

Taxonomic Study on Korean *Schizopora*

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Schizopora paradoxa is a white rot fungus showing great variation in hymenophoral configuration. It has been often treated as close to *Irpex* or *Hyphodontia* and frequently confused with *S. flavipora* which was identified as an unrecorded species in Korea. Distinct features including sizes of basidia and basidiospores as well as hymenophoral shape make *S. paradoxa* differ from *S. flavipora*. Remarkable characters of hymenophores and microscopic structures are described and their significance is discussed for the taxonomy of Korean *Schizopora*.

KEYWORDS: *Schizopora flavipora*, *Schizopora paradoxa*

Schizopora Velenovsky is a genus of typical wood-rot fungi and decays various kinds of trees in forests. It causes a white rot by cellulase and lignase enzyme systems that enable to degrade all components of wood cell walls (Alexopoulos *et al.*, 1996; Gilbertson and Ryvarden, 1986). This genus has been accepted as a saprophyte because it fruits on dead wood of fallen branches or logs and decays wood of trees that are already dead. Especially, *S. paradoxa* used to be collected from recently dead trees to extremely rotten trees.

The decay of dead trees by wood-rotting fungi including *Schizopora* prevents the continuous accumulation of large amounts of woody materials on the ground but releases organic compounds and mineral nutrients to the soil, maintaining its productivity and ability to support continuous stands over long periods of time (Gilbertson, 1974). *Schizopora* species occur on all kinds of hardwood trees in Korea and are considered to be responsible for nearly all the decay in *Quercus* forests that dominate Korean mountains.

Schizopora species were the most economically important fungi that frequently occur on the bedlog of shiitake (*Lentinula edodes*) and reduce fruitbody yield (Maekawa and Arita, 1984). They also occur on the bedlog of *Phellinus linteus* which is famous for its antitumor activity. In general, *Schizopora* species inhabit wood of both hardwoods and conifers and sometimes cross the hardwood-conifer boundary.

Schizopora has variable hymenophores from poroid, lacerate to more or less irpicoid forms. Due to its versatile forms, *Schizopora* was treated as morphologically close to *Irpex* and microscopically almost same as *Hyphodontia* (Jung, 1987). The microscopic features of *Schizopora* similar to those of *Hyphodontia* supported that the true phylogenetic position of *Schizopora* was closely

related to that of the corticioid genus *Hyphodontia* (Eriksson *et al.*, 1984; Gilbertson and Ryvarden, 1987).

Recent phylogenetic analyses inferred from morphological characters (Langer, 1994) and molecular data (Lim, 2001; Paulus *et al.*, 2000) showed that *Schizopora* was nested inside the main clade of *Hyphodontia*. Both *Schizopora* and *Hyphodontia* seemed to make a natural group although they crossed the borderline between corticioid and poroid forms each other. This kind of example already showed that it was more convenient to define strictly artificial families than natural ones during the transition period of the classification in the Hymenomycetes (Donk, 1971).

Langer (1994) once treated those two genera together in his monograph on *Hyphodontia* and proposed to conserve *Hyphodontia* against *Schizopora* (Langer *et al.*, 1996). However, *Schizopora* has nomenclatural priority over *Hyphodontia*, and in the sense of Art. 14.1-2 of the ICBN Code, a disadvantageous change of nomenclature would result when both genera are combined into *Schizopora*. For that reason, many mycologists still use the genus name *Schizopora*.

Schizopora originally contained two species (Domański, 1969), *S. paradoxa* (type species) and *S. flavipora*. Then *S. radula* was added by Hallenberg (1983) and *S. nothofagi* by Cunningham (1965). Two species of *Schizopora*, *S. paradoxa* and *S. flavipora*, have been collected in Korea, and the latter species was confirmed new to Korea and is registered here with descriptions. Because of the great morphological variation of *S. paradoxa*, it is frequently confused with *S. flavipora* and believed to be of great interest to investigate the intraspecific hymenophoral variation and host specificity for the taxonomy of Korean *Schizopora*.

Materials and Methods

Fresh samples collected from field surveys and observed

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Table 1. List of *Schizopora* strains used in this study

Species	Sources	Locality	Substrate
<i>Schizopora flavipora</i>	SFC ^a 970926-4	Mt. Bukhan, Seoul	<i>Quercus serrata</i>
	SFC 980125-7	Ilyung, Gyunggi-do	<i>Pinus densiflora</i>
<i>Schizopora paradoxa</i>	SFC 970201-6	Mt. Moak, Cheonlabuk-do	<i>Pinus densiflora</i>
	SFC 970201-10	Mt. Moak, Cheonlabuk-do	<i>Quercus aliena</i>
	SFC 970719-2	Mt. Bukhan, Gyunggi-do	<i>Prunus leveilleana</i>
	SFC 970816-2	Jeundeung Temple, Gangwha Island, Incheon	<i>Castanea crenata</i>
	SFC 970830-7	Mt. Daemo, Seoul	<i>Pinus densiflora</i>
	SFC 970924-1	Mt. Bukhan, Gyunggi-do	<i>Pinus densiflora</i>
	SFC 971018-7	Mt. Bukhan, Gyunggi-do	<i>Quercus serrata</i>
	SFC 980201-10	Naega, Gangwha Island, Incheon	<i>Quercus acutissima</i>
	SFC 980508-B14	Mt. Chilgap, Chungcheongnam-do	<i>Quercus aliena</i>

^aSFC : Seoul National University Fungus Collection.

in this study are listed in Table 1. The samples were deposited in SFC (Seoul National University Fungus Collection) after examination. For the observation of specimens, laboratory techniques of Largent *et al.* (1977) were used and the measurements and drawings were made from slide preparations stained with 1% (w/v) aqueous phloxine and KOH for 3% potassium hydroxide (Jung, 1987; Hawksworth *et al.*, 1995). Hymenophoral morphology was observed under a Nikon stereomicroscope (magnification up to 60×) and pictures were taken using a 35 mm camera supplied as a part of Nikon Microflex system. Microscopic structures of taxonomic importance were observed under a Nikon compound microscope (magnification up to 15,000×) and sketches were made using a drawing tube attached to the microscope. Descriptive terminology for taxonomic characters was taken from Hawksworth *et al.* (1995). For the general taxonomy of the Aphyllophorales, Donkian concept (Donk, 1964) was adopted. The classification system of Gilbertson and Ryvarden (1986, 1987) and Ryvarden and Gilbertson (1993, 1994) were referred and the description of Jung (1987) on *Schizopora* of the United States was compared. And also the reference of Jung (1994) on fungal flora and distribution of Korean Aphyllophorales was consulted together.

Taxonomy

Schizopora Velenovsky emend. Donk, Persoonia 5: 76, 1967

Basidiomes annual, resupinate, orbicular, soon confluent, soft and coriaceous when fresh, firm and tough when dry, adnate; hymenophore tubular to irpicoid, of medium-sized pores; context whitish, thin; hyphal system monomitic; generative hyphae distinct, hyaline, thin- to somewhat thick-walled, septate with clamps; cystidioles present, thin-walled; basidia clavate, with 4 sterigmata; basidiospores hyaline, ellipsoid, smooth, non-amyloid.

Type species: *Schizopora paradoxa* (Fries) Donk

Remarks: *Schizopora* is morphologically close to *Irpex* but its microscopic structures are almost same as those of *Hyphodontia* (Jung, 1987). For such a reason, Langer (1994) treated this genus as a member of *Hyphodontia* in his monograph. However, it is known that *Schizopora* requires a more extensive taxonomic investigation to solve the species delimitation (Gilbertson and Ryvarden, 1987). According to recent phylogenetic analyses based on molecular data (Paulus *et al.*, 2000; Lim, 2001), *Schizopora* is nested inside the main *Hyphodontia* clade, showing that *Schizopora* and *Hyphodontia* might form a natural taxon together.

Schizopora flavipora (Cooke) Ryvarden, Mycotaxon 23: 186, 1985 크림좁구멍버섯 (산청) (Figs. 1A, 2A)

= *Poria flavipora* Cooke, Grevillea 15: 25, 1886

= *Poria lignicola* Earle & Murrill, Mycologia 12: 307, 1920

= *Schizopora carneo-lutea* (Rodway & Cleland) Kotlaba & Pouzar, Cesk Mykol. 33: 21, 1979

Basidiomes annual, resupinate, coriaceous to tough fibrous; hymenophore poroid, white to cream, appressed, angular to daedaleoid or irpicoid, 5~6 per mm, with thin dissepiments; margin usually sterile, whitish.

Hyphal system monomitic; generative hyphae with clamps, hyaline, thin- to thick-walled, 3.2~4 µm in diam, often ending in a capitate globose swollen apex up to 10 µm wide; cystidia absent; basidia clavate, with 4 sterigmata, 12~15×3~5 µm, with a basal clamp; basidiospores ellipsoid, hyaline, smooth, 3.5~4.5×2.5~3.5 µm, non-amyloid.

Specimens examined: On dead standing wood of *Quercus serrata*, Mt. Bukhan, Seoul (SFC 970926-4); on dead standing wood of *Pinus densiflora*, Ilyung, Gyunggi-do (SFC 980125-7), Mungyong Saejae, Gyunggangbuk-do (SFC 990326-6, 991003-34).

Remarks: This fungus was incidentally listed in the checklist of the Aphyllophorales of Mungyong Saejae with no descriptions (Lim *et al.*, 2000), so it is formally

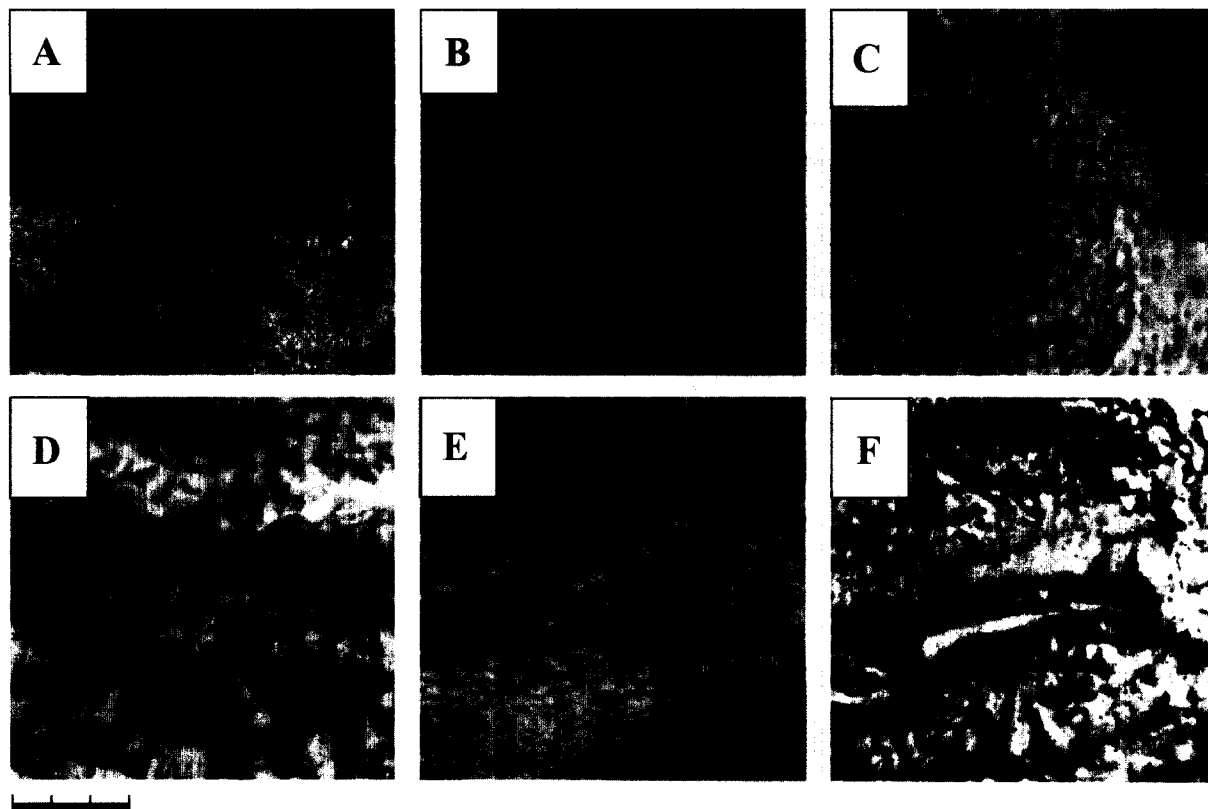


Fig. 1. Hymenophores of *Schizopora flavipora* (A) and *S. paradoxa* (B-F). (A) appressed hymenophoral form (SFC 970926-4). (B) irregular and partly split pores (SFC 970719-2). (C) irregular and labyrinthine form (SFC 970816-2). (D) slightly dentate pores (SFC 980201-10). (E) regular pores (SFC 970830-7). (F) irregular and hydroid hymenophoral form (SFC 970924-1). Bar = 3 mm.

described here. This species has been frequently confused with *S. paradoxa* and some intermediate forms always occur. However, the appressed form of hymenophore, small pores, small spores and basidia, small clamp connections, the absence of cystidioles, and the presence of thick-walled hyphae are distinctive features of *S. flavipora* (Lim, 2001). *Schizopora paradoxa* appears at lower sides of fallen branches as well as on standing dead trunks but *S. flavipora* fruits mainly on trunks of standing dead trees. Such habitat relationships may affect the orientation and growth of basidiocarps and seem to have something to do with their basidial sizes, basidiospore sizes and hymenophoral shapes, which phenomena are also found in various groups of corticioid fungi (Lim, 2001).

Schizopora paradoxa (Fr.) Donk Persoonia 5: 76, 1967
쭈구멍버섯 (Figs. 1B-1F, 2B)

= *Hydnum paradoxum* Fries, Syst. Mycol. 1: 424, 1821

= *Poria versipora* (Persoon) Romell, Svensk Bot. Tidskr. 20: 15, 1926

Basidiomes annual, fully resupinate, coriaceous to tough fibrous; hymenophore usually poroid (3~4 per mm), irregularly hydroid (up to 1 per mm), denticulate, to labyrinthine (1~3 per mm), white to cream; tubes of varying

sizes; margin normally not differentiated, forming shallow or networked tubes, sterile, whitish.

Hyphal system monomitic; generative hyphae regularly clamped, hyaline, thin- to somewhat thick-walled, 3.2~4 μm in diam, often ending in a capitate globose swollen apex up to 9.5 μm wide; cystidioles scattered, incrustated with granular crystals on hyphal tips of pore mouths; basidia clavate, with 4 sterigmata, 15~21 $\times$ 3.5~5 μm , with a basal clamp; basidiospores ellipsoid, hyaline, smooth, 4~5.7 $\times$ 3~4 μm , non-amyloid.

Specimens examined: On the lower side of fallen trees of *Prunus leveilleana*, Mt. Bukhan, Gyunggi-do (SFC 970719-2), *Quercus* species, Mt. Moak, Cheonlabuk-do (SFC 970201-10), Mt. Bukhan, Gyunggi-do (SFC 971018-7), Naega, Gangwha Island, Incheon (SFC 980201-10), Mt. Chilgap, Chungcheongnam-do (SFC 980508-B14), and *Pinus densiflora*, Mt. Daemo, Seoul (SFC 970830-7), Mt. Bukhan, Gyunggi-do (SFC 970924-1); on dead standing wood of *Castanea crenata*, Jeundeung Temple, Gangwha Island, Incheon (SFC 970816-2) and *Pinus densiflora*, Mt. Moak, Cheonlabuk-do (SFC 970201-6).

Remarks: In the United States, *Schizopora* occurs on hardwoods in all kinds of forests (Gilbertson and Ryvarden, 1987). In Korea, it occurs on most of hardwood trees and seems to be really active in the decay of

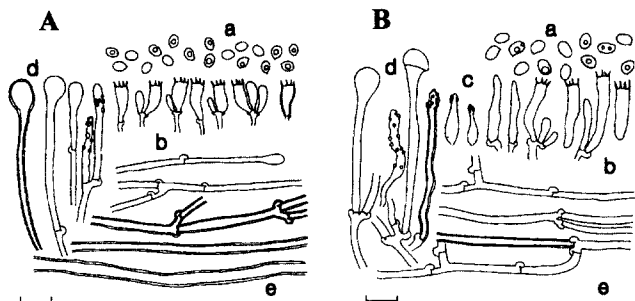


Fig. 2. Microscopic structures of *Schizopora flavipora* (A) and *S. paradoxa* (B). a, basidiospores; b, basidia; c, cystidioles; d, hyphal ends with spherical swellings; e, generative hyphae. Bar = 10 μ m.

Quercus trees throughout Korean mountains. This fungus represents the genus *Schizopora* and has been regarded as a highly variable species in morphology of fruitbodies. There are various hymenophores of rounded, angular, split pores to almost hydroid forms (Fig. 1). However, these various forms are obviously different from appressed hymenophoral forms of *S. flavipora*. Microscopically, *S. paradoxa* has cystidioles incrustated with crystals and there is again variation in sizes of basidiospores and basidia most of which are apparently larger than those of *S. flavipora*.

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References

- Alexopoulos, C. J., Mims, C. W. and Blackwell, M. 1996. Introductory Mycology, 4th ed. John Wiley and Sons, Inc., New York. 868 p.
- Cunningham, G. H. 1965. Polyporaceae of New Zealand. *DSIR Bulletin* 164: 1-304.
- Donk, M. A. 1964. A conspectus of the families of Aphyllophorales. *Persoonia* 3: 199-324.
- _____. 1971. Multiple convergence in the polyporaceous fungi. Pp. 393-422. In: Petersen, R. H. ed. Evolution in the Higher Basidiomycetes. The University of Tennessee Press, Knoxville.
- Domański, S. 1969. Wood-inhabiting fungi in Białowieża virgin forests in Poland, VIII. *Schizopora phellinoides* (Pil.) comb. nov. and its diagnose. *Acta Soc. Bot. Poloniae* 38: 255-269.
- Eriksson, J., Hjortstam, K. and Ryvarden, L. 1984. The Corticiaceae of North Europe, Vol. 7. Fungiflora, Oslo. 1449 p.
- Gilbertson, R. L. 1974. Fungi that Decay Ponderosa Pine. The University of Arizona Press, Tucson. 197 p.
- _____. and Ryvarden, L. 1986. North American Polypores, Vol. 1. *Abortiporus-Lindtneria*. Fungiflora, Oslo. 433 p.
- _____. and _____. 1987. North American Polypores, Vol. 2. *Megasporoporia-Wrightoporia*. Fungiflora, Oslo. 885 p.
- Hallenberg, N. 1983. On the *Schizopora paradoxa* complex (Basidiomycetes). *Mycotaxon* 18: 303-313.
- Hawksworth, D. L., Kirk, P. M., Sutton, B. C. and Pegler, D. N. 1995. Ainsworth & Bisby's Dictionary of the Fungi, 8th ed. CAB International, Wallingford. 616 p.
- Jung, H. S. 1987. Wood-rotting Aphyllophorales of the Southern Appalachian Spruce-fir Forest. *Bibl. Mycol. Band* 119. J. Cramer, Stuttgart. 260 p.
- _____. 1994. Floral studies on Korean wood-rotting fungi (II) - on the flora of the Aphyllophorales (Basidiomycota). *Korean J. Mycol.* 22: 62-99.
- Largent, D. L., Johnson, D. and Watling, R. 1977. How to Identify Mushrooms to Genus III. Microscopic Features. Mad River Press, Eureka. 148 p.
- Langer, E. 1994. Die Gattung *Hyphodontia* John Eriksson. J. Cramer, Berlin. 298 p.
- _____, Hallenberg, N., Knudsen, H., Köljal, U., Langer, G., Larsson, K. H., Oberwinkler, F., Parmasto, E., Ryvarden, L. and Vesterholt, J. 1996. Proposal to reject the names *Xylodon* and *Schizopora* in favour of *Hyphodontia*, nom. cons. (Fungi, Corticiaceae). *Taxon* 45: 685-686.
- Lim, Y. W. 2001. Systematic Study of Corticioid Fungi Based on Molecular Sequence Analyses. Ph. D. Thesis, Seoul National University, Seoul.
- _____, Kim, Y. H. and Jung, H. S. 2000. The Aphyllophorales of Mungyong Saejae. *Mycobiology* 28: 142-148.
- Maekawa, M. and Arita, I. 1984. Antagonistic effects of *Phlebia* species on the mycelial growth of *Lentinus edodes*. *Rep. Tottori Mycol. Inst.* 22: 74-75.
- Paulus, B., Hallenberg, N., Buchanan, P. K. and Chambers, G. K. 2000. A phylogenetic study of the genus *Schizopora* (Basidiomycota) based on ITS DNA sequences. *Mycol. Res.* 104: 1155-1163.
- Ryvarden, L. 1985. Type studies in the Polyporaceae 17. Species described by W.A. Murrill. *Mycotaxon* 23: 169-198.
- _____. 1991. Genera of Polypores: Nomenclature and Taxonomy. Fungiflora, Oslo. 363 p.
- _____. and Gilbertson, R. L. 1993. European Polypores, Part 1. *Abortiporus-Lindtneria*. Fungiflora, Oslo. 387 p.
- _____. and _____. 1994. European Polypores, Part 2. *Meripilus-Tyromyces*. Fungiflora, Oslo. 743 p.