

Preliminary List of Phallales (Phallomycetidae, Basidiomycota) in Taiwan

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Abstract. Fourteen species (8 genera, 3 families) belonging to the order Phallales in Taiwan were confirmed by a fieldwork in 2008 as well as herbarium and literature searches. One species, *Phallus impudicus*, is newly reported from Taiwan.

Key words: distribution, fungi, mushrooms, stinkhorns, taxonomy.

Introduction

The order Phallales was originally described by Fischer (1900) to accommodate taxa commonly referred to as stinkhorns (family Phallaceae) and lattice stinkhorns (family Clathraceae). Both families produce epigeous fruit bodies with spongy structures, which allow them to grow rapidly when they absorb water from surrounding environment. Most notably, their spore masses (glebae) become slimy and emit distinct odor (often described as “fetid”, “obnoxious”, or “unpleasant”) when matured (Arora, 1986). It has been considered that the odor attracts small insects, especially flies, and their spores are dispersed by those insects (Fulton, 1889). This classical mycophagous behavior by insects on stinkhorns has been well-known for more than a century, and virtually all species belonging to Phallaceae and Clathraceae depend on insects as spore dispersal agents (Fulton, 1889).

Cunningham (1931) first recognized that some taxa with non-stinkhorn-like fruit bodies, i.e., Claustulaceae, should also be included in the order Phallales. This monotypic family, which contains a genus *Claustula*, is characterized by having sequestrate or truffle-like fruit bodies, and the gleba is enclosed by peridium and never exposed to the air. Subsequent studies also revealed that more sequestrate or truffle-like taxa, such as

genera *Protuberata* (Malloch, 1989), *Gelopellis* (Beaton & Malajczuk, 1986) and *Phallobata* (Castellano & Beever, 1994), are closely related to stinkhorn taxa.

Molecular phylogenetic studies clearly demonstrated that stinkhorns are closely related to morphologically and ecologically distinct taxa, such as earthstars (Geastrales), coral and club fungi (Gomphales) (Humpert *et al.*, 2001; Hosaka *et al.*, 2006). Currently, Phallales is recognized as a well-supported monophyletic group with six well-supported subclades within it (Hosaka *et al.*, 2006). It is noteworthy that three basal clades within Phallales were characterized by truffle-like taxa, indicating that stinkhorn-like fruit bodies are derived from truffle-like morphologies in Phallales (Hosaka *et al.*, 2006). Hosaka *et al.* (2006) also discussed the possibility that spore dispersal of Phallales, including truffle-like taxa, is entirely dependent on arthropods.

For many species of stinkhorns, the center of diversity lies in tropical regions of the world (Dring, 1980). The presence of many (presumably) endemic taxa in tropical regions, such as Africa (Dring, 1964, 1980; Dring & Rose, 1977), West Indies (Dennis, 1953), Central America (Miller *et al.*, 1991) and Yunnan, China (Zang & Petersen, 1989), is consistent with the hypothesis that the origins of many, if not all, species of stinkhorns are tropical areas. In fact, some wide-

ly distributed stinkhorn taxa in North America, such as *Clathrus archeri* (Arora & Burk, 1982), *Clathrus ruber* (Burk, 1979) and *Pseudocolus fusiformis* (Blanton, 1976; Burk, 1976; Coker & Rebell, 1949), are believed to have been transferred from other parts of the world, possibly tropics.

Although it is not clear how stinkhorns had spread their distribution, a long-distance dispersal of spores by wind throughout the Southern Hemisphere was documented for rust fungi (Watson & de Sousa, 1983). If this is correct, long-distance dispersal, including trans-oceanic dispersal, of macrofungi should happen much more frequently than we currently recognize. A recent trend in biogeographical studies is to re-evaluate the importance of long-distance dispersal (de Queiroz, 2005), and frequent long-distance dispersal was postulated for many organisms, including some macrofungi (Hosaka *et al.*, 2008; Hosaka & Castellano, 2008; Moyersoen *et al.*, 2003).

This paper is a result of biogeographic studies of subclass Phallomycetidae. Taiwan is located in subtropical region between Japan and China, and understanding its stinkhorn flora will surely clarify distributional patterns and biogeographical history of stinkhorns. So far, no comprehensive list of Phallales in Taiwan is available. The list provided here is based solely on a one-year survey and therefore should be considered preliminary. There is no doubt that future survey will reveal richer stinkhorn flora from Taiwan.

Materials and Methods

Fieldwork was conducted by the author in the year of 2008 (August 27–September 2). The main collecting sites were located in central Taiwan, including Nantou County and Taichung County. Specimens collected in Taiwan by the author were deposited at the fungal herbarium of the National Museum of Nature and Science, Tsukuba, Japan (TNS). In addition to dried materials, small fragments of freshly collected samples were soaked in 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) under 4°C. These samples are available upon request to the author for future DNA studies. I have also surveyed for additional specimens of Phallales from Taiwan housed at the TNS for this study. If no specimens were available, collecting records were retrieved by the literature survey.

List of the Species

A total of 14 species (8 genera, 3 families) that belong to the order Phallales from Taiwan were recognized based on field collecting, herbarium and literature surveys. Short comments on identification and distribution, and literature records from Taiwan are given for each species. For two species that have been collected by the author (*Phallus cf. impudicus* and *Pseudocolus fusiformis*), photographs of habitat and fruit bodies are also provided.

Subclass **Phallomycetidae** Hosaka, Castellano & Spatafora, *Mycologia* 98: 955, 2006.

Order **Phallales** Fischer in Engler & Prantl, *Die Natürlichen Pflanzenfamilien* 1: 276, 1900, “Phallineae”.

Family **Phallaceae** Fries, *Systema Mycologicum* 2: 281, 1823, “Phalloideae”.

Dictyophora cinnabarina Lee, *Mycologia* 49: 156, 1957.

Records from Taiwan:

Lee, *Mycologia* 49: 156, 1957.

Liu, *Beih. Nova Hedwigia* 76: 52, 1984.

Remarks. This species was first discovered from bamboo (*Dendrocalamus latiflorus*) stands near Taipei (Lee, 1957), but now reported from other parts of the world, including Hawaii (Hemmes & Desjardin, 2002). It usually grows in farmland in Hawaii (Hemmes & Desjardin, 2002), and it is likely that the species was introduced to Hawaii from Taiwan by humans. The species was not found during the fieldwork in Taiwan by the author in 2008.

Dictyophora indusiata (Vent.) Desv., in Seaver & Chardón, J. Bot., Paris 2: 92, 1809.

Synonyms: *Phallus indusiatus* Vent[k1].: Pers., Syn. Meth. Fung. 244, 1801; *Dictyophora phalloidea* Desv., J. de Bot. 2: 92, 1809.

Records from Taiwan:

Sawada, List of fungi found in Taiwan (Formosa). 273, 1961.

Liu, Beih. Nova Hedwigia 76: 50, 1984.

Wang *et al.*, List of the Fungi in Taiwan. 119, 1999.

Remarks. This species has also been reported from Japan, China, North America, Australia (Imazeki & Hongo, 1989), South America, India, Sri Lanka (Liu, 1984), West Indies (Dennis, 1953) and Africa (Dring, 1964). The species was not found during the fieldwork in Taiwan by the author in 2008.

Dictyophora multicolor Berk. & Broome, Trans. Linn. Soc. London, Bot., Ser. 2 2: 65, 1882.

Record from Taiwan:

Liu, Beih. Nova Hedwigia 76: 49, 1984.

Remarks. This species has also been reported from Australia, China, Indonesia, Sri Lanka, Malaysia, Papua New Guinea, Zaire (Liu, 1984), and Hawaii (Hemmes & Desjardin, 2002). The species was not found during the fieldwork in Taiwan by the author in 2008.

Mutinus bambusinus (Zoll.) E.Fisch., Ann. Jard. Bot. Buitenzorg 6: 30, 1886.

Synonyms: *Mutinus boninensis* Lloyd, Mycol. Writ. 2: 402, 1908; *Jansia boninensis* (Fisch.) Lloyd, Syn. known phalloids. 32, 1909

Records from Taiwan:

Fan, Liu & Liu, Nova Hedwigia 108: 9, 1994.

Wang *et al.*, List of the Fungi in Taiwan. 132, 1999.

Remarks. This species has also been reported from Japan, Micronesia (Imazeki & Hongo, 1989), Africa (Dring, 1964), and Hawaii (Hemmes & Desjardin, 2002). The species was not found during the fieldwork in Taiwan by the author in 2008.

Phallus formosanus Kobayasi, Nova Fl. Japonica, Hymenogastrineae et Phallineae. 73, 1938.

Records from Taiwan:

Kobayasi, Nova Fl. Japonica, Hymenogastrineae et Phallineae. 73, 1938.

Liu, Beih. Nova Hedwigia 76: 45, 1984.

Remarks. This species is known only from Hualian in Taiwan (Kobayasi, 1938; Liu, 1984). *P. formosanus* sensu Lee (1957) is a later homonym and is therefore invalid. The species was not found during the fieldwork in Taiwan by the author in 2008.

Phallus impudicus L: Pers., Syn. Meth. Fung. 242, 1801. [Fig. 1: A, B, C, D]

Specimen examined. TAIWAN, Nantou Co., Ren-Ai township, Chui-Feng, 27 August 2008, leg. K. Hosaka (KH-TW08-001, TNS).

Remarks. The specimen from 2008 was collected in plantations of *Cryptomeria japonica*. *Cryptomeria* has been introduced from Japan and widely planted throughout Taiwan. Even so, no report of this species from Taiwan was found. As far as I know, this is the first official report of this species from Taiwan. Although only immature eggs were available, their white color clearly separates them from all other species of *Phallus* from Taiwan, which show distinct reddish tint on fruit bodies. The specimen is tentatively identified here as *P. impudicus*, but DNA studies are necessary to confirm it.

Phallus rubicundus (Bosc) Fr., Syst. Myc. 2: 284, 1823.

Record from Taiwan:

Liu, Beih. Nova Hedwigia 76: 40, 1984.

Remarks. This species has also been reported from Australia, China, Japan, India, West Indies, North America (Liu, 1984), Hawaii (Hemmes & Desjardin, 2002), and Africa (Cunningham, 1944; Dring & Rose, 1977). The species was not found during the fieldwork in Taiwan by the author in 2008.

Phallus rugulosus Lloyd, Mycol. Not. 63: 960, 1920.

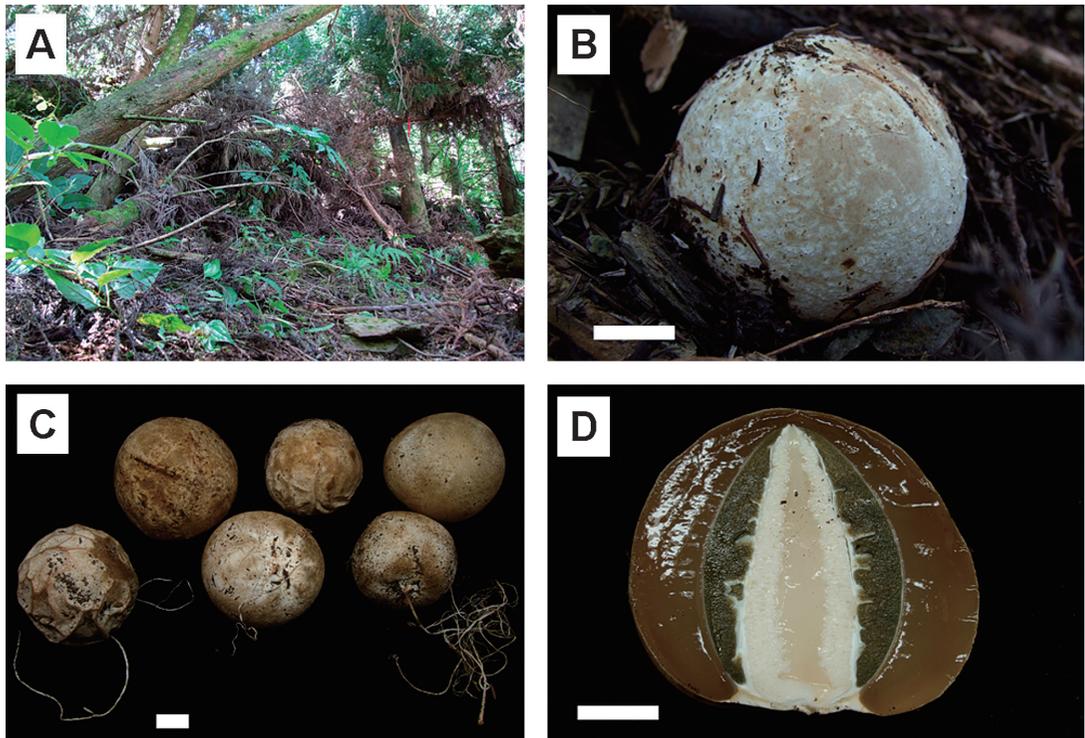


Fig. 1. Habitat and basidiomata of *Phallus impudicus*. A. Habitat of *Phallus impudicus* in Taiwan. Note dense fallen leaves of *Cryptomeria japonica*. B. Immature fruit body of *P. impudicus* from Taiwan (KH-TW08-001). C. Immature fruit bodies of *P. impudicus* (KH-TW08-001). Note thick and long rhizomorphs attached at base. D. Longitudinal section of immature fruit body of *P. impudicus* (KH-TW08-001). Note white color of receptacle without reddish tint. Bars=1 cm.

Record from Taiwan:

Wang *et al.*, List of the Fungi in Taiwan. 143, 1999.

Specimen examined. TAIWAN, Taipei Co., Xindian, 14 October 1934, leg. K. Sawada (TNS-F-2453).

Remarks. Some authors consider this species as synonym of *P. rubicundus* (Cunningham, 1944; Liu, 1984), but is treated here as separate species. The species has also been reported from Thailand (Chandrasrikul *et al.*, 2008), but was not found during the fieldwork in Taiwan by the author in 2008.

Phallus taipeiensis Bau & Liu, in Bau & Liu, Life Science Advances, India 3: 52, 1984.

Synonyms: *Phallus taibeinsis* Liu et Bau, J. Shanxi Univ. 4: 97, 1982; *Phallus formosanus*

Lee, Mycologia 49: 157, 1957.

Records from Taiwan:

Bau & Liu, Life Science Advances, India 3: 52, 1984.

Liu, Beih. Nova Hedwigia 76: 42, 1984.

Remarks. This species is known only from Taipei, Taiwan (Liu, 1984). It grows in bamboo (*Dendrocalamus latiflorus*) stands (Liu, 1984). It was originally described as *P. formosanus* (Lee, 1957) but was invalid because it is a later homonym of *P. formosanus* Kobayasi (Kobayasi, 1938). The species was not found during the fieldwork in Taiwan by the author in 2008.

Family **Clathraceae** Chevallier, Flore Générale des Environs de Paris 1: 120, 1826.

Aseroë arachnoidea E.Fisch., Denkschr. Schweiz. Ges. Nat. 32: 76, 1890.

Records from Taiwan:

Sawada, List of fungi found in Taiwan (Formosa). 266, 1961.

Dring, Kew Bulletin 35: 86, 1980.

Liu, Beih. Nova Hedwigia 76: 26, 1984.

Wang *et al.*, List of the Fungi in Taiwan. 107, 1999.

Specimen examined. TAIWAN, Taipei Co., Taipei, 20 January 1934, leg. K. Sawada (TNS-F-208837).

Remarks. This species has also been reported from Africa (Dring, 1964, 1980), Thailand (Chandrasrikul *et al.*, 2008; Dring, 1980), Japan, China, Indonesia, Sri Lanka, Malaysia, and New Zealand (Imazeki & Hongo, 1989). The species was not found during the fieldwork in Taiwan by the author in 2008.

Clathrus crispatus E.Fisch., Denkschr. Schweiz. Ges. Nat. 33: 24, 1893.

Records from Taiwan:

Dring, Kew Bulletin 35: 24, 1980.

Wang *et al.*, List of the Fungi in Taiwan. 112, 1999.

Remarks. This species has also been reported from Sri Lanka, India, Thailand, Papua New Guinea, and Indonesia (Dring, 1980). The species was not found during the fieldwork in Taiwan by the author in 2008.

Pseudocolus fusiformis (E.Fisch.) Lloyd, Mycol. Writ. 7: 53, 1909. [Fig. 2: A, B, C, D]

Synonyms: *Anthurus javanicus* (Penz.) Cunn., Proc. Linn. Soc. N.S. Wales 56: 186, 1931; *Pseudocolus javanicus* Lloyd, Mycol. Writ. 3: 456, 1910; *Colus schellenbergiae* Sumst., Mycologia 8: 183, 1916; *Pseudocolus schellenbergiae* (Sumst.) Johnson, Bull. Ohio Biol. Surv. 22: 336, 1929.

Records from Taiwan:

Dring, Kew Bulletin 35: 65, 1980.

Liu, Beih. Nova Hedwigia 76: 29, 1984.

Wang *et al.*, List of the Fungi in Taiwan. 114, 1999.

Specimens examined. TAIWAN, Nantou Co., Taroko National Park, Mt. Chilai, 28 August 2008, leg. K. Hosaka (KH-TW08-021, KH-TW08-022, KH-TW08-023, TNS).

Remarks. The specimens from 2008 were collected from dense bamboo stands with *Abies kawakamii*. This species has also been reported from China, Japan, North America, Indonesia, New Zealand, Australia (Dring, 1980; Imazeki & Hongo, 1989), South America (Liu, 1984) and Hawaii (Hemmes & Desjardin, 2002). The North American populations of the species were probably introduced by humans (Coker & Rebell, 1949; Blanton, 1976; Burk, 1976; Dring, 1980). Their exact origins, however, are unclear. Although they are treated as synonyms here, *P. fusiformis*, *P. schellenbergiae*, and *P. javanicus* all show slightly different colorations on fruit bodies (Imazeki & Hongo, 1989). Future studies may reveal that the populations from different continents represent distinct species.

Simblum periphragmoides Klotzsch, Botanical Miscellany 2: 164, 1831.

Synonyms: *Lysurus periphragmoides* (Klotzsch) Dring, Kew Bull. 35: 70, 1980; *Simblum gracile* Berk., in Lloyd, Syn. phall., 65, 1909.

Records from Taiwan:

Sawada, List of fungi found in Taiwan (Formosa). 291, 1961.

Dring, Kew Bulletin 35: 70, 1980.

Liu, Beih. Nova Hedwigia 76: 20, 1984.

Fan, Liu & Liu, Nova Hedwigia 108: 5, 1994.

Wang *et al.*, List of the Fungi in Taiwan. 165, 1999.

Remarks. This species is distributed in pantropical regions of the world, including China, Japan, Australasia, Africa, North and South America (Dring, 1980; Liu, 1984). The species was not found during the fieldwork in Taiwan by the author in 2008.

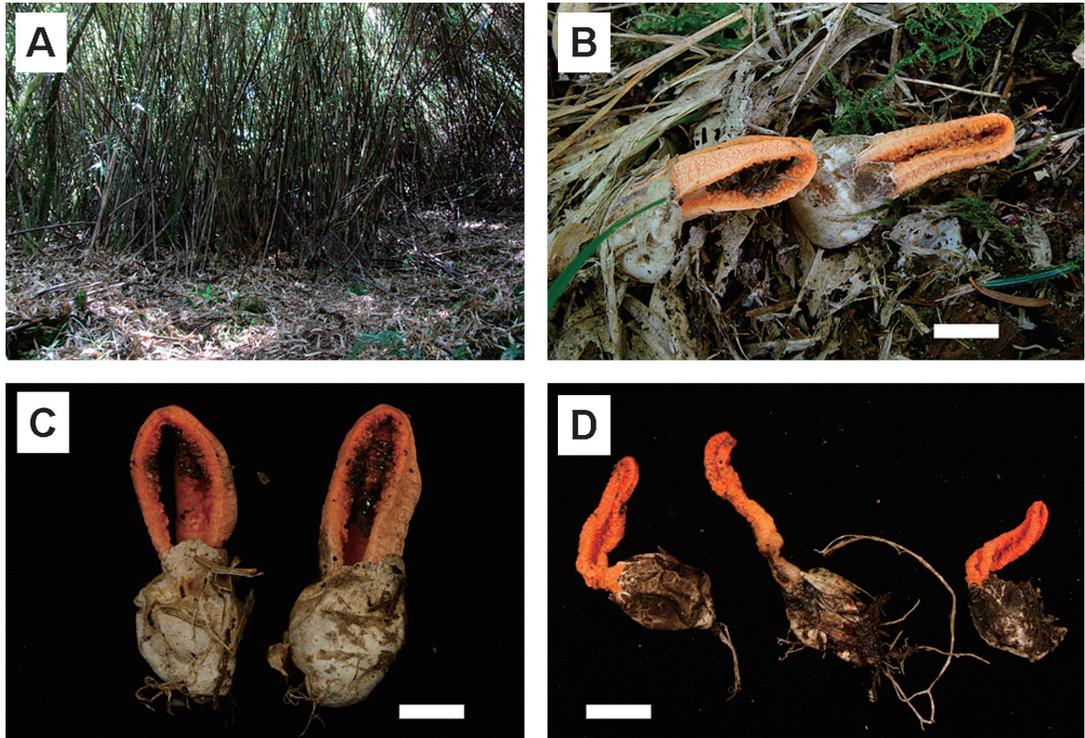


Fig. 2. Habitat and basidiomata of *Pseudocolus fusiformis*. A. Habitat of *Pseudocolus fusiformis* in Taiwan. Note dense bamboo stands. B, C. Mature fruit bodies of *P. fusiformis* (KH-TW08-022). D. Mature and slightly dried up fruit bodies of *P. fusiformis* (KH-TW08-021). Note thick and long rhizomorphs attached at base. Bars=1 cm.

Family **Lysuraceae** Corda, *Icones Fungorum* 5: 28, 1842, "Lysuroideae".

Lysurus mokusin (Cibot: Pers.) Fr., *Syst. Mycol.* 2: 286, 1822.

Synonyms: *Mutinus pentagonus* Bailey, *Queensland Bot. Bull.* 10: 35, 1895; *Colus pentagonus* (Bailey) Sawada, *Rept. Gov. Res. Inst. Dep. Agric. Formosa* 61: 64, 1933; *Lysurus sinensis* Lloyd, *Mycol. Writ.* 5: 718, 1917.

Records from Taiwan:

Sawada, *List of fungi found in Taiwan (Formosa)*. 272, 279, 1961.

Dring, *Kew Bulletin* 35: 74, 1980.

Liu, *Beih. Nova Hedwigia* 76: 33, 1984.

Wang *et al.*, *List of the Fungi in Taiwan*. 114, 136, 1999.

Remarks. This species has also been reported from China, Japan, North America and Australia (Dring, 1980; Imazeki & Hongo, 1989;

Liu, 1984). It is speculated that the species was introduced to Australia and North America from Asia (Cunningham, 1944). The genus has traditionally been treated as a member of Clathraceae, but phylogenetic analyses clearly demonstrated that *Lysurus* is more closely related to Phallaceae than it is to Clathraceae (Hosaka *et al.*, 2006). The species was not found during the fieldwork in Taiwan by the author in 2008.

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台湾のスッポントケ目（スッポントケ亜綱、担子菌門）（予報）

保坂健太郎

2008年に台湾中部の南投縣および台中縣において実施したフィールドサンプリング，国立科学博物館菌類標本庫の探索，文献による記録などに基づき，台湾に3科8属14種のスッポントケ類の存在が明らかになった。