Identification of three wood decay fungi in Yeoninsan Provincial Park, Korea

Sun Lul Kwon1, Seokyoon Jang1, Min-Ji Kim2, Kyeongwon Kim1, Chul-Whan Kim1, Yeongseon Jang3, Young Woon Lim2, Changmu Kim4 and Jae-Jin Kim1,*

1Division of Environmental Science & Ecological Engineering, College of Life Science & Biotechnology, Korea University, Seoul 02841, Republic of Korea
2School of Biological Sciences, Seoul National University, Seoul 08826, Republic of Korea
3Division of Wood Chemistry and Microbiology, National Institute of Forest Science, Seoul 02455, Republic of Korea
4Microorganism Resources Division, National Institute of Biological Resources, Incheon 22689, Republic of Korea

*Correspondent: jae-jinkim@korea.ac.kr

Though several wood decay fungi have been reported in the world-wide, only about 600 wood decay fungi have been reported in Korea to date. Thus, the objective of this study was to secure resources for the wood decay fungi in Korea. We investigated wood decay fungi in Yeoninsan Provincial Park, Korea, and the collected specimens were identified based on ITS sequence analysis. Two species were unrecorded species in Korea: Postia hirsuta (Polyporales, Basidiomycota) and Hyphodontia reticulata (Hymenochaetales, Basidiomycota). Another species was previously reported without detailed description: Ceriporia alachuana (Polyporales, Basidiomycota). Here, we provided additional detailed microscopic features and phylogenetic analysis of these species.

Keywords: Basidiomycota, ITS, morphology, phylogeny, taxonomy

© 2018 National Institute of Biological Resources
DOI:10.12651/JSR.2018.7.3.240

INTRODUCTION

Wood decay fungi play a significant role in forest ecosystems through wood decomposition, such as soil humus formation and nutrient recycling (Gilbertson 1984; Bader et al., 1995; Misra et al., 2014). They use various enzymes to obtain carbon sources and other nutrients from moist wood. The enzymes have been used in many industries such as pharmaceuticals and bioremediation (Buswell et al., 1987; Wasser, 2002; Asgher et al., 2008; Karigar and Rao, 2011; Lee et al., 2015a). Specifically, the ligninolytic fungi can degrade environmental pollutants; such as polychlorinated biphenyl (PCB), dichloro-diphenyl-trichloroethane (DDT), dioxins, and polycyclic aromatic hydrocarbons (PAHs) by using lignin peroxidase, laccase, and manganese peroxidases (Eriksson et al., 1990; Joshi and Gold, 1993; Reddy, 1995).

Traditionally, macro-fungi were classified by morphological characters (Johnson and Watling, 1977). Molecular methods have been applied for fungal research, and the internal transcribed spacer (ITS) region is used for fungal barcode marker (Schoch et al., 2012). Although the ITS show low species resolution for some fungi (Hong et al., 2015), it is suitable for most wood decay fungi (Jang et al., 2016b). In Korea, 5,056 fungal species have been reported (National Biodiversity Center, 2017). Among them, approximately 600 species are wood decay fungi (Lee et al., 2015b; Kim et al., 2016). Many of these species were identified based only on morphological characters, taxonomic studies have used molecular markers to identify species.

In order to describe indigenous basidiomycetes in Korea, we surveyed fungal diversity in Yeoninsan Provincial Park (Gapyeong-gun, Gyounggi-do, Korea) from 2015 to 2016 (Jang et al., 2016a). In a previous study, 79 fungal species were identified based on the ITS and nuclear large subunit ribosomal DNA region (LSU) sequence analysis and several wood decay fungi were confirmed as new species without morphological description (Jang et al., 2016a). During the process of updating the floral list of Yeoninsan Provincial Park, we found that Hyphodontia niemelaei (KUC20160721B-26) was misidentified. In this study, we correct this misidentification and provide detailed morphological descriptions. We also describe
Materials and Methods

Strains

We reassessed wood decay fungi collected from Mt. Yeonin in 2016 using ITS sequence analysis. *Hyphodonta* niemelaei (KUC20160721B-26) was shown to be *H. reticulata*, which is confirmed as a new species in Korea. Although *Ceriporia alachuana* (KUC20160825-21) was also an unrecorded species, no morphological description was previously provided. The other wood decay fungus, *Postia* specimen (KUC20161012-37), was determined as an unrecorded species. Here, we confirmed the identification of three specimens by morphological examination and molecular phylogenetic analysis.

Morphological examination

For the accurate identification, detailed morphological features were investigated. Macro- and microscopic features were noted from those specimens of unrecorded species. The colors of fruiting bodies were indicated with Munsell colors (2009). Measurements and drawings for microscopic features were performed from slide preparations mounted in Melzer’s reagent under an Olympus BX51 light microscope (Tokyo, Japan) (Johnson and Watling, 1977) at either 400× or 1000× magnification.

At least 30 basidiospores and 20 basidia (if possible) were measured per specimen.

The following abbreviations in the paper were used: L = mean spore length, W = mean spore width, n = number of spores from given number of specimens, Q = variation in the L/W ratios. In case of basidiospores, 5% of the measurements were rejected from each end of the range and are given in parentheses.

Molecular analysis

The AccuPrep Genomic DNA Extraction Kit (Bioneer, Daejeon, Korea) was used for genomic DNA extraction from the dry specimens. PCRs were conducted using the primers ITS1F and LR3 for the internal transcribed spacer (ITS) region amplification (White et al., 1990). The determined sequences were proofread using MAFFT.
7.130 (Katoh and Standley, 2013). To analyze each species, closely related sequences were downloaded from GenBank. These were aligned using MAFFT 7.130 (Katoh and Standley, 2013) and modified manually using MacClade 4.08 software (Maddison and Maddison, 2005). Datasets were tested by MrModeltest 2.3 using the Akaike information criterion (AIC) criteria with default options (Nylander, 2004). The GTR + I + G model for the Polyporales dataset, and the GTR + G for the Hymenochaetales were chosen for the AIC criteria as a result of the test. Bayesian analysis was performed with MrBayes 3.2.1 (Ronquist and Huelsenbeck, 2003).

**Results**

**Phylogenetic analysis**

The molecular phylogenies were constructed by Bayesian analysis using the ITS sequence datasets. The two phylogenetic trees were constructed using 24 taxa for KUC20160825-21 and KUC20161012-37 (Polyporales) and 13 taxa for KUC20160721B-26 (Figs. 1 and 2). KUC20160825-21 clustered with the *Ceriporia alachuana* and was placed in monophyletic clade with 100% posterior probabilities (PP) (Fig. 1). KUC20160721B-26 was in a clade with *Hyphodontia reticulata* with 97% PP (Fig. 2). *H. rhizomorpha* *H. niemelai*, and *H. apacheriensis* are morphologically and phylogenetically similar to *H. reticulata* (Fig. 2). KUC20161012-37 clustered with *Postia hirsuta* (Fig. 1) and monophyletic relationship is well supported (100% PP). The allied species was *P. lactea* (AJ006664).

**Taxonomy**

*Ceriporia alachuana* (Murrill) Hallenb, Iranian Journal of Plant Pathology 15(1-4): 14 (1979) (Fig. 3)

**Korean name:** 연노랑그물구멍버섯

Basidiocarp annual, resupinate, pore surface pale yellow (2.5Y8/2, 2.5Y8.5/2) to light yellowish brown (2.5Y5/6), pores angular 3-4 per mm. margin sterile, white (7.5YR9.5/1), soft-floccose, paler than the pore surface. Hyphal system monomitic, hyphae thin- to thick-walled, simple-septate, 2.5-5.0 (-5.4) μm. Basidia clavate with 4 sterigmata, simple septate at the bases, 12.0-17.0 (-17.5)×3.0-4.5 μm. Cystidia or other sterile hymenial elements absent. Basidiospores narrowly ellipsoid, ovoid, hyaline, smooth, 3.7-4.6 (-4.8)×1.8-2.5 (-2.7) μm, L = 4.0 μm, W = 2.18 μm, Q = 1.86 (n = 30/1).

**Habitat:** On hardwood

**Distribution:** Iran, Nepal, and Thailand, rare in Europe, and widespread in the Southern United States (Ryvarden, 1993); and Republic of Korea.

**Note:** The microscopic characteristics of *Ceriporia alachuana* KUC20160825-21 accord with Ryvarden (1993). It is known as a white rot fungus. The basidiospores are recognized with shorter length or more width than other *Ceriporia* species in Korea (Jung, 1994; Lim et al., 2000; Lee et al., 2002; Jang et al., 2012; Jang et al., 2016b). *C. reticulata* has similar macro-morphological characters with *C. alachuana*, but it is distinguished from spore size (6.0-8.0×2.0-3.0 μm) (Jung, 1994).

**Specimen examined:** Korea, Gyeonggi, Yeoninsan Provincial Park, Mt. Yeonin, 37°53′55″ N, 127°24′51″ E, 25 Aug 2016, on hard wood, Seokyoon Jang,
Fig. 3. The basidiocarp (A) and microscopic features (B-D) of *Ceriporia alachuana* KUC20160825-21. B, Basidiospores; C, Basidia; D, hyphae (scale bars: A = 1 cm, B-D = 10 μm).

Fig. 4. The basidiocarp (A) and microscopic features (B-F) of *Hyphodontia reticulata* KUC20160721B-26. B, Basidiospores; C, Basidia; D, Septated cystidia; E, Capitate cystidia; F, hyphae; G, Encrusted hyphae part of a dissepiment edge (scale bars: A = 0.5 cm, B-F = 10 μm).
KUC20160825-21 (KB, NIBRFg00000499641; Genbank accession no. MF774801).

**Hyphodontia reticulata** C.C. Chen & Sheng H. Wu, Mycological Progress 16 (5): 558 (2017) (Fig. 4)

Korean name: 그물돌기고약버섯

Basidiocarp annual, resupinate, loosely adnate, eft-fused, pore surface yellow (2.5Y8/6), pores angular 3-4 per mm; margin white (2.5Y9.5/1). Hyphal system monomitic, smooth, thin- to slightly thick-walled, no-dose-septate, sometimes encrusted, 2.0-3.0 μm. Basidia narrowly clavate with 4 sterigmata and basal clamp, sometimes slightly constricted, 15.0-20.0×4.0-5.5 μm. Basidiospores broadly ellipsoid, smooth, thin-walled, 4.9-6.1×3.4-3.9 μm, L = 5.36 μm, W = 3.66 μm, Q = 1.47 (n = 30/1).

**Habitat:** On hardwood

**Distribution:** Taiwan, Japan (Chen et al., 2017); and Republic of Korea.

**Note:** The capitulate cystidia width of Hyphodontia reticulata (KUC20160721B-26) is narrower than that of *H. reticulata* in the other study (5-6.5 μm), but microscopic characteristics are comparable (Chen et al., 2017). *H. reticulata* is morphologically similar to *H. apacheriensis, H. niemelaei*, and *H. rhizomorpha* (Chen et al., 2017). Especially, *H. niemelaei* has similar basidiospores, but it is distinguished from small capitulate cystidia (20-30×2.5-3.0 μm).

**Specimen examined:** Korea, Gyeonggi, Yeoninsan Provincial Park, Mt. Yeonin, 37°53′55″ N, 127°24′51″ E, 21 Jul 2016, on hard wood, Seokyoon Jang, KUC20160721B-26 (Genbank accession no. MF774798).

**Postia hirsuta** L.L. Shen & B.K. Cui, Cryptog. Mycol. 35(2): 202 (2014) (Fig. 5).

Korean name: 털손등버섯

Pileate basidiocarps annual, solitary, effused-reflexed, soft corky, white (2.5Y9.5/1) to very pale yellow (2.5Y9/2). Pore surface very pale yellow (2.5Y9/2) to yellow (10YR8/6). Pores round to angular 3-4 per mm; Hyphal system monomitic, generative hyphae with clamp connection, (2.6-)3.0-4.5 (-4.9) μm. Basidia clav-
Ceriporia Donk is a genus that is widely distributed from subtropic to subpolar regions (Dai, 2012). Approximately 70 species of Ceriporia have been reported (Spirin et al., 2016). Among them, only five species were reported in South Korea (Jung, 1994; Lim et al., 2000; Lee et al., 2002; Jang et al., 2012; Jang et al., 2016b).

Postia Fr. is a large and globally distributed genus, and it consists of brown rot fungi mostly grown on conifer wood (Shen and Cui, 2014). Over 69 species of the Genus Postia Fr. have been reported in Mycobank (http://www.Mycobank.org/) and Index Fungorum (http://www.indexfungorum.org/) as current name, but only seven species have been reported in South Korea (Lee et al., 2015b).

According to the Wensberg et al. (2003), wood decay fungi have the ability to degrade recalcitrant molecules that aid degradation of xenobiotics through biological metabolism. Such practical use can be found in the use of Ceriporia alachuana (Murrill) Hallenb (Kondo et al., 2003), which has been used in degrading dioxins. Further, fungi have been used in various industrial products such as clinical drugs, industrial enzymes (pulp and paper), biomimetics and pharmaceutical purposes (Margulis and Chapman, 2009). Additionally, some Postia species economically important. In China, Postia guttulata (Peck) Jülich and P. lactea (Fr.) P. Karst have been used in medicine. In the near future, these three unrecorded wood decay fungi in Korea can be studied for practical use.

ACKNOWLEDGEMENTS

This research was supported by the project on survey and excavation of Korean indigenous species of NIBR under the Ministry of Environment, Republic of Korea.

REFERENCES


Submitted: June 4, 2018
Revised: July 15, 2018
Accepted: July 17, 2018