

Description of *Chaetomium aureum*, *Corynascus sepedonium* and *Coniochaeta hansenii* newly recorded from Italy, and a key to coprophilous *Chaetomiaceae* and *Coniochaetaceae*

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Abstract: The ongoing survey of coprophilous basidiomycetes and ascomycetes from Italy results at this stage in describing further *Chaetomiaceae* and *Coniochaetaceae* species isolated from herbivore dung. The high frequency of occurrence on this substrate is explained with their supposed cellulolytic ability and with the abundance of cellulose and lignin in specific types of dung. *Chaetomium aureum*, *Corynascus sepedonium* and *Coniochaeta hansenii* are extensively discussed. A worldwide key to *Coniochaeta* with poly-spored asci is provided. A key to coprophilous *Chaetomiaceae* and *Coniochaetaceae* from Italy is also provided and each species is pictured by one or more coloured photographs.

Keywords: Ascomycota, coprophilous fungi, damp chamber cultures, herbivores, morphology.

Introduction

Our previous studies on coprophilous fungi from Italy allowed us to isolate twenty-seven *Chaetomiaceae* and three *Coniochaetaceae* from dung in damp chamber cultures (DOVERI, 2004, 2008, 2013). Living on and from dung is a fairly common style of life in mycobiota and *Chaetomiaceae* often colonize faecal material, particularly herbivore dung rich in cellulose, where they usually behave as decomposers (ARX *et al.*, 1986, 1988). Cellulolytic enzymes were also identified in *Coniochaeta* spp. (RAVINDRAN *et al.*, 2012) that probably explains why the two main groups of this genus are lignicolous or fimicolous. From a purely systematic point of view, lignicolous *Coniochaeta* spp. are identifiable by their ascospores with a partial germ slit, whereas those growing on dung have a complete germ slit, i.e. running the length of one side of the ascospores (LUNDQVIST, *in litt.*).

In the present work a morphologic study allowed me to identify three coprophilous species new to Italy: *Chaetomium aureum*, *Corynascus sepedonium* (*Chaetomiaceae* G. Winter), and *Coniochaeta hansenii* (*Coniochaetaceae* Malloch & Cain). This paper purpose is to describe and discuss the three species in detail and to place them in updated keys, consequently updating the number (277) of described coprophilous ascomycetes from Italy.

Material and methods

Chaetomium aureum, *Corynascus sepedonium* and *Coniochaeta hansenii* were obtained respectively from goat, sheep and hare dung collected in different regions of Italy and placed in non-sterilised damp chambers, following the methods suggested by DOVERI (2004). Cultured materials, incubated at room temperature (18–25°C), under natural light, were examined on alternate days using a stereomicroscope.

Microscopic examinations were carried out on specimens picked up from damp chambers and mounted in water, sometimes in Congo red and cotton blue in lactic acid. Spore length and width were measured in water on fifty ascospores discharged from mature ascomata.

Abbreviation: CLSM = author's personal herbarium.

Taxonomy and Discussion

Chaetomium aureum Chivers, *Proc. Amer. Acad. Arts & Sci.*, 48: 86 (1912), s. ARX *et al.* (1986) – Plates 1–3.

= *Chaetomium trilaterale* Chivers, *Proc. Amer. Acad. Arts & Sci.*, 48: 87 (1912).

- = *Chaetomium confusum* Van Warmelo, *Mycologia*, 58: 846 (1966).
- = *Chaetomium humicola* Van Warmelo, *Mycologia*, 58: 849 (1966).
- = *Chaetomium rubrogenum* Van Warmelo, *Mycologia*, 58: 852 (1966).
- = *Chaetomium soergelii* Sörgel, *in Seth, Beih. Nova Hedwigia*, 37: 100 (1972).
- = *Chaetomium trilaterale* var. *diporum* J.C. Cooke, *Mycologia*, 65: 1218 (1973).
- ? = *Chaetomium helicotrichum* J.P. Tewari & P.D. Agrawal, *Curr. Sci.*, 42: 176 (1973).
- = *Chaetomium angusti-ellipsoideum* G. Malhotra & Mukerji, *Rev. mycol. (Paris)*, 40: 179 (1976).
- (*vide* ARX *et al.*, 1986)

Perithecia 80–100 µm diam., globose, brownish by reflected light, membranous, wholly and densely hairy, with a small, inconspicuous ostiole. **Peridium** thin, a *textura angularis* of pale brown, polygonal, sometimes irregular cells, 7–11 × 6–9 µm, rarely disposed in a petaloid pattern around the hair bases. **Terminal hairs** very dense, greyish by reflected light, olive brown to reddish brown by transmitted light, warty, thick-walled, regularly septate, arcuate, circinate or 3–4-spirally coiled at the apex, 3.5–5 µm diam., slightly enlarged at the base, up to 6 µm. **Lateral and basal hairs** undulate, septate, 2–2.5 µm diam. **Asci** unitunicate, non-amyloid, lacking an apical apparatus, fasciculate, clavate, 8-spored, short-stalked, 30–38 × 10–12 µm. **Paraphyses** not seen. **Ascospores** irregularly biseriolate, hyaline in the early stages, containing one or more oil droplets, becoming greyish, (7.5–) 8–9 × 5–5.5 × 4.5–5 µm, inaequilateral, ovoidal or sometimes ellipsoidal in frontal view, flattened or concave at one side in lateral view, lunate, falcate, or dacryoid, thick-walled, with two germ pores, one at each end. **Asexual morph** not seen.

Material examined: ITALY, Livorno, isola di Montecristo, 42°20'330" N 10°17'31" E, 145 m a.s.l., about ten, superficial, gregarious specimens on Montecristo's goat (*Capra hircus*) dung, 8.4.2015, CLSM 006.15

CHIVERS (1912) described three new *Chaetomium* spp., *C. aureum*, *C. trilaterale*, *C. fusiforme*, very similar to each other in having globose or subglobose, small perithecia with unbranched, more or less arcuate terminal hairs, and inequilateral, usually biapiculate ascospores (CHIVERS, 1915). He distinguished *C. fusiforme* from the other two species by the longer and slender fusiform ascospores (15–16 × 4.8–5 µm versus 9–11 × 4.5–6 µm) and terminal hairs with circinate or convolute tips. He described *C. trilaterale* with perithecia slightly smaller than *C. aureum*, terminal hairs spirally coiled rather than incurved, and ascospores with the shape of a sphere section instead of irregularly ovate.

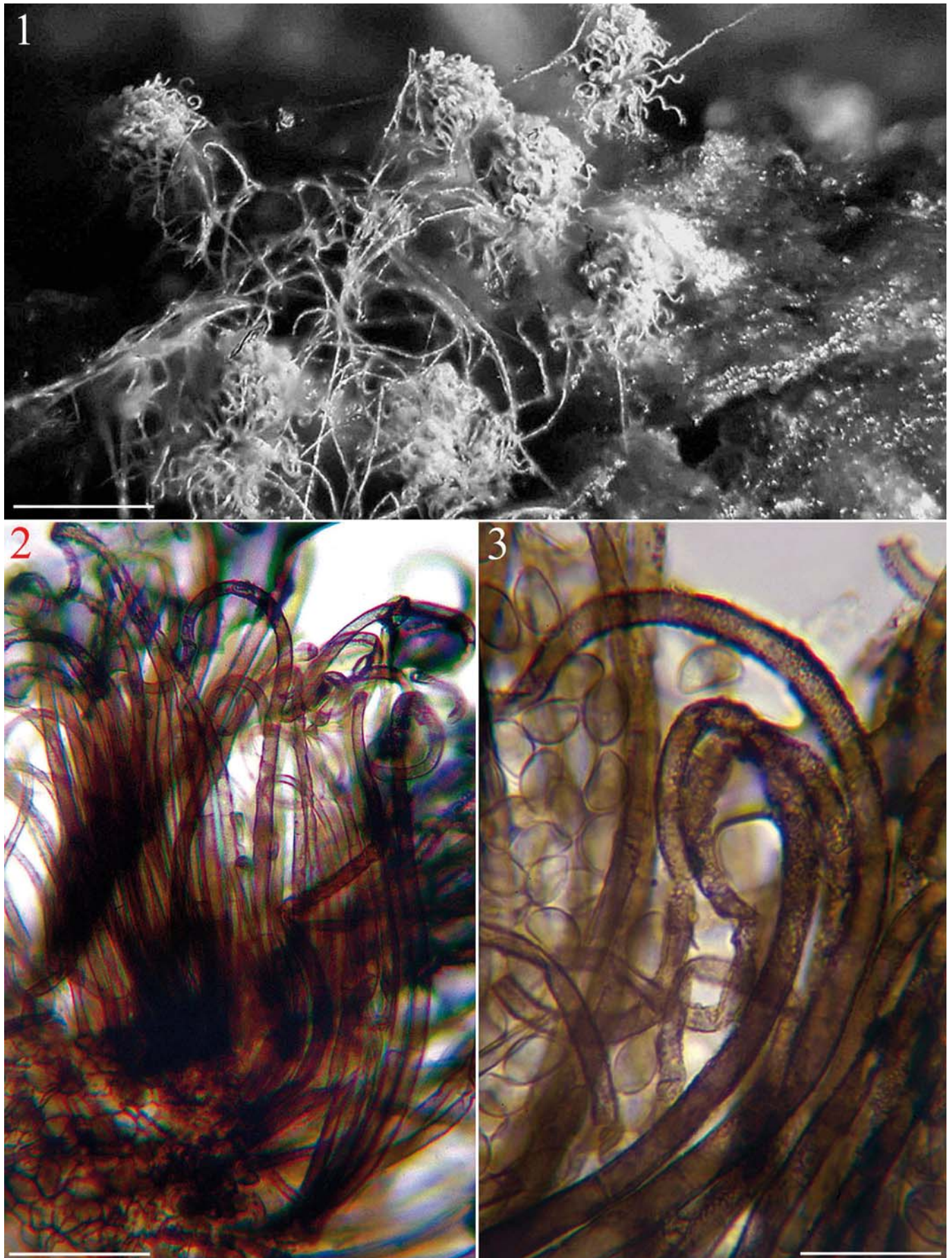


Plate 1 – *Chaetomium aureum*

1. Ascomata on dung. 2. Arcuate terminal hairs with circinate or coiled tips. 3. Arcuate terminal hairs. Scale bars: 1 = 200 μm ; 2 = 40 μm ; 3 = 20 μm .

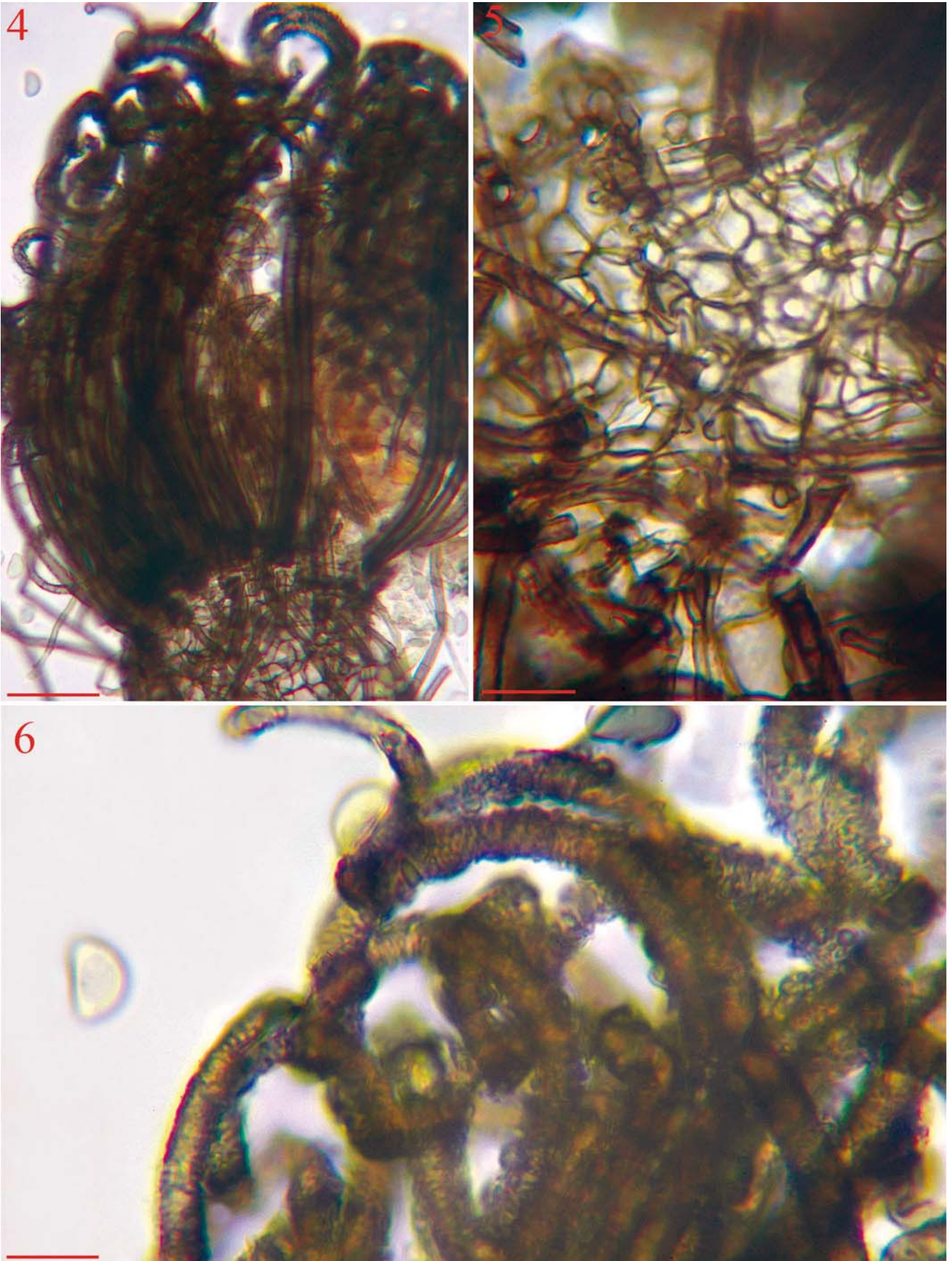


Plate 2 – *Chaetomium aureum*

4. Upper part of ascoma. 5. Detail of exoperidium. 6. Coiled tips of terminal hairs. Scale bars: 4 = 25 μm ; 5 = 15 μm ; 6 = 10 μm .

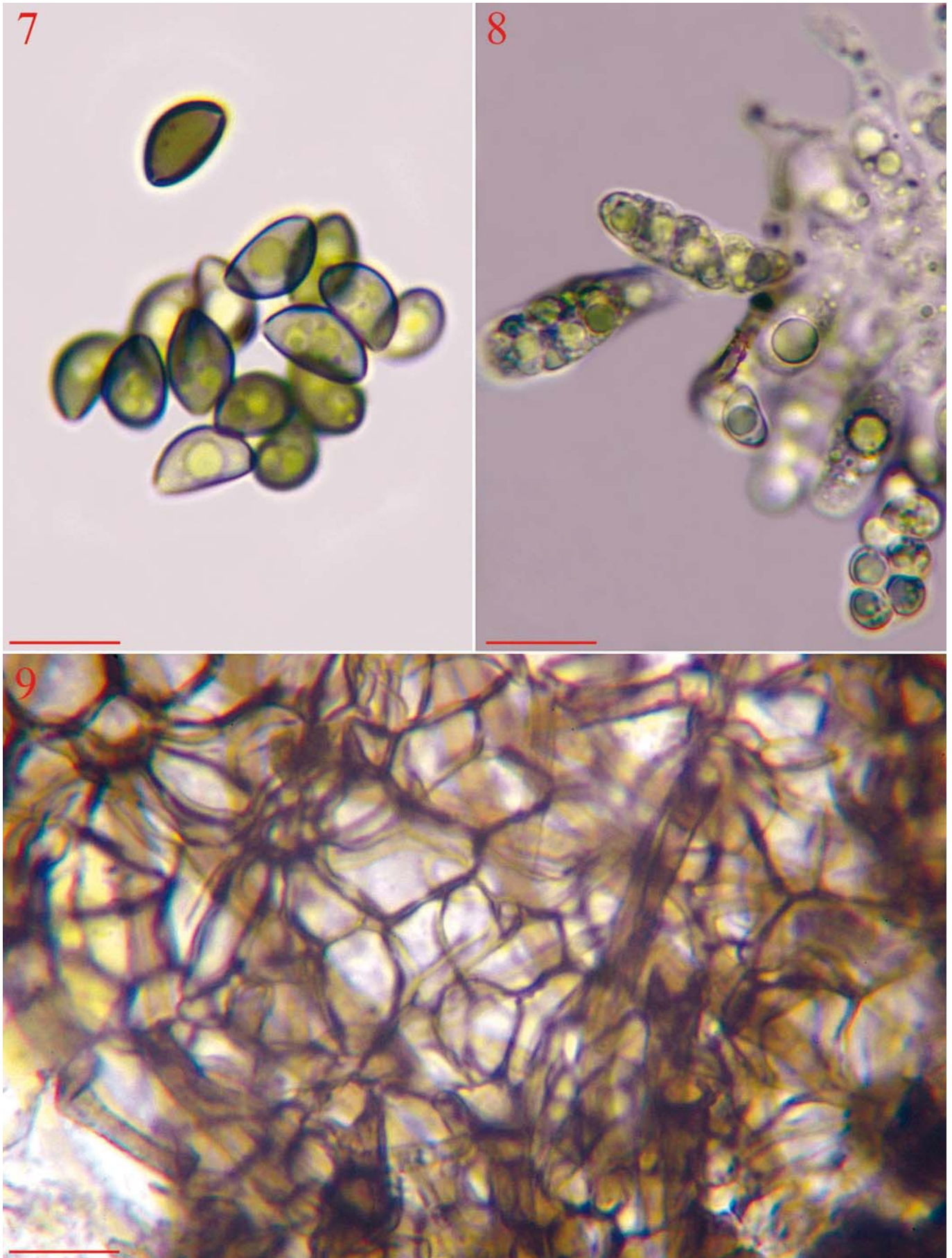


Plate 3 – *Chaetomium aureum*

7. Ascospores. 8. Asci. 9. Detail of exoperidium. Scale bars: 7 = 10 μm ; 8 = 15 μm ; 9 = 8 μm .

DREYFUSS (1976) regarded *Chaetomium aureum*, *C. trilaterale* and *C. fusiforme* as a single, strongly variable taxon, including in this variability also three species established by WARMELO (1966), *C. confusum*, *C. humicola* and *C. rubrogenum*.

In agreement with DREYFUSS (1976) and after revising the types of all these species, ARX *et al.* (1986) regarded them as a single taxon under the priority name *Chaetomium aureum*, except for *C. fusiforme*, considered as an independent taxon due to its longer ascospores and thinner hairs. ARX *et al.* (1986) also reduced *Chaetomium trilaterale* var. *diporum* J.C. Cooke to a mere synonym of *C. aureum*, the former conceived by its author (COOKE, 1973) different from *C. trilaterale* var. *trilaterale* in having ovate, larger perithecia and somewhat larger ascospores.

COOKE (1973) had the merit of highlighting for the first time the presence of two germ pores, one at each end, in the ascospores of *C. trilaterale* type collection. Based on this observation, he introduced two new varieties, *C. trilaterale* var. *chiversii* J.C. Cooke and *C. trilaterale* var. *cupreum* (L.M. Ames) J.C. Cooke, similar to *C. trilaterale* var. *trilaterale* and to *Chaetomium trilaterale* var. *diporum* in hair and spore shape, but different particularly in having ascospores with a single germ pore, and var. *cupreum* also in having typical orange-copper perithecial hairs.

Chaetomium trilaterale var. *cupreum* was originally described as *Chaetomium cupreum* (AMES, 1949), later regarded as synonym of *C. trilaterale* by SKOLKO & GROVES (1953), UDAGAWA (1960) and SETH (1970), and regarded again as an independent species (ARX *et al.*, 1986), which differs from *C. aureum* (inclusive of *C. trilaterale*) in hair colour and number of germ pores.

Based on morphological features, ABDULLAH & AL-BADER (1989) established *Chaetomium subcurvisporum*, characterized by straight terminal hairs, reniform or slightly curved ascospores, sometimes flattened at one side, with one or sometimes two germ pores. It is evident that this species belongs to the aureum-group. The authors compared it with *C. trilaterale* var. *pseudocupreum* Guarro, considering the two taxa separated by small differences. The latter is now regarded (Index Fungorum: <http://www.speciesfungorum.org/Names/SynSpecies.asp?RecordID=162479>) as synonym of *C. trilaterale*.

PORNURIYA & SOYTONG (*in* PORNURIYA *et al.*, 2011) established *Chaetomium siamense* based on morphological features and molecular data. This species was compared with the very similar *C. cupreum*, but not with *C. fusiforme*, which in our opinion is even closer to *C. siamense* due to the presence of inequilateral fusiform ascospores with two germ pores. The phylogenetic tree provided by PORNURIYA *et al.* (2011) is not extensive, leaving still much uncertainty in this group.

Red exudates are usually present in axenic cultures of this group, but not in my culture in damp chamber, possibly because few specimens developed directly on dung, none on blotting paper at its base.

My Italian collection has morphological features more similar to *C. trilaterale* s. CHIVERS (1912, 1915) than to *C. aureum* s. CHIVERS, but I prefer for the time being to call it *C. aureum* s. ARX *et al.* (1986), waiting for the molecular data to clarify this complex group of taxa.

There are several records worldwide of *Chaetomium aureum* s. ARX *et al.* from dung (SKOLKO & GROVES, 1953; LIU & CHEN, 1979; MILLNER, 1975; CARTER & KHAN, 1982; ERIKSSON, 2009; LÉCURU, 2013), besides from soil and paper.

Corynascus sepedonium (C.W. Emmons) Arx, *Proc. K. Ned. Akad. Wet., Ser. C, Biol. Med. Sci.*, 76: 292 (1973) – Plates 4–5.

≡ *Thielavia sepedonium* C.W. Emmons, *Bull. Torrey bot. Club*, 59: 417 (1932) (basionym).

≡ *Chaetomidium sepedonium* (C.W. Emmons) Lodha, *Taxonomy of Fungi (Proc. Int. Symp. Madras, 1973)*, Pt. 1: 248 (1978).

≡ *Myceliophthora sepedonium* (C.W. Emmons) van den Brink & Samson, *in* Brink *et al.*, *Fungal Divers.*, 52: 206 (2012).

= *Thielavia sepedonium* var. *minor* B.S. Mehrotra & Bhattacharjee, *Antonie van Leeuwenhoek*, 32: 391 (1966).

= *Myceliophthora similis* (Stchigel, Cano & Guarro) van den Brink & Samson, *in* Brink *et al.*, *Fungal Divers.*, 52: 206 (2012).

Ascomata cleistothecial, globose, 80–100 µm diam., shining black by reflected light, glabrous, membranous, dehiscing at maturity by random splitting. **Peridium** very thin, a *textura epidermoidea* of brown, thick-walled, pitted to reticulate, irregular cells, 8–17 × 6–9 µm. **Paraphyses** absent. Asci ephemeral, only one ascus observed, 8-spored, broadly ellipsoidal, thin-walled, 25 × 20 µm. **Ascospores** clustered inside the ascus, hyaline at first, becoming ochraceous with one or two large drops or with many droplets, brown at maturity, one-celled, 14–16 (–17) × 7.5–8 µm, broadly fusiform, rarely slightly inequilateral (Q = 1.75–2.26; average Q = 1.93), exceptionally navicular, smooth, with two prominent, terminal germ pores, one at each end, approx. 1 µm diam., exceptionally with some additional pores. **Asexual morph** not observed.

Material examined: ITALY, isola di Sardegna, Ogliastra, Supramonte di Uzulei, 1000 m a.s.l., 40°5'39" N 9°30'40" E, dozens of gregarious, superficial specimens, embedded in the aerial mycelium, on sheep (*Ovis aries*) dung in damp chamber culture, L. Levorato, 28.4.2015, CLSM 005.15.

Corynascus was established by ARX (1973) to accommodate two *Thielavia* Zopf spp., *T. sepedonium* C.W. Emmons (regarded as the type species of the new genus) and *T. novoguineensis* Udagawa & Y. Horie, both different from all the other *Thielavia* species in having asexual morphs (*Sepedonium* Link or *Chrysosporium* Corda-like) and ascospores with two, rather than one, terminal germ pores. *Corynascus* shares cleistothecial, translucent, usually glabrous ascomata and epidermoid peridia with *Thielavia* but differs in that it has reticulate or verrucose peridial cells and is consistently mesophilic (GUARRO *et al.*, 2012; MARÍN-FELIX *et al.*, 2015), whereas *Thielavia* spp. are mesophilic or thermophilic. Species of *Corynascus* are homothallic (MARÍN-FELIX *et al.*, 2015) and usually isolated from soil (GUARRO *et al.*, 2012).

ARX *et al.* (1988) recognised five *Corynascus* spp., i.e. *C. heterothallicus* (Klopotek) Arx, *C. novoguineensis*, *C. sepedonium*, *C. setosus* (Dade) Arx, and *C. thermophilus* (Fergus & Sinden) Klopotek.

STCHIGEL *et al.* (2000), based on morphological and molecular studies, established three new thermotolerant species, i.e. *Corynascus sexualis* Stchigel, Cano & Guarro, *C. similis* Stchigel, Cano & Guarro, and *C. verrucosus* Stchigel, Cano & Guarro.

GUARRO *et al.* (2012) recognised all these species besides *C. polygonoperdus* (Matsush.) Guarro & Stchigel, which they recombined from *Thielavia*.

Based upon a molecular study and according to Melbourne Code (2011), BRINK *et al.* (2012) suggested to recombine all *Corynascus* spp. under the older name *Myceliophthora* Costantin, the latter regarded as the asexual morph of *Corynascus*. But based on a multidisciplinary study, MARÍN-FELIX *et al.* (2015) restricted *Myceliophthora* to the type species, *M. lutea* Costantin, which lacks a sexual morph, and re-established the genus *Corynascus*, removing both the heterothallic and thermophilic species from it. They also regarded *C. similis* as a synonym of *C. sepedonium* and established the new species *C. fumimontanus* Y. Marín, Stchigel & Cano, but they did not mention *C. polygonoperdus*, possibly because no gene sequence of this species has been deposited.

As the situation presently stands, *Corynascus* encompasses five species (*C. fumimontanus*, *C. novoguineensis*, *C. sepedonium*, *C. sexualis*, *C. verrucosus*) or six, if we include *C. polygonoperdus*.

C. sepedonium is characterised by reticulate peridial cells, broadly fusiform ascospores with two terminal germ pores, and an asexual state of echinulate conidia (EMMONS, 1932; ARX *et al.*, 1988; MARÍN-FELIX *et al.*, 2015). *C. novoguineensis*, the closest species in my opinion, differs in having verruculose peridial cells, somewhat larger ascospores

on average, and smooth conidia (UDAGAWA & HORIE, 1972; MARIN-FELIX *et al.*, 2015). *C. polygonoperdus* is close to both *C. novoguineensis* and *C. sepedonium* but is distinguishable by its smaller, often ovoidal ascospores (MATSUSHIMA, 1975; GUARRO *et al.*, 2012).

Both *C. fumimontanus* and *C. verrucosus* differ from *C. sepedonium* in that they have verrucose peridial cells, *C. fumimontanus* also irregularly shaped ascospores (MARIN-FELIX *et al.*, 2015), *C. verrucosus* ascospores with eccentric germ pores (STCHIGEL *et al.*, 2000).

C. sexualis is different from the other *Corynascus* spp. by lacking

an asexual morph, and distinguishable from *C. sepedonium* also in having limoniform ascospores (STCHIGEL *et al.*, 2000).

C. sepedonium was usually isolated from soil (RAMA & REDDY, 1964; MEHROTRA & BHATTACHARJEE, 1966; MATSUSHIMA, 1971; ARX, 1975), but few collections are known from dung (MALLOCH & CAIN, 1973), some others were never recorded but are deposited in international herbaria (TRTC 66.1093r, IMI 238461).

I have not isolated my collection of *C. sepedonium* in pure culture, so I have not observed its asexual morph, but the morphological features of the sexual morph are enough to define this species.

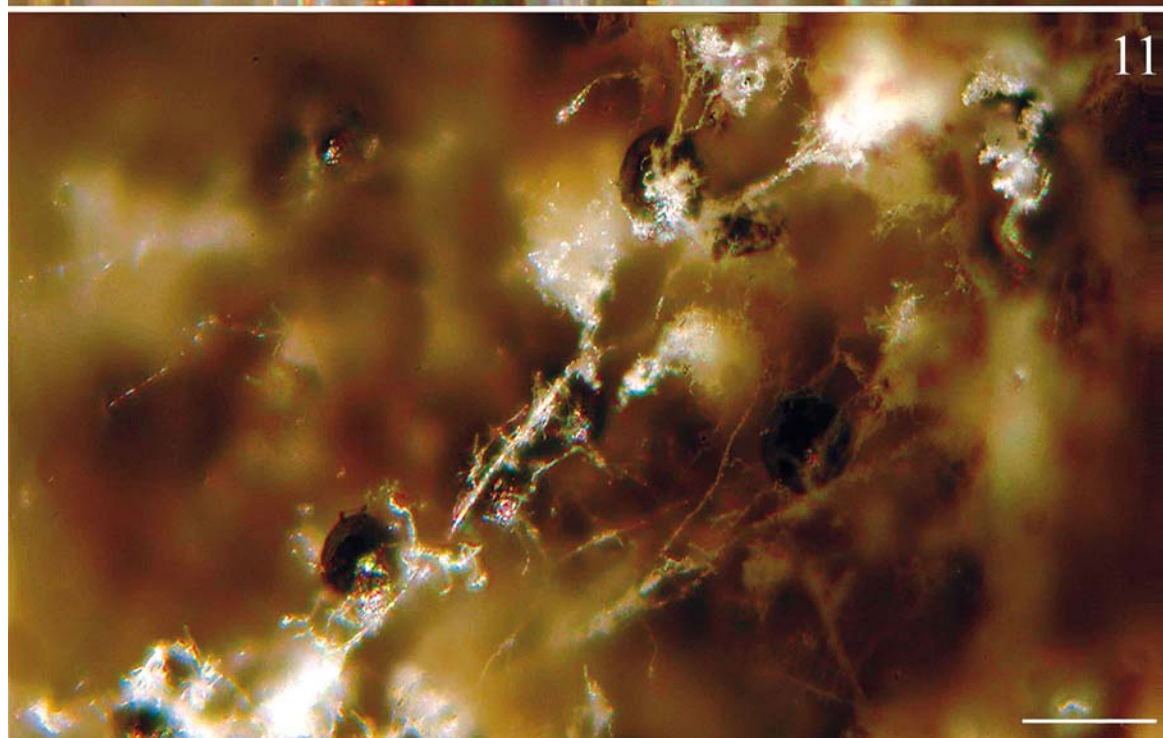
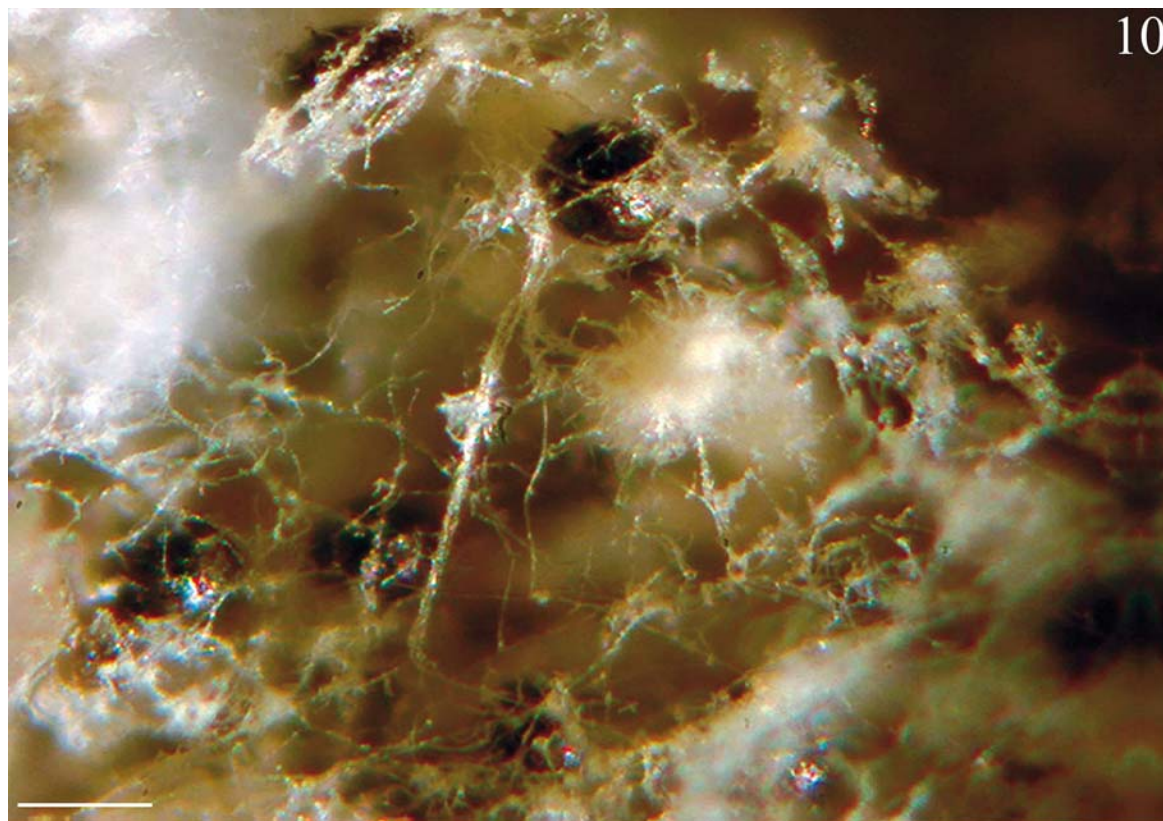


Plate 4 – *Corynascus sepedonium*

10–11. Ascomata on dung. Scale bars: 10 = 100 μm ; 11 = 120 μm .

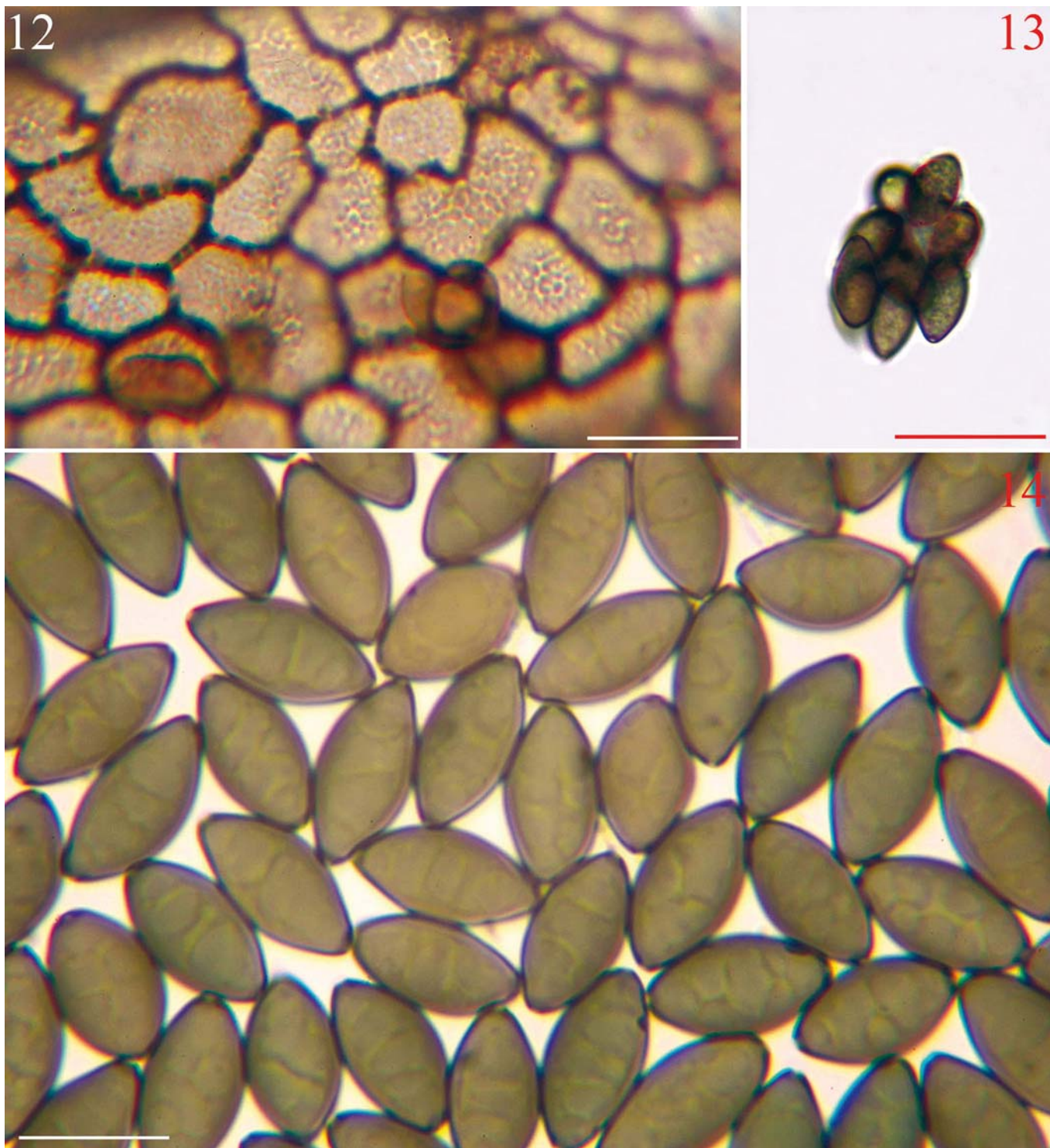


Plate 5 – *Corynascus sepedonium*

12. Detail of peridium. 13. Ascus with conglobate ascospores. 14. Ascospores. Scale bars: 12 = 10 μm ; 13 = 18 μm ; 14 = 12 μm .

Coniochaeta hansenii (Oudem.) Cain, *Studies of Coprophilous Spaeriales in Ontario*: 63 (1934) – Plates 6–8.

≡ *Sordaria hansenii* Oudem., *Hedwigia*, 21: 123 (1882) (basonym).

≡ *Philocopra hansenii* (Oudem.) Oudem., *Hedwigia*, 21: 160 (1882).

Perithecia 480–680 \times 350–430 μm , subglobose to pyriform, dark brown, membranous, setulose in the upper portion. **Neck** 100–200 \times 140–270 μm , broadly papillate, hemispherical or subcylindrical, densely dark setulose, sometimes slightly curved. **Peridium** two-layered: endostratum pseudoparenchymatous, of a *textura angularis* of pale, thin-walled, polygonal cells, 14–22 \times 10–15 μm , supporting many periphyses at the neck; exostratum of a *textura angularis* of

dark brown, thick-walled, polygonal cells, 5–7 \times 4–5 μm , often covered with a *textura intricata* in the lower two thirds of the perithecium, due to densely interweaving hyphae. **Setae** plentiful, 30–110 μm long, the longest on the neck, dark brown, rarely pale grey, paler at the pointed apex, straight or slightly curved, usually not septate or rarely with one septum, thick-walled (ca. 1 μm), with a simple, usually bulbous base, 4–5 μm diam., or with a polymorphous base, up to 11 μm diam. **Hyphoid hairs** pale brown, 2–3 μm diam., often branched, septate. **Paraphyses** cylindrical-moniliform, gradually tapering towards the apex, septate, often somewhat narrowing at the septa, containing hyaline vacuoles, 3–4 μm diam. at the apex. **Asci** more than 120-spored (possibly 128-spored), cylin-

Worldwide key to coprophilous species of *Coniochaeta* with poly-spored asci

- 1a) Asci 32-spored, cylindrical to clavate, 90–110 × 13–20 µm. Ascospores discoidal, 5.5–8 × 8 µm ... ***C. philocoproides*** (Griffiths) Cain
 1b) Asci 64-spored or more **2**
- 2a) Asci 64-spored, clavate, 160–200 × 35–45 µm. Ascospores discoidal, 13–16.5 × 9.5–13.5 × 5.5–9 µm.
 Neck setae up to 35 µm long. ***C. polymegasperma*** M.J. Richardson
 2b) Ascospores smaller. Setae up to 175 µm long **3**
- 3a) Asci 64–128-spored. Ascospores discoidal or ellipsoidal **4**
- 3b) Asci more than 128-spored. Ascospores discoidal **5**
- 4a) Asci 64–128-spored, clavate, rarely cylindric-clavate or saccate, 125–230 × 17–32 µm. Ascospores discoidal,
 6–10 × 4–9 × 3.5–7 µm ***C. hansenii*** (Oudem.) Cain
 4b) Asci 128-spored, cylindrical, 60 × 10 µm. Ascospores ellipsoidal, 5–8 × 4–5 µm ***C. polyspora*** (W. Phillips & Plowr.) N. Lundq.
- 5a) Asci 512-spored **6**
- 5b) Asci about 1000-spored, broadly cylindric-clavate, 200–250 × 42–50 µm. Ascospores 5–6 × 3–6 µm in frontal view
 ***C. multispora*** Cain
- 6a) Asci broadly cylindrical to clavate, 200–250 × 50–55 µm. Ascospores 7–8 × 6–8 × 4–4.5 µm ***C. polysperma*** Furuya & Udagawa
 6b) Asci clavate, 195–250 × 50–80 µm. Ascospores 9–14.5 × 6.5–12.8 × 5–6.5 µm ***C. burtii*** M.J. Richardson

dric-claviform, 170–230 × 20–27 µm, slightly flattened at the apex, with a well-developed apical ring, often with a somewhat enlarged subapical part, short-stalked (10–15 µm). **Ascospores** multiseriate, oblate, spherical or broadly ellipsoidal in frontal view, narrowly ellipsoidal in side view, (5.5–) 6–8 (–8.5) × 5–6.5 × 3.5–4.5 µm, usually rounded at the ends in side view, seemingly lacking a gelatinous sheath, at first hyaline, pale brown later, dark reddish brown at maturity, smooth, thick-walled, with a complete germ slit. **Asexual morph** not seen.

Material examined: ITALY, Verona, Ferrara di Monte Baldo, 1200 m a.s.l., 45° 41' 21" N 10° 51' 11" E, about thirty, gregarious, semi-immersed specimens on hare (*Lepus* sp.) dung, P. Cugildi and E. Bizio, 12 Jun. 2014, CLSM 006.03 bis.

Coniochaeta (Sacc.) Cooke is characterised by setulose perithecia, non-amyloid asci, and one-celled, often discoidal, smooth ascospores with a germ slit (MAHONEY & LAFAVRE, 1981; CHECA *et al.*, 1988). In the same family, *Ephemeroascus* Emden (1973) differs from *Coniochaeta* in having ascospores with inconspicuous germ slits, *Poroniochaeta* Udagawa & Furuya (1979) pitted ascospores, *Coniochaetidium* Malloch & Cain (1971) cleistothecioid ascomata, *Germ-litospora* Lodha cleistothecioid ascomata and pitted ascospores. All genera in *Coniochaetaceae* have a phialidic imperfect state (BARR, 1990; CANNON & KIRK, 2007), which distinguishes them from those of the close family *Xylariaceae* Tul. & C. Tul. (*Xylariales* Nannf.) with a holoblastic conidiogenesis.

Molecular studies on *Sordariales* Chadeff. ex D. Hawksw. & O.E. Erikss. proved the monophyly of *Coniochaetaceae* and justified their removal from *Sordariales* and the placement in the new order *Coniochaetales* (HUHNDORF *et al.*, 2004).

Previous morphological studies had shown that the presence or absence of an ostiole is an extremely variable feature even in the same species and isolate (ARX, 1973; GUARRO *et al.*, 1997, SUH & BLACKWELL, 1999).

Combined molecular and morphological studies on *Coniochaetaceae* (GARCÍA *et al.*, 2006) proved that *Coniochaeta*, *Coniochaetidium*, *Ephemeroascus* and *Poroniochaeta* are not monophyletic and some macro- and microscopic differences, such as perithecial or cleistothecial ascomata, smooth or ornamented ascospores, are homoplastic and have not a taxonomic value at the genus rank.

So *Coniochaetidium*, *Ephemeroascus*, *Poroniochaeta* were definitively regarded as synonyms of *Coniochaeta* (GARCÍA *et al.*, 2006).

DOVERI (2004) described some coprophilous *Coniochaeta* spp. from Italy and mentioned all species established after CHECA *et al.* (1988) monograph on this genus. Since then eight recombinations in *Coniochaeta* were made, based on molecular studies (GARCÍA *et al.*, 2006), one new name, *Coniochaeta ornata* Dania García, Stchigel &

Guarro (replacing *Poroconiochaeta tetraspora* Dania García, Stchigel & Guarro), and six new species were established, only *C. burtii* M.J. Richardson being poly-spored and coprophilous.

KIRK *et al.* (2008) recognised 65 species of *Coniochaeta*, GUARRO *et al.* (2012) about 50. The latest comprehensive key to this genus is that of ASGARI *et al.* (2007), whereas GUARRO *et al.* (2012) provided a key to the soil-borne species.

The introduction of *C. burtii* has increased the number of poly-spored *Coniochaeta* spp. to seven. All of them are coprophilous.

The widespread and quite common *C. hansenii* was mostly recorded from leporid (hare, rabbit) droppings (OUDEMANS, 1882; CAIN, 1934; MUNK, 1957; KOBAYASI, 1979; MUROI & UDAGAWA, 1984; BARRASA GONZALES, 1985; CHECA *et al.*, 1988; LORENZO, 1992; MOYNE & PETIT, 2006; HEINE & WELT, 2008; RICHARDSON, 2008; LÉCURU, 2013). Others (MUNK, 1957; ERIKSSON, 2009; RICHARDSON, *in litt.*) also recorded it from elk, horse, roe deer and sheep dung, still others (MOREAU, 1953; DENNIS, 1981; BELL, 1983, 2005) described *C. hansenii* but did not clearly mention its dung source. My collection on hare dung is the first record from Italy.

Other worldwide records of the other poly-spored *Coniochaeta* spp. are usually from leporid dung (PHILLIPS & PLOWRIGHT, 1881; GRIFFITHS, 1901; CAIN, 1934; FURUYA & UDAGAWA, 1976; ERIKSSON, 1992, 2009; RICHARDSON, 1998). Only *C. burtii* was reported from roe deer dung (RICHARDSON, 2006).

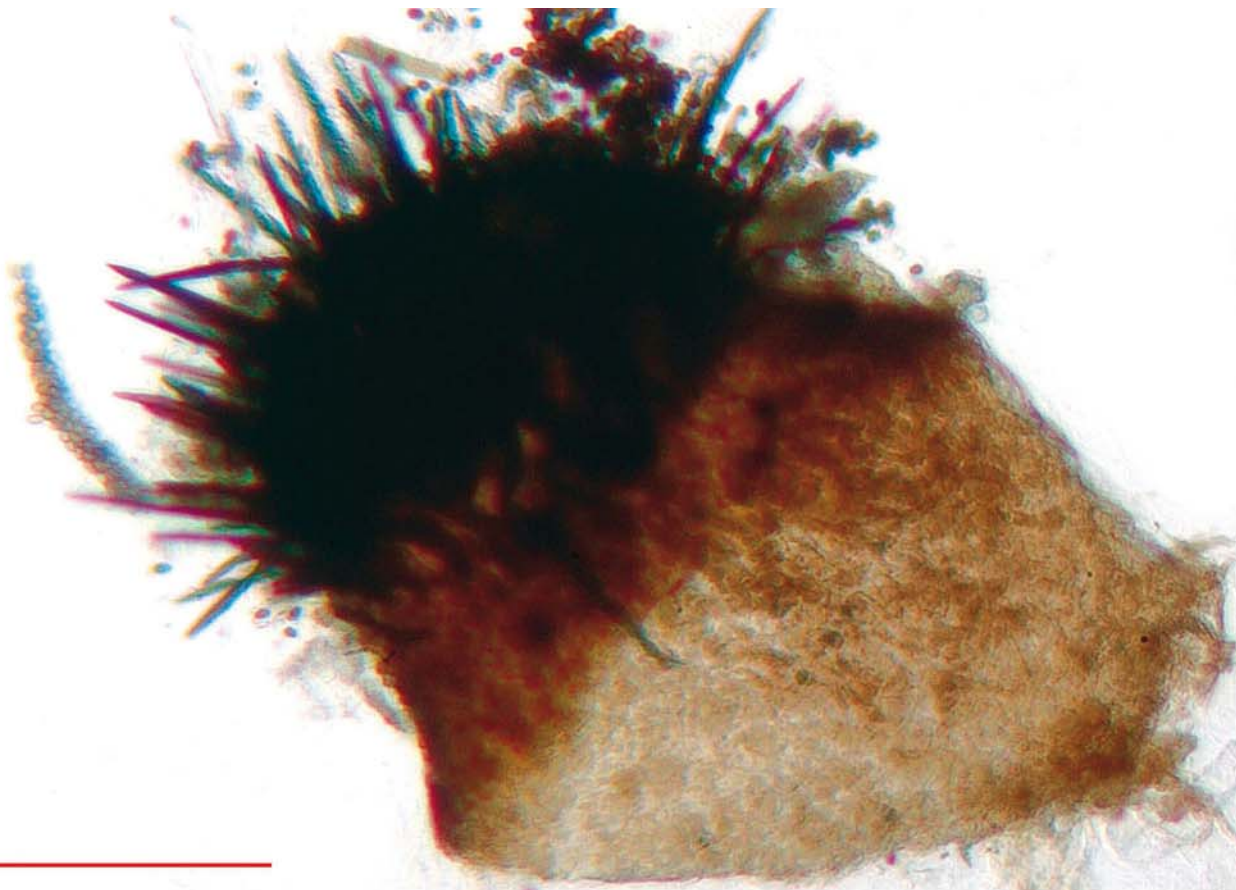
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15



16

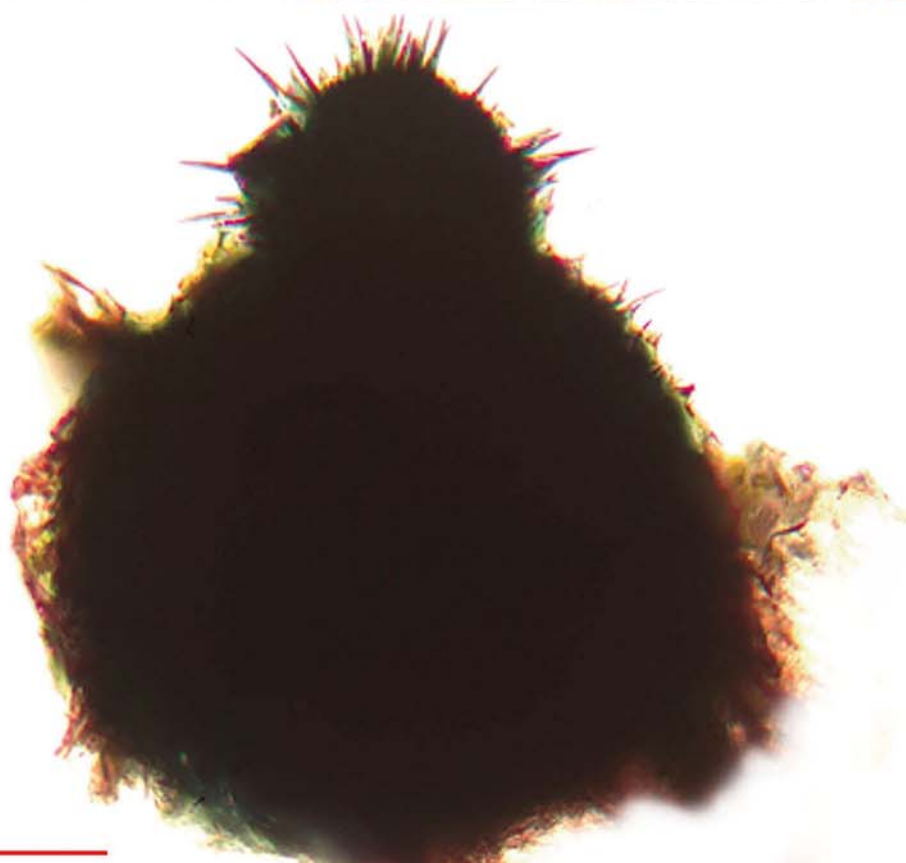


Plate 6 – *Coniochaeta hansenii*

15. Upper portion of ascoma. 16. Ascoma in water. Scale bars: 15 = 150 μ m; 16 = 200 μ m.

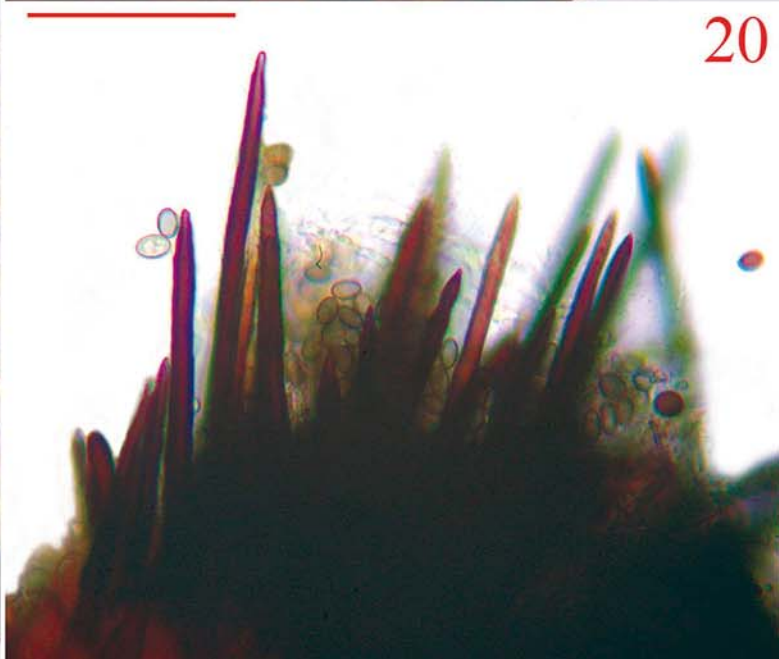
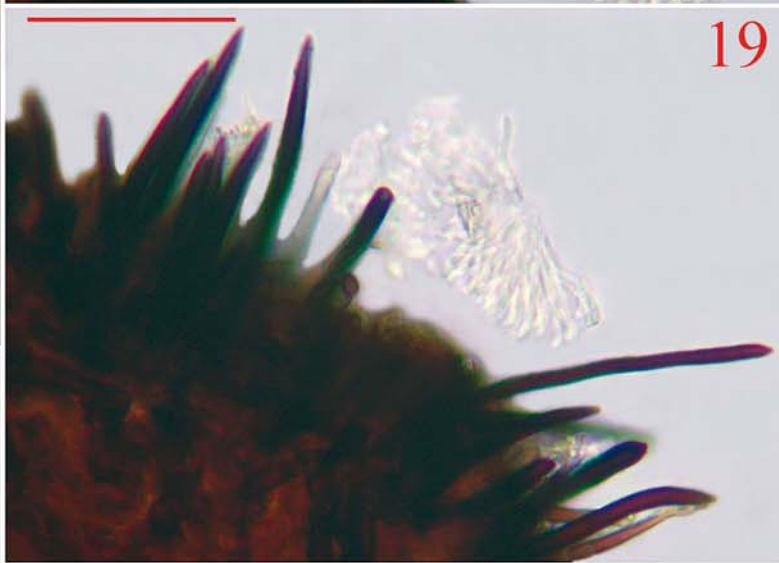
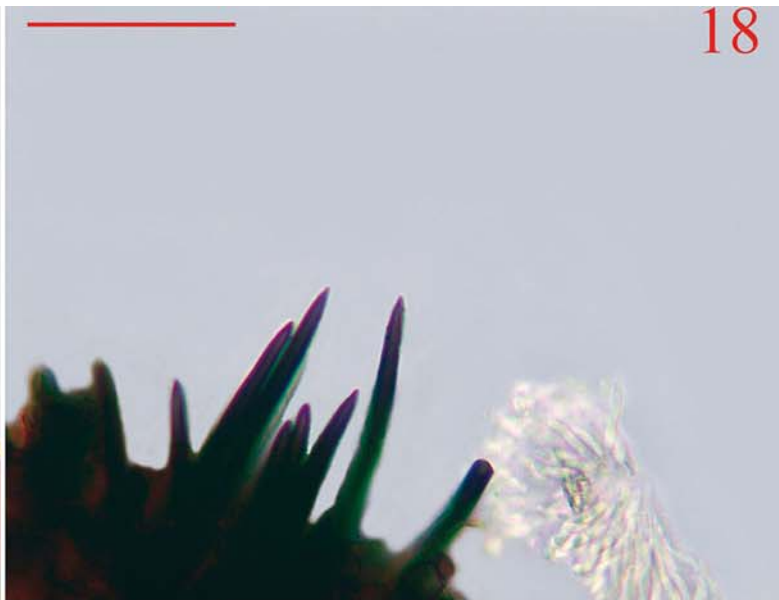
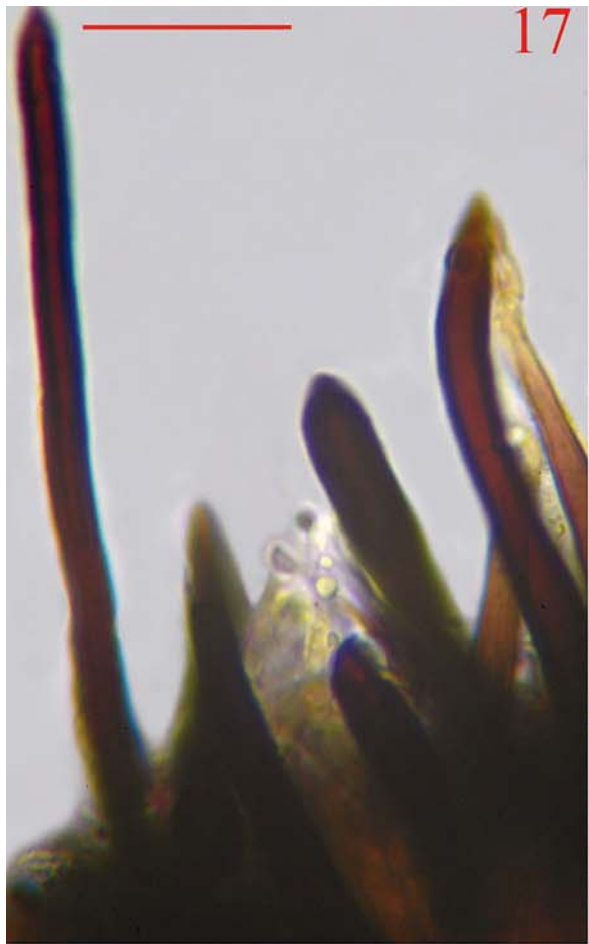


Plate 7 – *Coniochaeta hansenii*

17–21. Neck setae (18–19, 21 with periphyses). Scale bars: 17 = 25 μm ; 18–20 = 60 μm ; 21 = 20 μm .

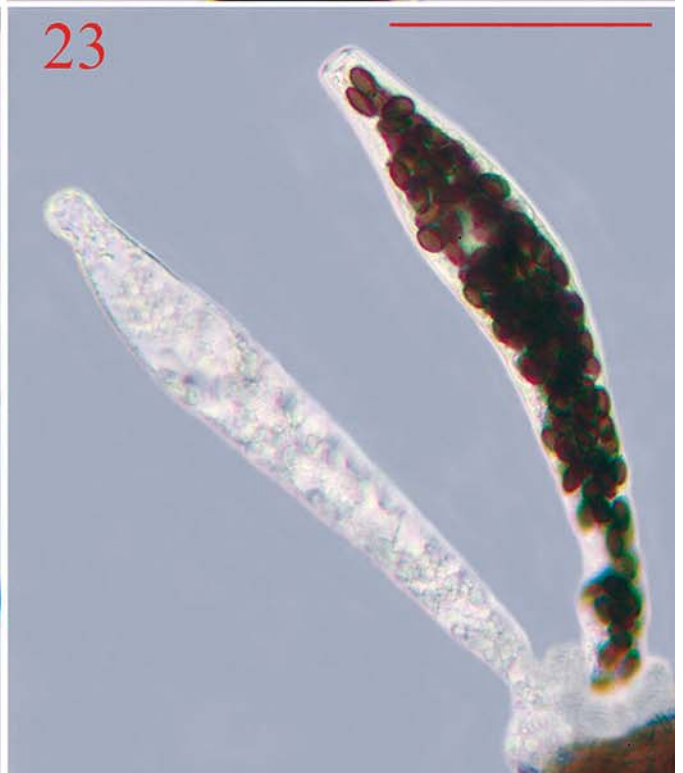
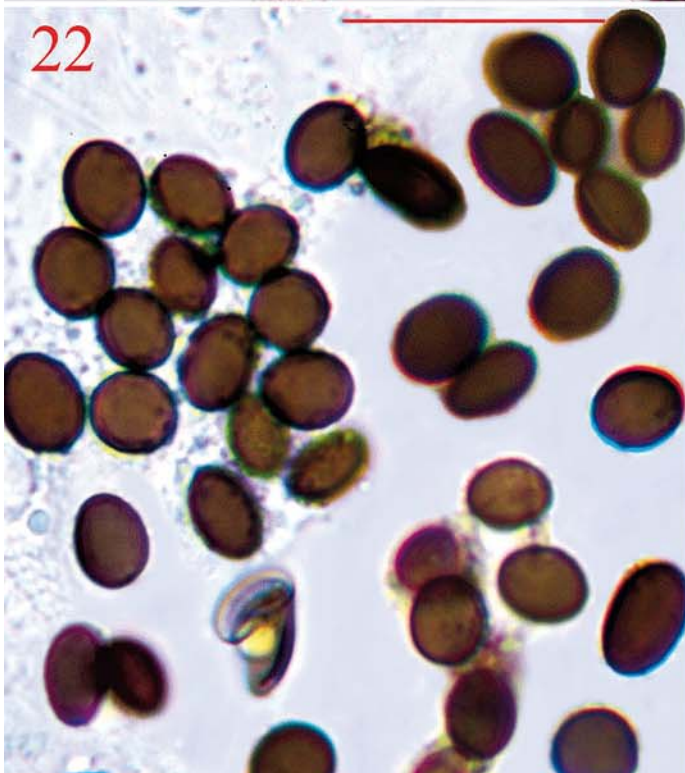
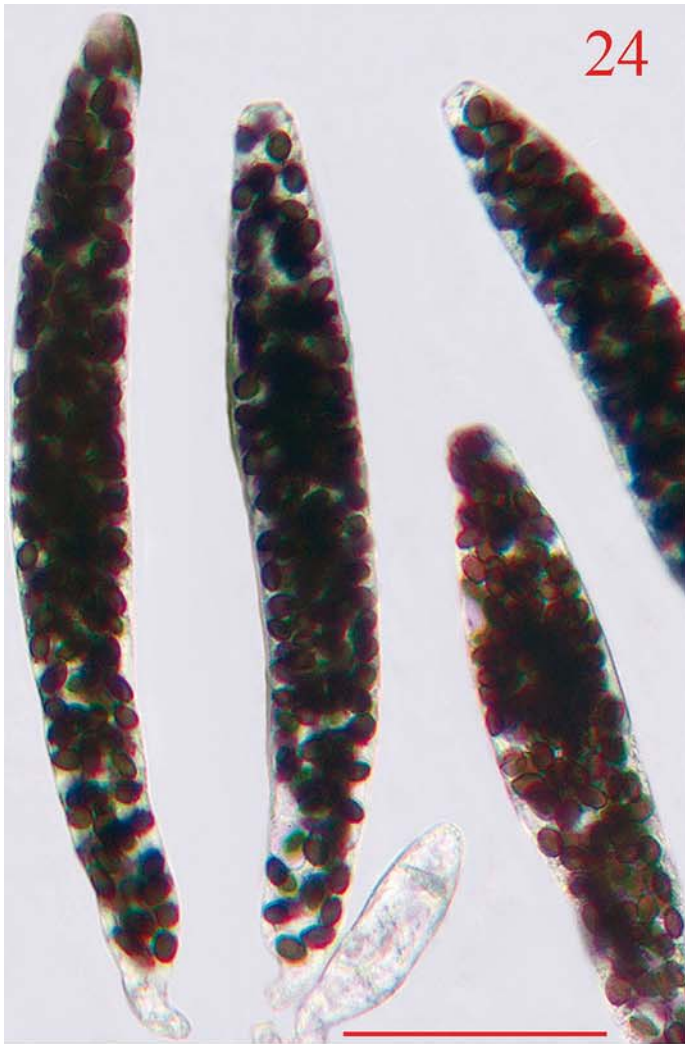


Plate 8 – *Coniochaeta hansenii*

22. Free ascospores. 23–25. Immature and mature asci with ascospores. Scale bars: 22 = 20 μ m; 23 = 60 μ m; 24 = 50 μ m; 25 = 25 μ m.

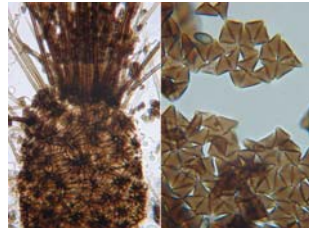
Key to coprophilous *Chaetomiaceae* and *Coniochaetaceae* from Italy

- 1) Ascomata perithecial or cleistothecial, with hairs or setulae, rarely glabrous. Asci non-amyloid, polymorphous, without an apical apparatus, usually 8-spored. Ascospores sometimes dextrinoid, with 1 or 2 germ pores, without a gelatinous perisporium. Paraphyses absent or ephemeral. Asexual state lacking or hyphomycetous. *Chaetomiaceae* **2**
- 1*) Ascomata usually perithecial, setulose. Asci exceptionally amyloid, usually cylindrical, with an apical apparatus, 4- to poly-spored. Ascospores not dextrinoid, often discoidal, with a germ slit, sometimes with a gelatinous perisporium. Asexual state hyphomycetous. *Coniochaetaceae-Coniochaeta* **30**
- 2) Ascomata perithecial, dark hairy or setulose. Ascospores smooth, with one germ pore, exceptionally with two. *Chaetomium* **3**
- 2*) Ascomata cleistothecial, hairy or smooth **27**

Chaetomium

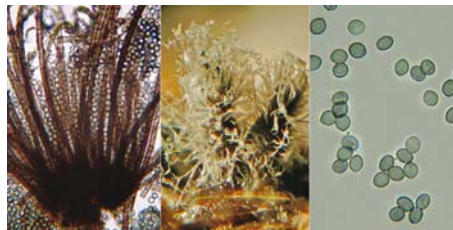
(partly based on DOVERI, 2008, 2013)

- 3) Ascospores triangular in frontal view, 8.5–9.5 × 4.5–5.5 × 4–4.5 μm. Peridium cephalothecoid ***C. trigonosporum***



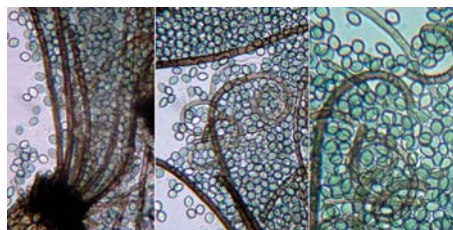
C. trigonosporum

- 3*) Ascospores different in shape **4**
- 4) Ascospores oblate, 7.5–8 × 7.5 × 4.5–5 μm, with one, indistinct germ pore. Peridium of *textura angularis*. Terminal hairs 2–2.5 μm diam., spirally coiled and circinate at the apex ***C. oblatum***
(see ARX *et al.*, 1986, plate 60)
- 4*) Ascospores different in shape, usually with distinct germ pore(s) **5**
- 5) Asci clavate. Ascospores biseriata, often irregularly **6**
- 5*) Asci cylindrical. Ascospores uniseriate, broadly ovoidal, bilaterally flattened. Peridium of *textura angularis*. Terminal hairs spirally coiled **24**
- 6) Ascospores with two apical germ pores, inaequilateral, often lunate, 8–9 × 5–5.5 × 4.5–5 μm. Terminal hairs arcuate, up to 5 μm diam., circinate or spirally coiled at the apex ***C. aureum* s. ARX *et al.*** (see Plates 1–3)
- 6*) Ascospores with one germ pore **7**
- 7) Germ pore apical **8**
- 7*) Germ pore subapical or lateral **21**
- 8) Ascomata with a dark collar around the ostiole. Peridium of *textura angularis*. Terminal hairs spirally coiled. Immature ascospores dextrinoid, pale grey at maturity, limoniform, biapiculate, bilaterally flattened **9**



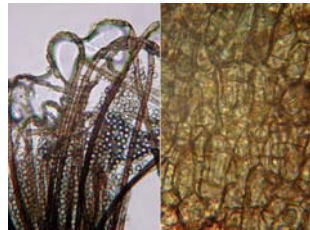
C. bostrychodes and *C. robustum*

- 8*) Ascomata without a dark collar. Immature ascospores not dextrinoid **10**
- 9) Ascomata ovoidal to ellipsoidal. Peridium entirely a *textura angularis*. Terminal hairs with spirally coiled, often branched ends. Ascospores 7–7.5 × 5.5–6.5 μm ***C. bostrychodes***

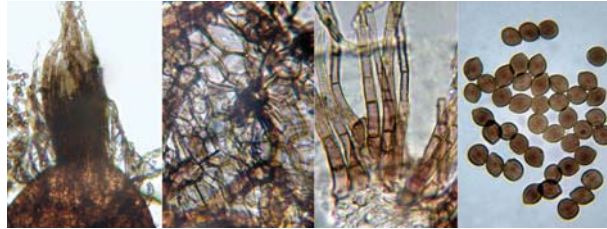


C. bostrychodes

- 9*) Ascomata usually ampulliform. Upper peridial portion a *textura prismatica* of elongated cells in vertical rows. Terminal hairs rarely branched. Ascospores 6–6.5 × 5–6 μm ***C. robustum***
- 10) Ascomata ampulliform with an elongated neck. Peridium of *textura angularis*. Terminal hairs seta-like, unbranched. Ascospores limoniform, brown, 7–9 × 5.5–7 × 4.8–5.2 μm ***C. homopilatum***
- 10*) Ascomata globose to broadly ellipsoidal or ovoidal, lacking an elongated neck **11**

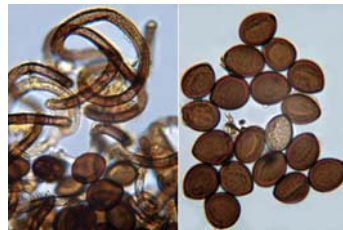


C. robustum



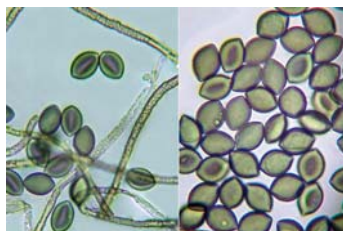
C. homopilatum

- 11) Ascospores $13-14.5 \times 11-12.5 \times 8-10 \mu\text{m}$, brown, watermelon seed-shaped, broadly ovoidal in frontal view, broadly ellipsoidal in side view. Peridium of *textura angularis*. Terminal hairs spirally coiled **C. semen-citrulli**



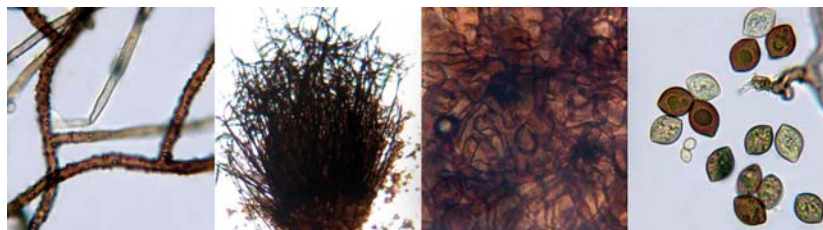
C. semen-citrulli

- 11*) Ascospores smaller and/or different in shape **12**
 12) Ascospores limoniform, bilaterally flattened, biapiculate, brown. Terminal hairs variously shaped but not seta-like **13**
 12*) Ascospores ellipsoid-fusiform or ovoidal, rarely limoniform, then mixed with ovoidal ascospores **15**
 13) Colonies without coloured exudates. Terminal hairs wavy to flexuous, unbranched. Peridium of *textura intricata* or *epidermoidea* at intervals. Ascospores $10-12 \times 7.5-9 \times 7-8 \mu\text{m}$ **C. subaffine**



C. subaffine

- 13*) Colonies often with greenish yellow exudates. Terminal hairs different in shape **14**
 14) Terminal hairs flexuous, dichotomously branched. Peridium usually of *textura epidermoidea*. Ascospores $11-11.5 \times 7.5-8.5 \times 6.5-7 \mu\text{m}$ **C. elatum**



C. elatum

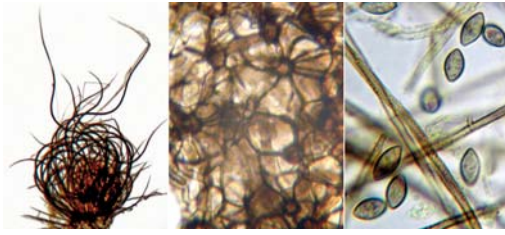
- 14*) Terminal hairs flexuous or often spirally coiled, unbranched. Peridium of *textura intricata*. Ascospores $8-10 \times 6.5-9.5 \times 5.5-7.5 \mu\text{m}$ **C. globosum**



C. globosum

- 15) Ascospores ellipsoid-fusiform, with attenuated, sometimes apiculate ends **16**
 15*) Ascospores different in shape **19**

- 16) Ascospores $8.5\text{--}10.5 \times 4.8\text{--}5.2 \mu\text{m}$, greyish blue. Peridium of *textura angularis*. Terminal hairs of two kinds: shorter and arcuate, or longer and wavy **C. carinthiacum**



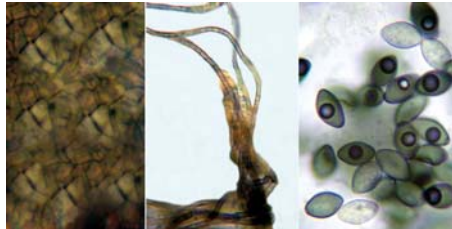
C. carinthiacum

- 16*) Ascospores larger, greyish brown. Terminal hairs different in shape **17**
 17) Peridium of *textura cephalothecoidea*. Terminal hairs straight, open circinate at the apex. Ascospores sometimes slightly inequilateral, $15.5\text{--}17.5 \times 9\text{--}10.5 \mu\text{m}$ **C. ancistrocladum**



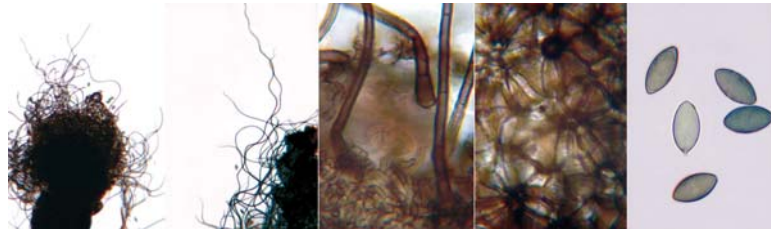
C. ancistrocladum

- 17*) Peridium and terminal hairs different **18**
 18) Peridium of *textura angularis*. Terminal hairs undulate to loosely spirally coiled. Ascospores slightly inequilateral, $13\text{--}13.5 \times 7.5\text{--}8 \mu\text{m}$ **C. succineum**



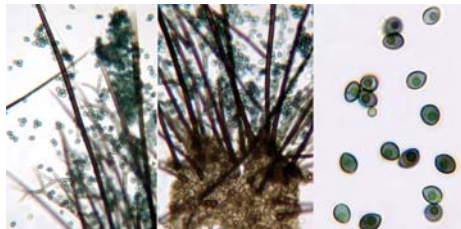
C. succineum

- 18*) Peridium of *textura angularis* to *epidermoidea*, *cephalothecoidea* at intervals. Terminal hairs flexuous and often open circinate at the apex. Ascospores usually equilateral, $13\text{--}16 \times 7.5\text{--}9 \mu\text{m}$ **C. murorum**



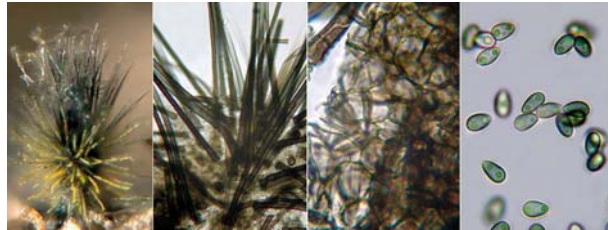
C. murorum

- 19) Ascomata clearly ostiolate. Peridium with an outer layer of *textura intricata*. Terminal hairs of two kinds: seta-like and unbranched, or dichotomously branched. Ascospores limoniform or ovoidal, dark grey, $5.5\text{--}6 \times 3.8\text{--}4.2 \times 3\text{--}3.5 \mu\text{m}$ **C. funicola**

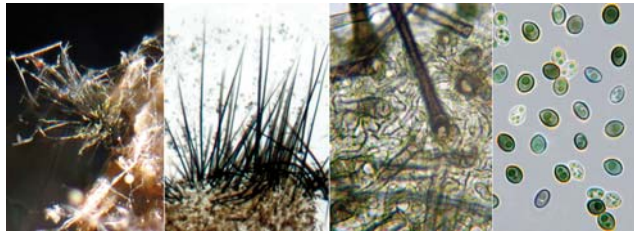


C. funicola

- 19*) Ascomata apparently non-ostiolate or ostiolate at late maturity. Terminal hairs seta-like, usually unbranched. Ascospores ovoidal **20**
 20) Ascomata ostiolate at late maturity. Peridium of *textura angularis*, *cephalothecoidea* at intervals. Ascospores $6\text{--}7 \times 3\text{--}4 \mu\text{m}$, ovoidal to narrowly ovoidal, rarely flattened at one side, non-apiculate, pale greyish **C. spinosum**
 20*) Ascomata non-ostiolate or ostiolate at late maturity only. Peridium of a *textura intricata* to *epidermoidea*. Ascospores $5.5\text{--}6.5 \times 4\text{--}4.5 \times 3\text{--}3.5 \mu\text{m}$, broadly ovoidal, uni- or bilaterally flattened, apiculate, pale brown to greyish **C. variostiolatum**

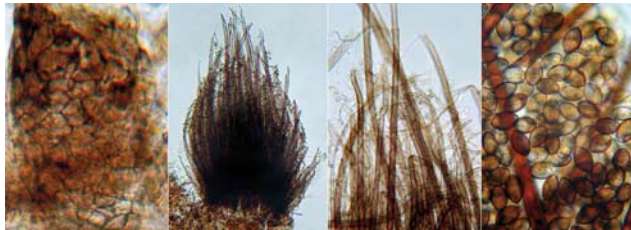


C. spinosum



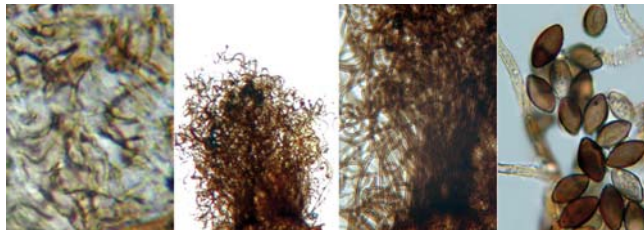
C. variostiolatum

- 21) (from 7*) Ascospores with an oblique to slightly eccentric germ pore (but central in our Italian collection), ellipsoid-fusiform, greyish blue, $8.5-10.5 \times 4.8-5.2 \mu\text{m}$. Peridium of a *textura angularis*. Terminal hairs of two kinds: shorter and arcuate, or longer and wavy ***C. carinthiacum*** (see pictures under 16)
- 21*) Ascospores with a subapical to lateral germ pore. Terminal hairs different **22**
- 22) Peridium of a *textura angularis*. Terminal hairs of two kinds: pale, strongly ramified, thin-walled; or darker, less ramified, thicker. Ascospores ellipsoid-narrowly limoniform ($Q = 1.70$), $9.5-11.5 \times 5.5-6.5 \mu\text{m}$ ***C. cuniculorum***



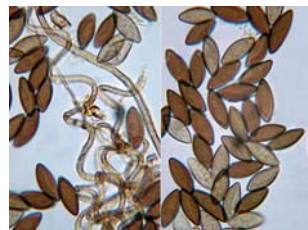
C. cuniculorum

- 22*) Peridium with a superficial layer of *textura intricata*. Terminal hairs with long spirally coiled ends. Average Q larger **23**
- 23) Ascospores ellipsoid-subfusiform, usually symmetrical, with rounded, often subumbonate ends, $14-17 \times 8-9.5 \mu\text{m}$ ***C. gangligerum***



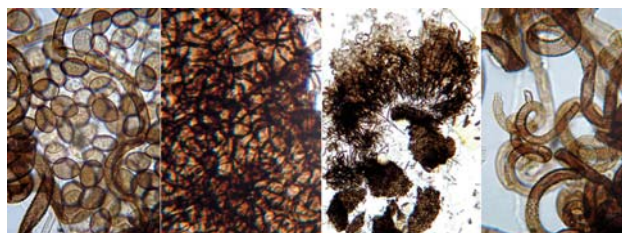
C. gangligerum

- 23*) Ascospores fusiform, often inequilateral, with fairly pointed ends, $16-18.5 \times 6-7 \mu\text{m}$ ***C. fuisporum***



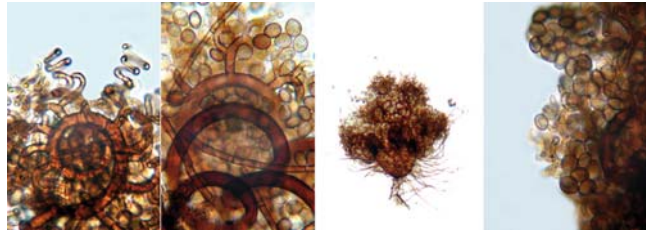
C. fuisporum

- 24) (from 5*) Ascospores $11-12 \times 8-9 \mu\text{m}$. Spirally coiled hairs unbranched ***C. crispatum***
- 24*) Ascospores smaller **25**



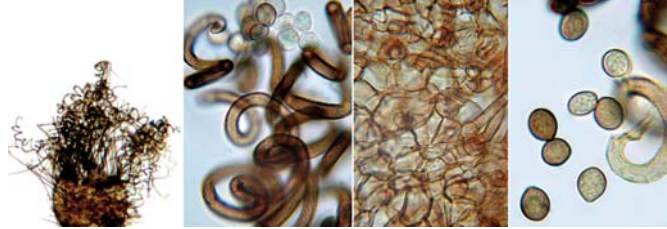
C. crispatum

- 25) Terminal hairs $5-8 \mu\text{m}$ diam., with spirally coiled branches. Ascospores $7-7.5 \times 5.5-6.5 \mu\text{m}$ ***C. medusarum***
- 25*) Terminal hairs $4-6.5 \mu\text{m}$ diam., unbranched **26**



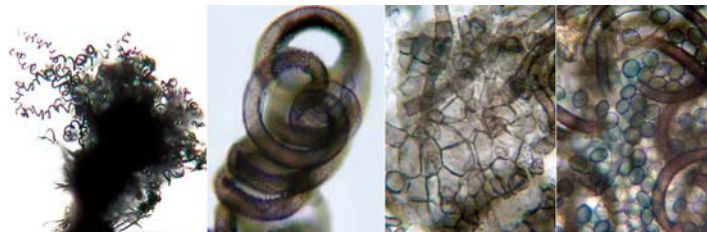
C. medusarum

26) Ascospores $9-9.5 \times 7.5-8 \mu\text{m}$ **C. mollicellum**



C. mollicellum

26*) Ascospores $6.5-7.5 \times 6-6.5 \mu\text{m}$ **C. brasiliense**

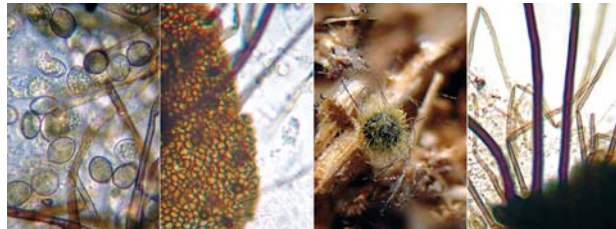


C. brasiliense

- 27) (from 2*) Ascomata usually glabrous. Peridium of *textura epidermoidea* of reticulate cells. Asci broadly ellipsoidal. Ascospores with 2 germ pores, broadly fusiform, $14-16 \times 7.5-8 \mu\text{m}$. Asexual state myceliophthora-like **Corynascus p.p.** - *C. sepedonium* (see Plates 4-5)
- 27*) Ascomata hairy. Peridium of *textura angularis* or *cephalothecoidea* of smooth cells. Asci usually clavate and stalked. Ascospores with 1 germ pore. Asexual state acremonium-like, botryotrichum-like, or absent. **Chaetomidium** **28**

Chaetomidium

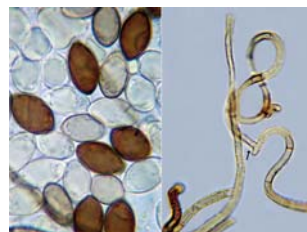
28) Ascospores limoniform, bilaterally flattened, $12-14 \times 9-11 \times 7.5-8 \mu\text{m}$. Peridium of *textura angularis*. Hairs flexuous, of two types: greenish, shorter and encrusted, or blackish, longer and smooth **C. fimeti**



C. fimeti

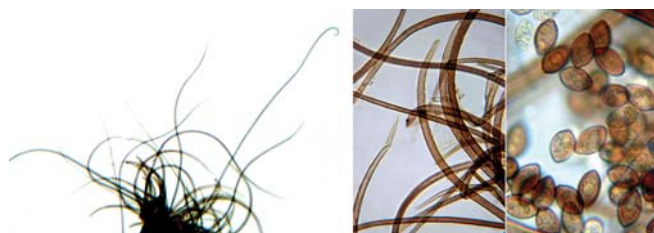
28*) Ascospores ellipsoid-fusiform, not flattened. Peridium of *textura cephalothecoidea* **29**

29) Ascospores $19-21.5 \times 11-13 \mu\text{m}$. Hairs verrucose, $2-4 \mu\text{m}$ diam., often apically branched at right angle **C. megasporum**



C. megasporum

29*) Ascospores $13.5-17 \times 8-9 \mu\text{m}$. Hairs smooth to verruculose, $4-7 \mu\text{m}$ diam., often circinate at the apex **C. cephalothecoidea**

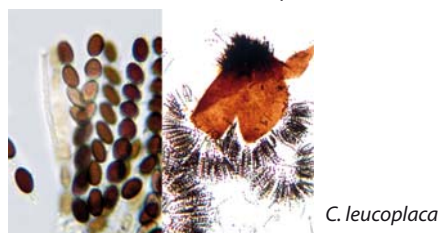


C. cephalothecoidea

Coniochaeta

- 30) (from 1*) Asci 64–128-spored. Ascospores discoidal, $6\text{--}10 \times 4\text{--}9 \times 3.5\text{--}7 \mu\text{m}$ **C. hansenii** (see Plates 6–8)
 30*) Asci 8-spored **31**

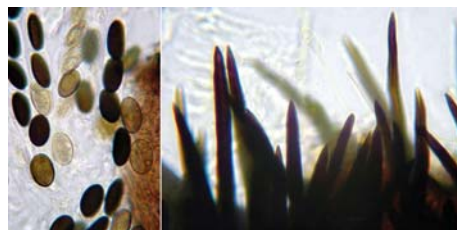
31) Ascospores $8.5\text{--}9.5 \times 6.5\text{--}7.5 \times 4.5\text{--}5.5 \mu\text{m}$. Neck setae short, $30\text{--}45 \times 4\text{--}5 \mu\text{m}$ **C. leucoplaca**



C. leucoplaca

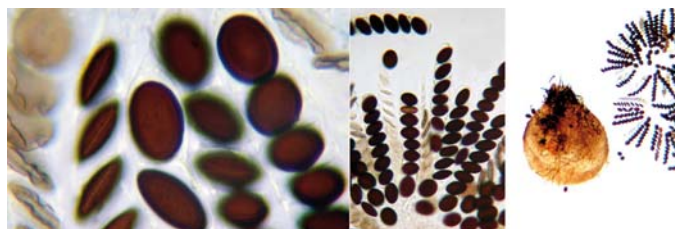
31*) Ascospores larger. Neck setae longer on average **32**

32) Ascospores $13.5\text{--}16 \times 10.5\text{--}12.5 \times 6.5\text{--}9.5 \mu\text{m}$ **C. vagans**



C. vagans

32*) Ascospores $18\text{--}21 \times 13.5\text{--}16 \times 6.5\text{--}9 \mu\text{m}$ **C. scatigena**



C. scatigena

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