii (Corda) Singer

Materials examined: Myanmar: Bo Cho Island (10.676936, 98.248632), alt. 19 m, in broadleaf forest, 18 May 2017, K. Hosaka (KH-MYA17-043); Lampi Island (10.841444, 98.231806), alt. 22 m, in broadleaf forest, 21 May 2017, N. Tanaka (KH-MYA17-077).

Type locality: Czech Republic.

Remarks: The species has been recorded from all continents except for Antarctica (GBIF, 2021), but its main distribution areas are generally considered tropical to subtropical regions (Imazeki and Hongo, 1987; Hosaka and Linn, 2021). The ITS sequences of materials from Myanmar showed 97.74% to 99.15% identity with those of Japanese and New Zealand materials, respectively (Table 2), The species has been recorded from Thailand (Chandrasrikul *et al.*, 2008), but this is the first record of the species from Myanmar.

Neonothopanus nambi (Speg.) R.H.Petersen & Krisai

Material examined: Myanmar: Bo Cho Island (10.676936, 98.248632), alt. 19 m, on hardwood, 18 May 2017, K. Hosaka (KH-MYA17-031).

Type locality: Paraguay.

Remarks: The species has been reported mostly from tropical regions of Africa (Madagascar), Australia, Micronesia, South America, China and Southeast Asia (Malaysia) (Capelari *et al.*, 2011; GBIF, 2021). No records from Thailand, which is located next to Myanmar and therefore expected to have similar mycoflora, could be obtained. The ITS sequence of material from Myanmar (KH-MYA17-031) showed 99.19% identity with that of Vietnamese specimen (Table 2), and they can be considered conspecific. This species is known as bioluminescent, but the bioluminescent property of Myanmar materials has not been confirmed yet (Hosaka and Linn, 2021).

Phallus merulinus (Berk.) Cooke

Material examined: Myanmar: Bo Cho Island (10.668087, 98.243671), alt. 43 m, in broadleaf forest, 19 May 2017, K. Hosaka (KH-MYA17-064).

Type locality: Indonesia.

Remarks: The species has been recorded from South America (Cabral *et al.*, 2014), India and Southeast Asia (Indonesia, Philippines and Singapore) (GBIF, 2021). No records from Thailand, which is located next to Myanmar and therefore expected to have similar mycoflora, could be obtained. The ITS sequence of material from Myanmar (KH-MYA17-064) showed 99.61% identity with that of French Guianan specimen (Table 2), and they can be considered conspecific despite their long geographical distance from each other. This is the first record of the species from Myanmar.

Pisolithus albus (Cooke & Massee) Priest

Material examined: Myanmar: Moeyungyi Wetland Wildlife Sanctuary (17.589505, 96.575639), alt. 39 m, under *Acacia auriculiformis* and *A. mangium*, 24 May 2017, K. Hosaka (KH-MYA17-119).

Type locality: Australia.

Remarks: The species has been recorded from Australia, New Zealand, India and Southeast Asia (GBIF, 2021), but the records outside Australia are the results of the anthropogenic intro-

duction with ectomycorrhizal host trees (*Eucalyptus* and *Acacia*) (Martin *et al.*, 2002). Accordingly, the material of Myanmar, which was collected under *Acacia*, is also considered exotic, but it is the first record of the species from Myanmar. The ITS sequence of material from Myanmar (KH-MYA17-119) showed 100% identity with that of Thai specimen (Table 2).

Psathyrella candolleana (Fr.) Maire

Materials examined: Myanmar: Yangon, Kan Daw Gyi Lake (16.798038, 96.164525), alt. 35 m, in broadleaf forest, 27 Aug 2016, K. Hosaka (KH-MYA16-012); Mandalay, Wet win Protected Public Forest near Pyin Oo Lwin (22.08978, 96.632556), alt. 713 m, in broadleaf forest, 30 Aug 2016, K. Hosaka (KH-MYA16-085); Mandalay, Shwe Kyaung Village near Pyin Oo Lwin (21.801094, 96.419242), alt. 911 m, in broadleaf forest, 31 Aug 2016, K. Hosaka (KH-MYA16-121).

Type locality: Sweden [neotypified by Örstadius *et al.* (2015)].

Remarks: This species is generally considered widespread (Imazeki and Hongo, 1987), but the GBIF data showed only one record from Southeast Asia (Vietnam) (GBIF, 2021). The ITS sequences of materials from Myanmar showed at least 99.18% identity with those of Chinese or Nigerian materials (Table 2), and they can be considered conspecific. The species has been reported from Thailand (Chandrasrikul *et al.*, 2008), but this is the first record of the species from Myanmar.

Pycnoporus sanguineus (L.) Murrill

Material examined: Myanmar: Mandalay, Baw Reserve Forest No. 85 near Pyin Oo Lwin (21.908162, 96.541085), alt. 969 m, on hardwood, 29 Aug 2016, K. Hosaka (KH-MYA16-053).

Type locality: Suriname.

Remarks: The species has been recorded widely in tropical to temperate regions of the world (GBIF, 2021), including Thailand (Chandrasrikul *et al.*, 2008). The ITS sequence of material from Myanmar (KH-MYA16-053) showed 99.84% identity with that of Thai specimen (Table 2). This is the first record of the species from Myanmar.

Russula virescens (Schaeff.) Fr.

Material examined: Myanmar: Mandalay, Baw Reserve Forest No. 85 near Pyin Oo Lwin (21.908162, 96.541085), alt. 969 m, under *Quercus* sp., 29 Aug 2016, K. Hosaka (KH-MYA16-045).

Type locality: Germany.

Remarks: The species has been recorded widely in the Northern Hemisphere, including Southeast Asia (Imazeki and Hongo, 1989; Chandrasrikul *et al.*, 2008; GBIF, 2021). The ITS sequence of material from Myanmar (KH-MYA16-045) showed 97.06% identity with that of Chinese specimen (Table 2). This is the first record of the species from Myanmar.

Schizophyllum commune Fr.

Materials examined: Myanmar: Yangon, Kan Daw Gyi Lake (16.798038, 96.164525), alt. 35 m, on hardwood, 27 Aug 2016, K. Hosaka (KH-MYA16-013); Mandalay, Wet win Protected Public Forest near Pyin Oo Lwin (22.08978, 96.632556), alt. 713 m, on hardwood, 30 Aug 2016, K. Hosaka (KH-MYA16-094); Bo Cho Island (10.676936, 98.248632), alt. 19 m, on hardwood, 18 May 2017, K. Hosaka (KH-MYA17-038); Lampi Island (10.690818, 98.24412), alt. 33 m, on hardwood, 23 May 2017, K. Hosaka (KH-MYA17-112).

Type locality: Sweden.

Remarks: The species is considered cosmopolitan (Hosaka and Linn, 2021) and the GBIF records showed its distribution in all continents including Antarctica (GBIF, 2021). The ITS sequences of materials from Myanmar showed at least 99.84% identity with materials from various countries (Table 2), and they can be considered conspecific. The species has previously been reported from Myanmar (Thaung, 2007).

Trogia infundibuliformis Berk. & Broome

Material examined: Myanmar: Bo Cho Island (10.676936, 98.248632), alt. 19 m, on hardwood,

18 May 2017, K. Hosaka (KH-MYA17-033).

Type locality: Sri Lanka.

Remarks: The species is probably widely distributed throughout tropical regions of the world, but the GBIF data only showed scattered records from Southeast Asia (Laos) and Africa (Democratic Republic of the Congo) (GBIF, 2021). Further literature search indicated that the species is also distributed in India, Sri Lanka (Kumar and Manimohan, 2009) and Thailand (Chandrasrikul *et al.*, 2008). The ITS sequence of material from Myanmar showed 98.72% identity with that of Thai specimen (Table 2), and they can be considered conspecific. This is the first record of the species from Myanmar.

Turbinellus floccosus (Schwein.) Earle ex Giachini & Castellano

Material examined: Myanmar: Mandalay, Pyin Oo Lwin, National Kandawgyi Garden (21.992546, 96.471205), alt. 1114 m, under *Pinus* sp., 28 Aug 2016, K. Hosaka (KH-MYA16-017).

Type locality: United States of America.

Remarks: The species has been recorded from North America, Japan, China (Wang *et al.*, 2004; GBIF, 2021), India (Khaund and Joshi, 2014), and Thailand (Chandrasrikul *et al.*, 2008). The ITS sequence of material from Myanmar showed only 92.3% identity with that of Indian specimen (Table 2). It is, therefore, likely that the Myanmar material represents a new species to science. This is the first record of the species from Myanmar. In addition, *Turbinellus* (or *Gomphus*) was not reported by Thaung (2007), and therefore, it could be the first record of the genus and the family Gomphaceae from Myanmar.

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