

Clavariachaetaceae, a family of neotropical Hymenochaetales (Basidiomycota) including clavarioid, pileate and resupinate species

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Abstract: Family Clavariachaetaceae (Basidiomycota, Hymenochaetales), two its genera *Clavariachaete* and *Dichochaete*, and all four very rare species distributed in South America are described.

Kokkuvõte: Clavariachaetaceae, neotroopiline Basidiomycota sugukond.

Esitatakse kandseente sugukonna Clavariachaetaceae, selle kahe perekonna ja kõigi nelja, Lõuna-Ameerikas väga harva leitud liigi kirjeldused ja levikuandmed. Sugukonda kuuluvad nii harikulistetataoliselt harunenud, kübarjate kui ka liibunud viljakahadega liigid.

INTRODUCTION

Lloyd (1922) described a curious new species *Dendrocladium peckoltii* characterized by branched “clavariaeform” (= ramarioid) basidiomes and presence of setae, typical of *Hymenochaete*. Corner (1950) in his monograph of *Clavaria* and allied genera described a new genus *Clavariachaete* for this species and another, closely related one (*Lachnocladium rubiginosum* Berk. & M.A. Curtis ex Cooke). Both species were represented in herbaria with only one, sterile specimen. Twenty years later, Corner (1970) revised the description of the type species using four new specimens found in Brazil. Jülich (1982) described a new family Clavariachaetaceae including only the type genus in this. Later Corner (1991) indicated to the similarity in hericioid (*Hericium*-like) structure of basidiomes of *Clavariachaete* and *Hydnochaete resupinata* (= *H. setosa*), but did not draw any conclusions on taxonomy of the last named species. Parmasto (2001) described a new genus, *Dichochaete* for two species (*Hymenochaete ceratophora* Job and *Hydnochaete resupinata* (Sw. : Fr.) Ryvarden) having hericioid structure of basidiomes similar to those in *Clavariachate*. A taxonomic survey of all four species of the family Clavariachaetaceae is given below.

MATERIALS AND METHODS

The study is based on herbarium specimens deposited in the herbaria BAFC, BPI, K, LSUM,

NY, O, S, SP and TAAM. Colour notations are given using Munsell Book of Color (1976, abbreviated: M) and Kornerup & Wanscher's handbook (1967; K & W). Spore size was measured and *Q* (length/width quotient) value calculated as described in Parmasto, 2006. Herbarium acronyms are after Holmgren, Holmgren & Barnett (1990).

TAXONOMIC DESCRIPTIONS

CLAVARIACHAETACEAE Jülich, Higher taxa Basidiomyc. 360. 1982.

Basidiomes erect, branched (ramarioid), effuso-reflexed (with flabelliform or dimidiate pilei) or effused, brown or brownish, xanthochroic (turning dark brown in KOH solution). Hyphal system monomitic or dimitic (with generative and dichohyphae); generative hyphae without clamps; setal hyphae present, sometimes few or absent; hymenial setae present. Basidiospores hyaline, inamyloid, thinwalled, ellipsoid or almost subglobose, 2.5–7 µm long.

On soil or on rotten wood.

Two genera, distributed in Neotropics.

Type. *Clavariachaete* Corner.

Rem. The family Clavariachaetaceae has been recognized as an independent one by only few mycologists (Parmasto, 2001; Zmitrovich & Wasser, 2004), but synonymized with Hymenochaetaceae by Cannon & Kirk (2007: 441).

Key to the genera of Clavariachaetaceae

- Basidiome erect, branched, clavarioid
(*Ramaria*-like) **Clavariachaete**
 Basidiome resupinate, effused-reflexed or
 dimidiate with plagiotropic pilei
 **Dichochaete**

CLAVARIACHAETE Corner, Monogr. Clav. 691, 268-269 (1950); Suppl. Monogr. Clav. 176 (1970).

Basidiomes erect, branched, clavarioid (*Ramaria*-like), brownish or brown, xanthochroic, slightly tomentose; branches slender, terete, dichotomously branched. In section with a central cylinder of densely agglutinated almost parallel brown(ish) hyphae and peripheral layer of more loosely interwoven hyphae with thickened or thin walls; hyphae of the peripheral layer dichotomously branched, with thinning tips (*Vararia*-like). Hyphal system monomitic; setal hyphae absent. Setae cylindrical-conical or subfusoid, 30–100×7–16 µm. No cystidia; basidia up to 20 µm long, cylindrical or clavate, with 4 (?) sterigmata; spores hyaline, ellipsoid or almost subglobose, 5–6 µm long.

Two very rare species in South America (Brazil, Venezuela); on wood and/or soil.

Type. *C. peckoltii* (Lloyd) Corner.

Rem. *Clavariachaete* is the only genus in Hymenochaetales with negatively geotropic branched (clavarioid) basidiomes. It has some similarity with the poroid genus *Coltricia* which also has negatively geotropic basidiomes and dichotomously branching hyphae not found in other poroid Hymenochaetales (Núñez & Ryvarden, 2000). However, similar dichohyphae are common in two species of *Hymenochaete* (*H. ceratophora*, *H. resupinata*) recently transferred to a new genus *Dichochaete* (Parmasto, 2000).

The structure of the basidiome of *Clavariachaete* may be homologized with the structure of *Hymenochaete* species. The central cylinder called *medulla* by Corner (1950) has a peripheral tube of closely entwined hyphae with thick walls forming a black ring in transverse section; this is obviously homologous with cortex in *Hymenochaete* and some other Hymenochaetales. Surrounding the central tube outer layer has been called *sterile cortex* in the stem (trunk) of the basidiome (Corner, 1950: 268, 269) or *subhymenium* in the fertile branches (of *C. rubiginosa* – Corner, 1950: 269); it seems to be

homologous with hyphal layer in *Hymenochaete* (= *context* in poroid Hymenochaetales).

Key to the species of Clavariachaete

- Branches of the basidiome in upper part flattened, sometimes antler-like; spores ellipsoid, (4.8–)5.0–5.7×3.5–4.0(–4.2) µm
 **C. peckoltii**
 Branches cylindrical; spores broadly ellipsoid to subglobose, (4.8–)5.0–6.5(–7.0)×4.0–5.6 µm..... **C. rubiginosa**

CLAVARIACHAETE PECKOLTII (Lloyd) Corner, Monogr. Clav. 269, f. 100-101 (1950); Corner, Suppl. Monogr. Clav. 177, f. 44-45 (1970). *Dendrocladium peckoltii* Lloyd, Mycol. Writ. 7 (1) (Mycol. Notes 66): 1111, f. 2068 (1922). – Fig. 1.

Basidiomes branched (*Ramaria*-like), 2–10 cm high, 2–4 cm in diam, hard and fragile when dry, with short (0.5–1.5 cm) never hollow velu-



Fig. 1. *Clavariachaete peckoltii* (SP 92457). Photo by Urmas Tartes.

tinat stem or a few stems in a fascicle, 1–3(–5) mm in diam and numerous polychotomous below, dichotomous above flattened, sometimes antler-like subtomentose branches, dark ferrugineous below, ferrugineo-ochraceous above, in herbarium specimens light umber (M: 5 YR 4–5/6; K & W: 6 E 7) or dark fulvous (M: 5–7.5 YR 5/8); tips thin (0.3–1 mm), cylindrical, obtuse or subulate, sometimes lighter coloured (when dry light Sienna; M: 5 YR 7/6, K & W: 6 B 5).

In section, the branches of basidiome have a hard central cylinder composed of densely parallel agglutinated hyphae, and tomentose peripheral part of more loosely interwoven hyphae; in some specimens (SP 56225) distinct black line between these layers present.

Hyphal system monomitic; hyphae in central part of the basidiome with thick or thickened walls, brownish, 3–6(–7) μm in diam; in peripheral layer yellowish or brownish, with thickened walls, branched under right angle (sometimes in a crest-like way), 3–4 μm in diam, in distal part dichotomously forked with thinning tips and almost *Vararia*-like. Setae rare in some specimens, abundant in others, embedded, fusoid or conical, with acute or almost obtuse tip, dark reddish brown, 50–100(–200) \times 9–15 μm , without a hyphal sheath. Spores ellipsoid, with one side slightly flattened, (4.8–)5.0–5.7 \times 3.5–4.0(–4.2) μm .

Distribution. Brazil Southeast, very rare. All known specimens are collected near Rio de Janeiro and Sao Paulo.

Holotype studied. *Dendrocladium peckoltii*: Brazil, Rio de Janeiro, G. Peckolt (BPI 333294 = Lloyd Herb. 33031).

Other specimens studied. BRAZIL. Rio de Janeiro, Floresta da Tijuca, est. Guanabar, alt. 320 m, 5 May 1957 O. & K. Fidalgo 500/1300 (SP 46674 and 56225, det. E.J.H. Corner); 26 May 1957, same locality and collectors, no. 505/1305 (SP 56226, det. Corner); 4 Jul 1957, same locality and collectors, SP 46674 (LSUM); Mata da Tijuca, Est. Guanabara, 4 Apr 1966 B. Lowy 575BR, SP 92457 (a part in LSUM, det. E. Parmasto); Sao Paulo, Parque do Estado, 20 Jan 1971 B.V. Skvortzov 3 (LSUM 2341, det. E. Parmasto). – The specimens indicated in the Bononi's paper (1984: 45; SP 157396, 177756) are actually *Hymenochaete damicornis* (Link : Fr.) Lév.

Rem. Flattened axils and branches is one of the best distinguishing characters of this species. The 6–8-spored basidia described by Corner in the specimen no. 1300 have not been seen by me; the pip-shaped spores 3–3.5 \times 2–2.3 μm

described by him may be alien basidiospores, or conidia which are not rare in this specimen. In the holotype conidia about 4–5 \times 3 μm are seen in preparates near the tips of the branches of the basidiome; the weakly differentiated conidiophores seem to be of *Phialophora*-type. Setae have been described as abundant by Corner (1970) but are rare in most specimens studied by me.

Mean spore size (μm) and *Q* value:

5.27 \times 3.62	1.46	Brazil, SP 56225
5.31 \times 3.64	1.46	Brazil, SP 46674
5.48 \times 3.65	1.50	Brazil, SP 56226

CLAVARIACHAETE RUBIGINOSA (Berk. & M.A. Curtis ex Cooke) Corner, Monogr. Clav. 269, f. 100–101 (1950) (*‘rubiginosum’*). *Lachnocladium rubiginosum* Berk. & M.A. Curtis ex Cooke, Grevillea 20 (93): 11 (1891). – Fig. 2, 3.

Basidiomes fastigiate, richly branched, fasciculate, 2–8 cm high, 2–4 cm in diam, tough-textured when fresh, hard and fragile when dry, with short velutinate, in basal part hollow stem 2–3 cm long and 2–4 mm in diam, 4–5 times dichotomously or sympodially branched;



Fig. 2. *Clavariachaete rubiginosa*, holotype (K). Scanned by Sophie Kemp.



Fig. 3. *Clavariachaete rubiginosa* (NY, Halling 4151). Photo by R.E. Halling

branches round or slightly flattened, velutinous, near tips slightly pulverulent, light umber below (M: 5 YR 4–5/6; K & M: 6 D–E 7–8, rust brown or cocoa brown); tips thin (0.5–1 mm), obtuse or subulate, lighter coloured (M: 5 YR 6/6; K & W: 6 D 8).

In section, the branches of basidiome have a hard central cylinder composed of densely parallel agglutinated hyphae, and tomentose peripheral part of more loosely interwoven hyphae.

Hyphal system monomitic; hyphae in central part of the basidiome densely parallel, with thick walls, brown, 3–6 μm in diam; in peripheral layer interweaved, brownish (partly subhyaline), with thickened walls, branched at a wide angle or dichotomously, with rare septa, 3–6 μm in diam, in distal part dichotomously forked. Setae not numerous, mostly embedded, fusoid or cylindrical-conical, with acute tip, dark reddish brown, 30–70 \times 7–12 μm in the Halling's specimen, (80–)90–200 \times (8–)10–16(–20) μm in holotype, with somewhat granulose or encrusted with yellowish resinal matter tip, without a hyphal sheath. Subhymenium thin; basidia cylindrical, in upper part slightly constricted, 15–30 \times 6–7 μm , with 4 sterigmata; spores broadly ellipsoid to subglobose, some with one side slightly flattened, (4.8–)5.0–6.5(–7.0) \times 4.0–5.6 μm .

Distribution. Venezuela; find only three times.

Holotype studied. *Lachnocladium rubiginosum*: Venezuela (K 218).

Other specimen studied. Venezuela, Amazonas, Dpto. Rio Negro, near mouth of Cañon Grande, 00°50' N, 66°10' W, on sand, 3 Feb 1985 leg. & det. R.E. Halling 4151 (NY).

Rem. Similar to *C. peckoltii*; differs in not flattened slender branches, possibly also in basidiospore size. Setal size is different in the two specimens known, but setae seem to be very variable in both species of *Clavariachaete*.

Mean spore size (μm) and *Q* value:

5.26 \times 4.33 1.22 Venezuela, NY, Halling 4151

6.22 \times 5.06 1.23 Venezuela, K, holotype.

A macroscopically similar specimen collected and identified as *C. rubiginosa* by Leif Ryvar den has been found in Venezuela, Estado Bolivar, Las Nieves, on dead hardwood, 12 Jun 1995 (O 37933; cf. Hjortstam, Ryvar den & Iturriaga, 2005: 53). This specimen is without any spores, with rare hymenial setae in the upper part of the branches, more numerous in the middle part, 55–80 \times 8–9.5 μm , and numerous setae in the basal part of the stem, 90–145 \times 8.5–11(–13) μm . Only a few hyphae are dichotomously branched.

DICHOCHAETE Parmasto, Folia Cryptogamica Estonica 37: 56 (2001).

Basidiome effused or effuse-reflexed, pilei thick (up to 3 mm); pileal surface radiately fibrillose or strigose; hymenophore smooth, granulose, colliculose, then in *D. setosa* warted or hydroid. Tomentum and cortex absent. Hyphal system heteromitic with generative and dichohyphae; setal hyphae present in context and in pileal cover, up to 250 μm long; dichohyphae strongly dendroidly branched, abundant at fimbriate margin and in teeth, forming numerous dendrohyphidia; other types of hyphidia and cystidia absent; hymenial setae aculeate or subfusoid, not bifurcate at base, up to 80 μ long; basidia subclavate, with 4 sterigmata; spores broadly ellipsoid, small (up to 4 μm long), hyaline, thin-walled.

Type. *Thelephora setosa* Sw.: Fr

Key to the species of *Dichochaete*

1. Basidiome effused, closely adnated2
 - Basidiome effuso-reflexed or resupinate with elevated margins **D. setosa**

2. Setae (50–)60–110×6–10 μm , projecting up to 60 μm above the hymenium
 **D. ceratophora**
 – Setae 30–45(–50)×7–10 μm , embedded or projecting up to 20 μm
 **Dichochaete sp. 6500/6516**

DICHOCHAETE CERATOPHORA (Job) Parmasto, Folia Crypt. Estonica 37: 56 (2001). – *Hymenochaete ceratophora* Job, Rev. Invest. Agrop. INTA 20 (1): 146 (1985). – *H. alabastrina* Escobar ex Léger, Cryptogamie, Mycol. 11 (4): 294, f. 3 (1990); Léger, Hymenochaete 51 (1998).

Distribution. Costa Rica, Argentina, Brazil.

Rem. Basidiomes of the species and its distribution have been described in detail by Parmasto (2000: 56–57). Four new collections from Brazil, State of Alagoes have been published later by Gibertoni, Parmasto & de Queiroz Cavalcanti (2003).

Mean spore size (μm) and *Q* value:

5.56×2.63	2.12	Brazil, TAA, Gibertoni 05
6.46×2.15	3.00	Brazil, TAA 171370

DICHOCHAETE SETOSA (Sw. : Fr.) Parmasto, Folia Crypt. Estonica 37: 57 (2001). – *Thelophora setosa* Sw.: Fr., Fl. Ind. Occid. 3: 1929 (1806); Fr., Syst. mycol. 3, Index 189 (1832). – *Hydnochaete resupinata* (Sw. : Fr.) Ryvarden, Mycotaxon 15: 437 (1982); Valenzuela et al., Polibotánica 1: 10, f. 6–13. – *Hymenochaete aspera* Berk. & M.A. Curtis, J. Linn. Soc. Bot. 10: 334 (1868); Léger, Hymenochaete 57 (1998).

Nomenclature and basidiomes of the species and its distribution have been described by Parmasto (2000: 57); some additional data will be given below.

Basidiome effused, effuso-reflexed or resupinate with elevated margins, closely adnated but sometimes separable, cottony soft or papery when dry, 100–3000 μm thick; pilei confluent, imbricate, flabelliform to dimidiate, (0.5–)1–3(–5) cm long and to 10 cm wide, flexible when dry. Surface of the pilei dark sienna to umber (M: 5–7.5 YR 6/8, 4/6 or 4/4; K & W: 6 E 7 or 6 D 5–6); hymenophore dark sienna to light umber (M: 5–7.5 YR 5/7, 5/5 or 4.5/6; K & W: 6 C 3–6 E 6–7 at the center, 6 B 4 at the edges). Mycelial strands usually present at the margin and at the base of the basidiome, up to 10 mm long,

finger-like, sometimes brighter coloured than the hymenium.

Setal layer 40–100 μm thick (when present); setae innumerable or numerous, 40–80×5–10 μm , projecting to 30–40 μm , conical to fusiform, with acute tip, straight, naked or enmeshed in hyphal sheaths, without incrustation. Basidiospores ellipsoid, 2.5–4.2×1.8–2.5 μm .

Distribution. Mexico; Costa Rica, Cuba, Dominica, Jamaica, Trinidad; Argentina, Brazil, Chile, Colombia; Ecuador, Venezuela; India, Nepal.

New localities. Belize. P. Roberts B 129 (K). Puerto Rico. Municipio Luquillo, Luquillo Mts., Sabana, 30 Jun 1996 K.-H. Larsson 9698 (TAA, det. E. Parmasto).

Rem. Strigose pileal surface and granular to hydroid hymenium are the most important characteristics of this species. Spores have very rarely been seen in this species. Léger (1998: 59) has found these in only one specimen (3–4×2 μm).

Mean spore size (μm) and *Q* value:

3.09×1.99	1.55	Belize, K, P. Roberts B129
3.83×2.03	1.88	Puerto Rico, TAA, K.H. Larsson 9698

DICHOCHAETE SP. 6500/6516

Basidiome effused, loosely adnated, soft coriaceous, up to 700 μm thick; hymenium smooth, thick-pelliculare, fragile, not cracked, vinaceous buff (M: 7.5 YR 6/3–4; K & W: 6–7 D 3–4, light brown); margin thick, abrupt, dark fulvous (7.5 YR 6/7); context dark fulvous.

Tomentum and cortex indistinct or absent; context composed of hyphal layer and a darker setal layer 50–100 μm thick. Context hyphae loosely interwoven, above the setal layer almost parallel; hyphal system subdimittic, with generative and skeletoid hyphae; setal hyphae absent. Generative hyphae subhyaline or yellowish, thin-walled, septate, 2–3.5 μm in diam; skeletoids numerous, brown, with thickened walls, some of these dichotomously or sympodially branched, 2–3.5 μm in diam, some with numerous short sidebranches. In setal stratum and hymenium crystals usually present.

Setae rare or numerous, conical, 30–45(–50)×7–10 μm , embedded or projecting up to 20 μm , tip blunt; naked or enmeshed in hyphal sheath. In the setal layer very numerous dichohyphae. Hyphidia and cystidia absent; dendrohyphidia present as numerous tips of

branched dichohyphae, with thickened walls; in specimen no. 6516 hymenial layer consists of very numerous subhyaline thin-walled repeatedly branched dendrohyphidia with tapering endbranches about 1–2 µm in diam and 10–15 µm long. No basidia or spores seen.

Specimens examined. Brazil, Bahia, C. Torrend (Lloyd Herb. 6516, BPI 329809); Rio Janeiro, G. Peckolt 11 (Lloyd Herb. 6500, BPI 329811).

Rem. Both collections studied are very small, consisting of some pieces of basidiomes up to 5 mm (no. 6516) or 10 mm (no. 6500) long. They are without basidia and spores, and that is why I avoided describing a new species.

Development of basidiomes of this species seems to be similar to this in *H. escobarii*: hymenial surface of a growing basidiome is densely covered with thin-walled dendrohyphidia, setae are not numerous or hidden by these. Later the walls of dendrohyphidia thicken and setae may be very numerous.

DISCUSSION

The only genus of Hymenochaetales with negatively geotropic clavarioid branched basidiomes, *Clavariachaete* has such an unique combination of characters that for it a new family, Clavariachaetaceae was described by Jülich (1982). Corner (1991) pointed to the similarity in hericoid structure of basidiomes of erect *Clavariachaete* and plagiotropic (dorsiventral) *Hydnochaete resupinata* (= *D. setosa*): hyphal ends are divaricately branching in both taxa. In *D. setosa*, context is “lacunose-fibrillose with branching and anastomosing fibrils” (Corner, 1991: 165).

In some of the specimens of *H. setosa* studied by me, at the margin of the basidiomes, but usually also on the hairy surface of pilei clavarioid outgrowths have been developed. These are obviously homologous with the basidiomes of *Clavariachaete*. Similar structure of basidiomes (presence of dichohyphae, ramarioid habitus) is unknown in other *Hymenochaete* or *Hydnochaete* species except *Hymenochaete ceratophora* Job. Parmasto (2001) published a new genus *Dichochoaete* to join the two taxa, different from all other *Hymenochaete* species. It is possible, that effused or narrowly pileate form of basidiomes (their plagiotropic construction) in *Dichochoaete* species is a plesiomorphic

character, and the ramarioid structure in *Clavariachaete* is an apomorphic character.

Dichohyphae are present in only some few species of Hymenochaetaceae s. l. – e.g., in *Coltricia focicola* (Berk. & M.A. Curtis) Murrill and *C. montagnei* (Fr.) Murrill (cf. Ryvardeen, 2004). Several species of this genus have basidiomes with a stipe with very hard core – a character common with *Clavariachaete* species.

We have made several attempts to get DNA from the basidiomes of *Clavariachaete* species, but almost in vain. Dr. Ellen Larsson managed to get a rather short (845 positions) sequence of the LSU region from *C. rubiginosa* (NY 4151); in our preliminary NJ analysis of *Hymenochaete* and *Hydnochaete* species (2002, unpublished) it was situated in a basal clade together with *Hymenochaete villosa* (Lév.) Bres. In 2008, Irja Saar (unpublished data) carried out a phylogenetic analysis of some 175 taxa of Hymenochaetaceae s. l. based on LSU region of rDNA. In the bootstrap analysis of MP trees, in one 0.84-supported clade *Clavariachaete rubiginosa*, *Dichochoaete ceratophora*, but also 4 *Hymenochaete* species were joined (*H. corrugata* (Fr.) Lév., *H. luteobadia* (Fr.) Höhn. & Litsch., *H. semistupposa* Petch, *H. villosa*). In the sister clade, all 5 *Coltricia* and 3 *Coltriciella* species studied were together. In another analysis using Neighbour Joining method, the same two sister clades joined into a common clade were found. However, *Dichochoaete setosa* had distinctly separate position in the trees far from the clades described above. Until further molecular taxonomic studies with more specimens involved will be continued, the taxonomic position of the two genera and four species of Clavariachaetaceae will remain unclear. Nevertheless, relation of Clavariachaetaceae and *Coltricia* seems to be worth of special attention.

One of the aims of this paper is to stimulate new efforts to find the extremely rare *Clavariachaete* species again in hopes, that their molecular characters will be studied.

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