

Competing sexual-aseexual generic names of *Pezizomycetes* and recommendations for use

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Abstract: Following the change that eliminated dual naming of sexual and asexual morphs of fungi, generic names of *Pezizomycetes* have been evaluated to determine which of the competing names should be recommended for use. Evaluation is based on congruence of type species to determine if the names are congeneric and which name is most commonly cited as well as priority. In the *Pezizomycetes* six pairs of generic names were determined to compete. In all cases the older name, representing the sexual morph, is recommended for use, specifically *Caloscypha* rather than *Geniculodendron*, *Desmazierella* rather than *Verticicladium*, *Miladina* rather than *Actinosporella*, *Morchella* rather than *Costantinella*, *Sarcoscypha* rather than *Molliardiomyces*, and *Trichophaea* rather than *Dichobotrys*.

Key words:

Ascomycota
dual nomenclature
Pezizomycetes
pleomorphic fungi
protected lists
taxonomy

Article info: Submitted: 8 November 2016; Accepted: 15 November 2016; Published: 23 November 2016.

INTRODUCTION

With the changes in the *International Code of Nomenclature for algae, fungi, and plants* (ICN; McNeill *et al.* 2012), one species of fungus may no longer be referred to by more than one scientific name. The practice of giving separate scientific names to sexual and asexual morphs (dual nomenclature) of the same species is no longer acceptable (Art. 59). As for all organisms governed by the ICN, the correct scientific name for fungal species is determined primarily by the principle of priority of publication (Art. 11). However, in some cases it is expedient to use a later generic or specific name as determined by an international cadre of mycologists familiar with the fungal group. Reviews of competing generic names along with recommendations for names to use have been published by Working Groups of the International Commission for the Taxonomy of Fungi (ICTF; e.g. Rossman *et al.* 2015, Réblová *et al.* 2016). This paper reviews the competing sexual and asexual generic names in the *Pezizomycetes* and makes recommendations for the application of names.

The class *Pezizomycetes*, sometimes referred to by the ordinal name *Pezizales* or simply as ‘operculate discomycetes’, includes about 200 genera with 2000 species placed in 16 families (Kirk *et al.* 2008, Lumbsch & Huhndorf 2010). Molecular phylogenetic studies have added new families (Landvik *et al.* 1997, Harmaja 2002, Pfister *et al.* 2008), and demonstrate that additional research is needed to circumscribe the families and genera in this class (Hansen & Pfister 2006, Perry *et al.* 2007, Pfister *et al.* 2013,

Hansen *et al.* 2013). Most species are known primarily as sexual morphs although asexual morphs are increasingly discovered. Studies of asexual morphs have been useful in defining species (Paden 1972, 1986, Paden *et al.* 1978, Carris *et al.* 2015).

Here we consider six competing generic names with pleomorphic type species in the *Pezizomycetes*. In all cases the generic name recommended here represents the older sexual morph as summarized in Table 1, thus no action is needed such as protection of a name or approval of the Nomenclature Committee for Fungi (NCF). No new combinations of species names are needed. Below is the detailed rationale for these recommendations.

In the following notes, (A) = a name typified by an asexual morph, and (S) = a name typified by a sexual morph.

GENERIC NAMES RECOMMENDED FOR USE IN PEZIZOMYCETES

Use *Caloscypha* Boud. 1885 (S) rather than *Geniculodendron* G.A. Salt 1974 (A)

The type species of *Caloscypha*, *C. fulgens*, is associated with conifers in the Northern Hemisphere (Pfister *et al.* 2013) and develops in early spring after the snow melts. One additional name, *C. musiva* (Fr.) Boud 1907, is currently accepted in *Caloscypha* but its identity is unclear (Pfister *et al.* 2013). The monotypic genus *Geniculodendron* based on *G. pyriforme*

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Table 1. Generic names recommended and competing for use in the *Pezizomycetes* with citations and type species.

Recommended generic name, citation and type species	Suppressed generic name, citation, and type species
Caloscypha Boud. in Bull. Soc. Mycol. France 1 : 103. 1885. Type: <i>C. fulgens</i> (Pers.) Boud. 1885, basionym: <i>Peziza fulgens</i> Pers. 1822.	<i>Geniculodendron</i> G.A. Salt in Trans. Brit. Mycol. Soc. 63 : 339. 1974. Type: <i>G. pyriforme</i> G.A. Salt 1974, now regarded as <i>Caloscypha fulgens</i> (Pers.) Boud. 1885.
Desmazierella Lib. in Ann. Sci. Nat., Bot., sér. 1 17 : 83. 1829. Type: <i>D. acicola</i> Lib. 1829.	<i>Verticicladium</i> Preuss in <i>Linnaea</i> 24 : 127. 1851. Type: <i>V. trifidum</i> Preuss 1851, now regarded as <i>Desmazierella acicola</i> Lib. 1829.
Miladina Svrček in Česká Mykol. 26 : 213. 1972. Type: <i>M. lecithina</i> (Cooke) Svrček (1972), basionym: <i>Peziza lecithina</i> Cooke (1876).	<i>Actinosporella</i> Descals et al. in Canad. J. Bot. 76 : 1647. 1999. Type: <i>A. megalospora</i> (Ingold) Descals et al. 1999, basionym: <i>Actinospora megalospora</i> Ingold 1952, now regarded as <i>Miladina lecithina</i> (Cooke) Svrček 1972.
Morchella Dill. ex Pers. in Neues Mag. Bot. 1 : 116. 1794. Type: <i>M. esculenta</i> (L.) Pers. 1797.	<i>Costantinella</i> Matr., Rech. Developp. Mucedin: 97. 1892. Type: <i>C. cristata</i> Matr. 1892, now regarded as <i>Morchella esculenta</i> (L.) Pers. 1797.
Sarcoscypha (Fr.) Boud. in Bull. Soc. Mycol. France 1 : 103. 1885, basionym: <i>Peziza</i> trib. <i>Sarcoscyphae</i> Fr. 1822. Type: <i>S. coccinea</i> (Gray) Boud. 1885, basionym: <i>Macroscyphus coccineus</i> Gray 1821.	<i>Molliardiomyces</i> Paden in Canad. J. Bot. 62 : 21. 1984. Type: <i>M. coccineus</i> Paden 1984, now regarded as <i>Sarcoscypha austriaca</i> (Sacc.) Boud. 1907.
Trichophaea Boud. in Bull. Soc. Mycol. France 1 : 105. 1885. Type: <i>T. woolhopeia</i> (Cooke & W. Phillips) Boud. 1885.	<i>Dichobotrys</i> Hennebert in <i>Persoonia</i> 7 : 193. 1973. Type: <i>D. abundans</i> Hennebert 1973, now regarded as <i>Trichophaea abundans</i> (P. Karst.) Boud. 1907.

was described as a psychrophilic fungus pathogenic on seeds of various conifers (Salt 1974). Paden et al. (1978) proved that *G. pyriforme* is the asexual morph of *C. fulgens* through comparing cultural characteristics, conidiophore and conidial morphology, and growth-temperature and pathogenicity studies. *Geniculodendron* has been cited in pathogenicity studies alongside *Caloscypha* (e.g. Phillips & Burdekin 1992, Schröder et al. 2002), thus both names are used. Since *Caloscypha* is the earliest name, is more widely used, and has priority, it is recommended for use over *Geniculodendron*.

Use *Desmazierella* Lib. 1829 (S) rather than *Verticicladium* Preuss 1851 (A)

Verticicladium trifidum, type of *Verticicladium*, was linked to *Desmazierella acicola*, type of *Desmazierella*, by Hughes (1951) using physical association and morphological methods, thus these generic names are synonyms. *Verticicladium trifidum*, the asexual morph, has long been associated with decaying pine needles (Mitchell et al. 1978). The asexual morph was most recently determined to consist of eight geographical lineages using ITS rDNA sequences, but morphology could not effectively distinguish most lineages (Martinović et al. 2016). These authors suggested that the sexual morph should be studied to determine whether there are multiple lineages (cryptic species) within the current concept of *Verticicladium*. It was suggested that the strains studied by Hughes (1951) belong to a European clade (Martinović et al. 2016). While RPB2 and 28S sequences of a sexual morph identified as *D. acicola* matched sequences of the asexual form in the Martinović et al. (2016) study, no ITS sequence of the sexual morph is available, and the types have not been sequenced. Historical confusion over the delimitation of *Verticicladium* is evidenced by the placement of many former species into other genera by Subramanian (1956), Hughes (1958), and Gams & Holubova-Jechova (1976). It is apparent that this genus requires a deeper study

using molecular phylogenetics and comparative morphology of sexual morphs. We recommend the use of *Desmazierella* over *Verticicladium* because *Desmazierella* has priority. This was the recommendation of Martinović et al. (2016).

Use *Miladina* Svrček 1972 (S) rather than *Actinosporella* Descals et al. 1999 (A)

The monotypic genus *Miladina* is based on *Peziza lecithina*. The orange ascomata of *Miladina* occur mostly on partly submerged woody substrates in freshwater streams. An aquatic hyphomycete *Actinospora megalospora* was described in the illegitimate monotypic fungus genus *Actinospora* (Ingold 1952; non *Actinospora* Turtzianov 1835, *Ranunculaceae*) and later renamed *Actinosporella megalospora*, type of the monotypic *Actinosporella* (Descals et al. 1999). The connection between *Miladina lecithina* and *Actinosporella megalospora* was originally ascertained by monoascospore isolates from *M. lecithina* yielding *A. megalospora* conidia after submerging pieces of the cultures in water (Descals & Webster 1978). Thus these two generic names are synonyms. Apothecia of *M. lecithina* from nature were sequenced; this species was placed in the well-supported *Scutellinia/Miladina* lineage of *Pyronemataceae* (Hansen et al. 2013). Isolates from the asexual morph were not sequenced. The generic names of both morphs are used more or less equally. *Miladina* has priority and is recommended for use rather than *Actinosporella*.

Use *Morchella* Dill. ex Pers. 1794 (S) rather than *Costantinella* Matr. 1892 (A)

The type species of *Morchella*, *M. esculenta*, has long been known to be associated with an asexual morph described as *Costantinella cristata* (Molliard 1904), a name regarded as *C. terrestris* by Hughes (1958). The linkage between *Morchella* and *Costantinella* was confirmed by later authors through cultural and molecular studies (Paden 1972, Volk & Leonard 1990, Carris et al. 2015). Since the type species of *Costantinella*,

C. cristata, refers to the asexual morph of the type species of *Morchella*, *M. esculenta*, these generic names are synonyms. The genus *Morchella* includes at least 65 phylogenetically distinct species, many of which are highly prized edibles, and commercially valued in the morel-rich countries of China, Europe, Turkey, and the USA (Du *et al.* 2015, Richard *et al.* 2015), with significant advances toward their cultivation (e.g. Ower *et al.* 1986, 1988, Masaphy 2010). A costantinella-like asexual morph was determined with molecular methods to also occur in the related genera *Disciotis* Boud. 1885, *Gyromitra* Fr. 1849, and *Hydnotrya* Berk. & Broome 1846 (Carris *et al.* 2015). *Costantinella* is less frequently used than *Morchella* and includes only seven species. There is no question that the generic name *Morchella* has priority and is widely used, thus we recommended it for adoption.

Use *Sarcoscypha* (Fr.) Boud. 1885 (S) rather than *Molliardiomyces* Paden 1984 (A)

The asexual morph of *Sarcoscypha coccinea*, type of *Sarcoscypha*, was originally described as *Molliardiomyces coccineus*, type of *Molliardiomyces*, suggesting that these generic names are synonyms. Later, as part of a monographic account of *Sarcoscypha* in North America, Harrington (1990) concluded that the sexual morph of *M. coccineus* is *S. austriaca* while the asexual morph of *S. coccinea* is *M. eucoccineus* F.A. Harrington 1990. Nevertheless, the type species of *Sarcoscypha* and *Molliardiomyces* are congeneric and the generic names are synonyms. Ten names have been placed in *Molliardiomyces*, however, these have been linked to species throughout the family *Sarcoscyphaceae*. *Molliardiomyces domingensis* Paden 1984 is considered the asexual morph of *Phillipsia domingensis* Berk. 1881 while *M. cupressinus* Paden 1984 was described as the asexual morph of *Pithya cupressina* (Batsch) Fuckel 1870 (Paden 1984). Most of the names in *Molliardiomyces* were established by Paden (1984) using cultural methods, and thus are later names than those of their sexual morphs. *Sarcoscypha* is widely used, includes over thirty species, and has priority, thus the use of *Sarcoscypha* is recommended.

Use *Trichophaea* Boud. 1885 (S) rather than *Dichobotrys* Hennebert 1973 (A)

The genus *Dichobotrys* was established for *D. abundans*, and considered to be the asexual morph of *Trichophaea abundans*. In the same study, three additional species of *Dichobotrys* were connected to described species of *Trichophaea*: *D. brunnea* Hennebert 1973 was linked to *Trichophaea brunnea* (Alb. & Schwein.) L.R. Batra 1963, *D. parvispora* Hennebert 1973 was linked to *T. saccata* (H.C. Evans) Korf 1973, and *D. sessilispora* Hennebert 1973 was linked to *T. minuta* (Cain) Korf (Hennebert 1973). The linkage between sexual and asexual morphs was determined by the production of both morphs in the same culture (Hennebert 1973). Hansen *et al.* (2013) showed through a multi-gene phylogenetic analysis that the type species of *Trichophaea*, *T. woolhopeia*, was congeneric with *T. abundans*. *Trichophaea* has been demonstrated to be paraphyletic, but the majority of sequenced species, including *T. brunnea*, *T. minuta*, and *T. saccata*, belong to the clade with *T. woolhopeia* (Perry *et al.* 2007, Hansen *et al.* 2013). Neither

Trichophaea hybrida nor *T. hemisphaerioides*, which are only distantly related to the core clade of *Trichophaea*, are known to produce an anamorph. While *Trichophaea* includes 46 species, *Dichobotrys* with four species has not been widely used. Given its widespread use and priority, the use of *Trichophaea* is recommended.

REFERENCES

- Carris LM, Peever TL, McCotter SW (2015) Mitospore stages of *Disciotis*, *Gyromitra* and *Morchella* in the inland Pacific Northwest USA. *Mycologia* **107**: 729–744.
- Descals E, Marvanová L, Webster J (1999) New taxa and combinations of aquatic hyphomycetes. *Canadian Journal of Botany* **76**: 1647–1659.
- Descals E, Webster J (1978) *Miladina lecithina* (Pezizales), the ascigerous state of *Actinospora megalospora*. *Transactions of the British Mycological Society* **70**: 466–472.
- Du X-H, Zhao Q, Yang ZL (2015) A review on research advances, issues, and perspectives of morels. *Mycology* **6**: 78–85.
- Gams W, Holubová-Jechová V (1976) *Chloridium* and some other dematiaceous hyphomycetes growing on decaying wood. *Studies in Mycology* **13**: 1–99.
- Hansen K, Pfister DH (2007) (2006). Systematics of the *Pezizomycetes*-the operculate discomycetes. *Mycologia* **98**: 1029–1040.
- Hansen K, Perry BA, Dranginis AW, Pfister DH (2013) A phylogeny of the highly diverse cup-fungus family *Pyrenomataceae* (*Pezizomycetes*, *Ascomycota*) clarifies relationships and evolution of selected life history traits. *Molecular Phylogenetics and Evolution* **67**: 311–335.
- Harrington FA (1990) *Sarcoscypha* in North America (*Pezizales*, *Sarcoscyphaceae*). *Mycotaxon* **38**: 417–458.
- Hennebert G (1973) *Botrytis* and botrytis-like fungi. *Persoonia* **7**: 183–204.
- Hughes SJ (1951) Studies on microfungi IX. *Calcarisporium*, *Verticicladium* and *Hansfordia* (gen. nov.). *Mycological Papers* **43**: 3–25.
- Hughes SJ (1958) Revisions hyphomycetum aliquot cum appendice de nominibus rejiciendis. *Canadian Journal of Botany* **36**: 727–836.
- Ingold CT (1952) *Actinospora megalospora* n. sp., an aquatic hyphomycete. *Transactions of the British Mycological Society* **35**: 66–70.
- Kirk PM, Cannon PF, Minter DW, Stalpers JA (2008) *Ainsworth & Bisby's Dictionary of the Fungi*. 10th edn. Wallingford: CAB International.
- Landvik S, Egger KN, Schumacher T (1997) Towards a subordinal classification of the *Pezizales* (*Ascomycota*): phylogenetic analyses of SSU rDNA sequences. *Nordic Journal of Botany* **17**: 403–418.
- Lumbsch HT, Huhndorf SM (2010) Myconet 14. Outline of *Ascomycota* – 2009. *Fieldiana, Life Earth Sci.* **1**: 1–42.
- Martinović T, Koukol O, Hirose D (2016) Distinct phylogeographic structure recognized within *Desmazierella acicola*. *Mycologia* **108**: 20–30.
- Masaphy S (2010) Biotechnology of morel mushrooms: successful fruiting body formation and development in a soilless system. *Biotechnology Letters* **32**: 1523–1527.

- McNeill J, Barrie FF, Buck WR, Demoulin V, Greuter W, et al. (eds) (2012) *International Code of Nomenclature for algae, fungi, and plants (Melbourne Code)*. [Regnum vegetabile no. 154.] Königstein: Koeltz Scientific Books.
- Mitchell CP, Millar CS, Minter DW (1978). Studies on decomposition of Scots pine needles. *Transactions of the British Mycological Society* **71**: 343–348.
- Molliard M (1904) Forme conidienne et sclerotes de *Morchella esculenta* Pers. *Revue Generale de Botanique* **16**: 209–218.
- Ower R, Mills G, Malachowski J (1986) Cultivation of *Morchella*. US Patent No 4,594,809.
- Ower R, Mills G, Malachowski J (1988) Cultivation of *Morchella*. US Patent No 4,757,640.
- Paden JW (1972) Imperfect states and the taxonomy of the *Pezizales*. *Persoonia* **6**: 405–414.
- Paden JW (1984) A new genus of hyphomycetes with teleomorphs in the *Sarcoscyphaceae* (*Pezizales*, *Sarcoscyphineae*). *Canadian Journal of Botany* **62**: 211–218.
- Paden JW (1986) On the anamorph of *Phillipsia cristata*. *Mycotaxon* **25**: 165–174.
- Paden JW, Sutherland JR, Woods TAD (1978) *Caloscypha fulgens* (*Ascomycetidae*, *Pezizales*): the perfect state of the conifer seed pathogen *Geniculodendron pyriforme* (*Deuteromycotina*, *Hyphomycetes*) *Canadian Journal of Botany* **56**: 2375–2379.
- Perry BA, Hansen K, Pfister DH (2007) A phylogenetic overview of the family *Pyronemataceae* (*Ascomycota*, *Pezizales*). *Mycological Research* **111**: 549–571.
- Pfister DH, Slater C, Hansen K (2008) *Chorioactidaceae*: a new family in the *Pezizales* (*Ascomycota*) with four genera. *Mycological Research* **112**: 513–27.
- Pfister DH, Agnello C, Lantieri A, LoBuglio KF (2013) The *Caloscyphaceae* (*Pezizomycetes*, *Ascomycota*), with a new genus. *Mycological Progress* **12**: 667–674.
- Phillips DH, Burdekin DA (1992) *Diseases of forest and ornamental trees*. 2nd edn. London: Macmillan Press.
- Réblová M, Miller AN, Rossman AY, Seifert KA, Crous PW, et al. (2016) Recommendations for competing sexual-asexually typified generic names in *Sordariomycetes* (except *Diaporthales*, *Hypocreales*, and *Magnaporthales*). *IMA Fungus* **7**: 131–153.
- Richard F, Bellanger J-M, Clowetz P, Hansen K, O'Donnell K et al. (2015) True morels (*Morchella*, *Pezizales*) of Europe and North America: evolutionary relationship inferred from multilocus data and a unified taxonomy. *Mycologia* **107**: 359–382.
- Rossman AY, Adams GC, Cannon PF, Castlebury LA, Crous PW et al. (2015) Recommendations of generic names in *Diaporthales* competing for protection or use. *IMA Fungus* **6**: 145–154.
- Salt GA (1974) Etiology and morphology of *Geniculodendron pyriforme* gen. et sp. nov., a pathogen of conifer seeds. *Transactions of the British Mycological Society* **63**: 339–351.
- Schröder T, Kehr R, Hüttermann A (2002) First report of the seed-pathogen *Geniculodendron pyriforme*, the imperfect state of the ascomycete *Caloscypha fulgens* on imported conifer seeds in Germany. *Forest Pathology* **32**: 225–230.
- Subramanian CV (1956) *Hyphomycetes* -- II. *Journal of the Indian Botanical Society* **35**: 446–494.
- Volk TJ, Leonard TJ (1990) Cytology of the life cycle of *Morchella*. *Mycological Research* **94**: 399–406.