On a new species of Chaetomidium, C. vicugnae, with a cephalothecoid peridium and its relationships with Chaetomiaceae (Sordariales)

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Introduction

My studies on coprophilous ascomycetes (DOVERI, 2004, 2011) allowed me to meet with several representatives of Sordariales Chaetomiaceae. In 2004, D. Hawksw. & O.E. Erikss., an order identifiable with the so-called “pyrenomycetes” s.str., i.e. fungi with an ascohymenial ontogeny resulting in dark, membranous to coriaceous, perithecial or cleistothecial ascomata with true walls. Sordariales are also characterised by a usually paraphyletic crustaceous, non-amyloid asci often with an apical apparatus, usually dark-pigmented, one- to poly-celled ascospores with germ pore(s), sometimes with gelatinous equipment, and a saprobic development as decomposers of dung, vegetable debris and soil (KIRK et al., 2008). The order, which formerly included ten families (ERIKSSON & HAWKSWORTH, 1998), was redefined based on phylogenetic analyses (HUHNDORF et al., 2004) and reduced to three families — the monophyletic Sordariales G. Winter, the paraphyletic Chaetomiaceae G. Winter and the Lasiosphaeriaceae Nannf.

Chaetomiaceae are characterised by dark, often hairy or setulose, non-stromatic perithecia or cleistothecia, with a pseudoparenchymatous, sometimes cephalothecoid peridium, fasciculate, ephemeral asci lacking an apical apparatus, and one-celled, pigmented ascospores with one or two (rarely more) germ pores, without a gelatinous perisporium, often extruded as a sticky cirrhus. Their assexual morph, when present, is hyphomycetous (AIRX et al., 1988; CANNOX & KIRK, 2007). Most are celluloletic saprobes (KIRK et al., 2008) with a high economic significance as contaminants of cellulose-containing materials, some behave as occasional opportunistic pathogens to humans and animals (YEGHEN et al., 1996; SCHULE et al., 1997; DE HOOG et al., 2000; SIKLER, 2002; SERENA et al., 2003; AHMED et al., 2016).

I recently had my first opportunity to analyse a sample of vicuña dung from a Chilean coastal desert. The rarity and plenty of pyrenomycetes occurring on this sample of vicuña dung impressed me so much that I wished to learn more about the animal, its communities and habitat. Vicuñas are wild camelids living in the Andean highlands of Chile, Argentina, Bolivia and Peru, between 3000 and 5000 m a.s.l. Families of 5–10 females, their pups and one adult male defecate in the same spots, which appear as dark circular areas of about one meter in diameter, surrounded by herbaceous vegetation.

The aim of this work is to describe a new species of Chaetomidium and define it within the complex family Chaetomiaceae, emphasising the importance of a future systematic study of vicuña dung for a better knowledge of the generic relationships in this family.

Materials and methods

A sample of vicuña dung was collected in the Atacama desert (Chile) and a few days later brought to Italy which, after a first observation, was placed in a non-sterilised damp chamber, following the methods suggested by DOVERI (2004). Cultured material, incubated at room temperature (18–25°C) under natural light, but not exposed to direct sunlight, was examined on alternate days under a stereomicroscope. When first observed all cleistothecia of the new Chaetomidium had already developed in their natural state. No development of new specimens was noticed in the next forty days. Slides for microscopic examinations were mounted in water, Congo red, cotton blue in lactic acid, methyl blue, and an iodide solution. Fifty spores from five specimens were measured in water.

Abbreviations: MCVE = herbarium of Civic Museum of Venice (Italy).

Keywords: Ascomycota, coprophily, germination, homoplaspy, morphology, peridial frame, systematics.

Abstract: A sample of vicuña dung from a Chilean coastal desert was submitted to the attention of the author, who at first sight noticed the presence of different pyrenomycetes. Several hairy cleistothecia particularly caught his attention and were subjected to a morphological study that proved them to belong to a new species of Chaetomidium. After mentioning the main features of Sordariales and Chaetomiaceae, the author describes in detail the macro- and microscopic characters of the new species Chaetomidium vicugnae and compares it with all the other Chaetomidium spp. with a cephalothecoid peridium. The extensive discussion focuses on the characterization and relationships of the genus Chaetomidium and Chaetomidium vicugnae within the complex family Chaetomiaceae. All collections of the related species are recorded and dung is regarded as the preferential substrate. Keys are provided to sexual morph genera of Chaetomiaceae and to Chaetomidium species with a cephalothecoid peridium.

Taxonomy

Chaetomidium vicugnae Doveri, sp. nov. — Mycobank 824904

Figs 1–12

Holotype: On dung of vicuña (Vicugna vicugna) at Miscanti lake, Atacama desert, San Pedro de Atacama, Chile, 23°44’6”S 67°46’8”W, alt. 4.200 m, 15 Feb. 2015, coll. M.T. Seu, Herb. MCVE 29549.

Etymology: “vicugnae” = as growing on vicuña dung.

Cleistothecia gregarious, sometimes crowded, superficial, globose, 250–350 µm diam., dark brown, membranous, hairy. Peridium two-layered, dehiscing by splitting: endostratum a textura angularis of pale brown, thin-walled, polygonal cells, 7–17 × 6–12 µm; exostromatum a textura cephalosporioides of cylindrical, wavy, thick-walled, dark brown cells, 2–3 µm diam., in frontal view appearing radiate from a central, translucent hole and forming poorly defined plates. Hairs widespread, hyaline to very pale brown, often undulate, septate, thin-walled, unbranched, encrusted, superficial, with a slightly enlarged base, usually roundish at the apex, up to 3.5 µm diam., 60–200 µm long, but possibly longer as brittle and hardly measurable. Paraphyses not observed. Ascii ephemeral, fasciculate, unitunicate, non-amyloid, 8-spored, broadly clavate, long-stalked, rounded at the apex, lacking an apical apparatus, 90–120 × 20–27 µm. Ascospores irregularly biseriate, hyaline and non-dextrinoid in the early stages, yellowish to greyish later, containing several droplets or 1–2 larger guttulae, dark greyish brown and opaque at maturity, (21–) 23–27 (–32) × (9–) 10–12 (–13) µm, lacking a gelatinous peris-
porium, narrowly ellipsoid to clearly fusiform, sometimes naviculate ($Q = 2.08–3.20$; average $Q = 2.43$), smooth, thick-walled, often somewhat inequilateral, with attenuated, more rarely slightly apiculate ends, sometimes containing a De Bary bubble in iodide solution, with two large, up to 2 µm diam., eccentric germ pores, one at each end, often with 1–4 additional small germ pores which are indifferently disposed at some level, fast germinating, even in the hyaline stages, so becoming pedunculate, clavate, or laterally knobby. 

Asexual morph not observed.

**Discussion**

**Circumscription of genera within Chaetomiaceae**


Achaetomium is characterised by a hyphal peridium, usually of textura intricata, covered with pale delicate hairs, cylindrical asci, and spherical to ellipsoid or limoniform, very dark ascospores with a germ pore. It was accommodated in Chaetomiaceae based on morphological (Rai et al., 1964; Mukerji & Saxena, 1975; Cannon, 1986; Arx et al., 1984, 1988) and phylogenetic or comparative studies (Lee & Hanlin, 1999; Rodríguez et al., 2004; Wang et al., 2016a).

Bommerella is morphologically very similar to Chaetomium, but distinct in having an association of setulose perithecial hairs, a cephalothecoid peridium, dextrinoid, triangular ascospores, and a sco- pulariopsis-like asexual morph. Arx et al. (1984, 1986) regarded it as a possibly independent genus from Chaetomium and Kirk et al. (2008) as an independent genus. Although DNA sequences of Bommerella were deposited in GenBank (under Chaetomium trigonosporum), they have not been utilised for phylogenetic studies.

The monotypic Chaetomiopsis was accepted in Chaetomiaceae by Kirk et al. (2008) and Lumbsch & Huhndorf (2010) on the basis of morphological features, which were earlier compared with Chaetomium (Moustafa & Abdul-Wahid, 1990) in their protologue. Molecular data are not available for this genus, characterised by densely hairy, dark perithecium with a peridium of textura angularis, clavate asci, and brown, prominently pitted, ellipsoidal to irregular ascospores, rounded at both ends, flattened at one side, with two eccentric or lateral germ pores.

Chaetomium, the type genus of the family, was subjected to extensive morphological (Bainier, 1909; Chivers, 1915; Ames, 1963; Seth, 1970; Cannon, 1986; Arx et al., 1986) and molecular studies (Lee & Hanlin, 1999; Unterreiner et al., 2001; Zhang et al., 2006; Krüys et al., 2015). The Arx et al. (1986) monograph forms the basis for the modern classification of the genus, which appears extremely heterogeneous. A broad conception of Chaetomium includes membranous, hairy or setose, ostiolate ascomata with several types of peridial frame, clavate, fusiform, or cylindrical asci in fascicles, pigmented, one-celled ascospores often extruded as a sticky cirrhus, variable in shape but usually limoniform, ovoidal or fusiform, exceptionally dextrinoid, with one, two or more germ pores, and several types of asexual morphs (Arx et al., 1986; Guarro et al., 2012; Ahmed et al., 2016).

Morphological studies combined with phylogenetic inferences based on six loci (Wang et al., 2016b) were used to define the limits of the so-called “Chaetomium globosum-complex”, a monophyletic group of thirty-six species that also included Chaetomium fimeti (Fuckel) Zopf, the type species of the genus Chaetomium. Linked phylogenetic analyses (Wang et al., 2016a) led them to recognise another thirteen monophyletic clades in Chaetomiaceae and to

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Plate 1 – Chaetomidium vicugnae
1. Hairy cleistothecia on dung. Scale bar: = 300 µm.
Plate 2 – Chaetodium vicugnae
confirm the taxonomic concept and monophyly of the *Chaetomium globosum*-complex. This complex is now regarded as a distinct lineage representing *Chaetomium s.str.* (Wang et al., 2016a). Some known genera of *Chaetomiaceae* have been supported by this study (Wang et al., 2016a) and new genera erected to accommodate species of *Chaetomium s.l.* forming distinct lineages outside the *Chaetomium globosum*-complex. The new taxonomic concept of *Chaetomium s.str.* has been enlarged to include species with both ostiolate and non-ostiolate (some taxa previously regarded as *Chaetomidium*) ascomata, but only those with hypha-like hairs, peridia with a *textura intricata* or *epidermoidea*, rarely *angularis*, clavate or fusiform asci, limoniform, globose or rarely irregular, bilaterally flattened ascospores and, when present, an acremonium-like asexual morph (Wang et al., 2016a).

*Farrowia* was erected by Hawkesworth (1975) to accommodate a group of chaetomium-like species with a usually long neck formed of elongated cells or fused setae, limoniform, biapiculate ascospores, and a botryotrichum-like (humicola-like according to Wang et al., 2016a) asexual morph. It was accepted as an independent genus also by Udagawa & Muroi (1981) but not by Arx et al. (1986). A more recent phylogenetic study (Untereiner et al., 2001) provided evidence that Farrowia is too close to Chaetomium to be accepted as a separate genus.

The monotypic *Guanomyces*, accommodated in *Chaetomiaceae* on the basis of comparative morphological and molecular studies (Gonzáles et al., 2000; Stichgel et al., 2006), is characterised by brown, hairy, long-necked perithecia with single glandular hairs at the neck sides and a tuft of apical hairs, peridium of *textura angularis*, 8-spored, long-stalked, clavate asci, hyaline, slightly aculeate, ellipsoidal ascospores without germ pores, and no asexual morph (Gonzáles et al., 2000).

*Subramaniula* was placed in *Chaetomiaceae* based on morphological studies (Cannon, 1986; Arx et al., 1988). More recently a few gene sequences of the genus have been deposited (Ahmed et al., 2016). *Subramaniula s.str.* is characterised by smooth, urniform ascomata with a broad ostiole surrounded by a collarette, a pale peridium of *textura angularis* to *epidermoidea*, 8-spored, subglobose or broadly clavate asci, broadly fusiform or dacyroid to irregular, brown ascospores with a germ pore, and an unknown or papulospora-like asexual morph (Guarro et al., 2012; Ahmed et al., 2016). Combined morphological and molecular studies (Wang et al., 2016b) expanded its generic concept to include some chaetomium-like species forming a monophyletic lineage with *Subramaniula* spp.

The monotypic *Boothiella* has pale, smooth cleistothecia with a peridium of *textura angularis*, 4-spored, cylindrical asci, and dark-pigmented, subspherical to broadly ovate ascospores with a basal germ pore. It was placed in *Chaetomiaceae* on the basis of morphological studies (Lodhi & Mirza, 1962; Arx & Mahmood, 1968; Mukerji & Saxena, 1975; Arx et al., 1984, 1988). Gene sequences of this genus are not deposited.

*Chaetomidium* is a heterogeneous genus encompassing species with usually hairy or setose cleistothecia, peridium of a *textura angularis* or *cephalothecoidea*, clavate or sometimes ovoidal (4)-8-spored asci, ovoidal, limoniform, fusiform, triangular ascospores with a germ pore, without an asexual morph or with an acremonium-like
Plate 4 – Chaetomidium vicugnae
8–10. Ascospores in different stages (arrows highlighting eccentric or lateral germ pores). Scale bars: 8–9 = 20 μm; 10 = 10 μm.
or botryotrichum-like asexual morph (Guarro et al., 2012). It was located in Chaetomiaceae after morphological (Arx, 1975; Mukerji & Saxena, 1975; Arx et al., 1984, 1988) and comparative studies (Silva & Hanlin, 1996), but phylogenetic analyses based on LSU, ß-tubulin and rpb2 sequence data (Greif et al., 2009) proved Chaetomidium to be polyphyletic, with the majority of its species scattered among the Chaetomiaceae and one species with an uncertain position in Lasiosphaeriaceae nannf.

Corynascus was placed in Chaetomiaceae after morphological (Arx, 1975; Arx et al., 1988) and comparative molecular studies (Stchigel et al., 2000; Kruys et al., 2015). Further phylogenetic studies (Brink et al., 2012) proved that Myceliophthora Costantin and Corynascus cluster together in Chaetomiaceae without an obvious separation and suggested that all Corynascus spp. should be recombined under the older name Myceliophthora. A comparative, phenotypic and phylogenetic study on Myceliophthora (Marín-Felix et al., 2015) split it into four strongly supported clades and restricted it to only the type species Myceliophthora lutea Costantin. Two new genera with a myceliophthora-like asexual morph, Crassicarpon Y. Marín, Stchigel, Guarro & Cano and Thermothelomyces Y. Marín, Stchigel, Guarro & Cano, were consequently erected and Corynascus was re-established. After this study the concept of Corynascus must be restricted to homothallic, mesophilic species with a peridium of textura epi-dermoidea formed of reticulate or verrucose cells, ellipsoidal, broadly fusiform, or irregularly shaped, dark ascospores with two terminal germ pores, and a myceliophthora-like asexual morph.

However, the taxonomic concept of Corynascus has evolved after phylogenetic analyses (Wang et al., 2016a) revealed that Myceliophthora lutea and the species of Corynascus with Myceliophthora asexual morphs cluster in a strongly supported clade, suggesting again that Corynascus be synonymized with Myceliophthora.

Corynascella is characterised by pale cleistothecia covered with dark appendages, a peridium of textura intricata to loosely epi-dermoidea, ovoidal or rarely broadly clavate, 8-spored asci, dark, ellipsoidal, fusiform or reniform ascospores with a thickened wall around the (1) 2 (4) germ pores, and an unknown asexual morph. It was placed in Chaetomiaceae according to morphological (Arx, 1975; Arx et al., 1988) and phylogenetic studies (Brink et al., 2012; Wang et al., 2016a). Guarro et al. (1997) also accommodated in this genus Corynascella arabica, which shows morphological features intermediate between Corynascella (broadly ellipsoidal, thick-walled ascospores with a germ pore at each end) and the group of Chaetomidium spp. with a cephalothecoid peridium (dark cleistothecia, clavate asci, peridial plates of radiating cells).

The monotypic, coprophilic Emilmuelleria has black cleistothecia with tufts of pale, spirally coiled hairs, a thick peridium of textura angularis, 8-spored, long-stalked, clavate asci, dextrinoid, greyish, ellipsoidal ascospores with an apical germ pore, and an unknown asexual morph. Morphological (Arx, 1985; Arx et al., 1988) and phylogenetic (Silva & Hanlin, 1996) studies suggested the placement of this genus in Chaetomiaceae. Combined morphological and phylogenetic studies (Wang et al., 2016a) confirmed its position in Chaetomiaceae but at the same time suggested its synonymy under the expanded genus Botryotrichum Sacc. & Marchal, which also includes some chaetomi-um-like ostiolate species.
**Thielavia** was subjected to numerous morphological (Booth, 1961; Malloch & Cain, 1973; Arx, 1975; Arx et al., 1984, 1988) and phylogenetic (Lee & Hanlin, 1999; Stichgel et al., 2002; Cain et al., 2006a) studies, which certainly proved that it belongs to *Chaetomiaceae* and represents a well-supported monophyletic lineage (Wang et al., 2016a). The genus encompasses more than twenty species characterised by usually glabrous or setose cleistothecia with a *textura epi-
dermoidea* peridium, 8-spored, ellipsoidal or saccate, rarely cylindrical asci, thin-walled, ellipsoid-fusiform, ovoidal or even subclavate, brown ascospores with a germ pore, and an occasional presence of chrysosporium-like aleuropoiodia (Stichgel et al., 2003).

**Melanocarpus** was erected by Arx (1975), who regarded it as related to *Thielavia*. Later, it was described and discussed by Arx et al. (1988), who compared it with *Boothiella*, and monographed by Guarro et al. (1996), who wished that molecular studies would better define the genus. Lumbsch & Hu¨nndorf (2010) placed *Melanocarpus* in *Sordariales incertae sedis*, although a comparative morphological and molecular study (Stichgel et al., 2002) proved that it is related to *Thielavia* in *Chaetomiaceae*. Its placement in *Chaetomiaceae*, where it represents a monophyletic clade, was confirmed by Wang et al. (2016a). The genus includes mesophilic and thermophilic species with dark cleistothecial ascomata covered with short setae or simple hyphae, a peridium of *textura angularis* or rarely epidermoidea, 8-spored, subglobule or cylindrical-saccate asci, thick-walled, brown, often oblate or broadly ellipsoid to ovoid ascospores with a germ pore, and a chrysosnilia-like asexual morph (Guarro et al., 2012).

**Historical survey of Chaetomidium**

*Chaetomidium* was erected by Zopf (1881) as a genus and regarded as an independent genus by Saccardo (1882), to accommodate a single species, *Chaetomidium fmeti*, with non-os-
tiolate ascomata and “wire-like” basal rhizoids. Bannier (1909), Cavers (1915), Skolko & Groves (1953) and Whiteside (1962) accepted *Chaetomidium* and Bannier (1909) also established two new taxa in this genus, *C. phyllactinum* and *C. magnum*, which Malloch & Cain (1973) transferred to *Thielavia* and Arx et al. (1988) considered doubtful species. Cain (1961) established *Chaetomidium minutum*, but Malloch & Cain (1973) transferred it to *Thielavia* and Guarro et al. (1996, 2012) confirmed it in the latter genus. Seth (1967) described *Chaetomidium subfmeti* as a new species from vegetable material, very close to *C. fmeti* but with somewhat smaller ascospores. Malloch & Cain (1973) did not accept *Chaetomidium* as a genus independent from *Thielavia*, stating that the presence of differentiated hairs in the former and glabrous cleistothecia in the latter are not enough to separate them at the genus rank, especially because intermediate forms are known. Arx (1975) did not attribute the same importance to the presence or absence of hairs, and recognised *Chaetomidium* as a genus independent from *Thielavia*, having pseudoparenchymatous rather than textura epidermoidea peridia and limoniform or laterally flattened ascospores. He accepted in *Chaeto-
midium* only species with clavate asci and ascospores with one germ pore, and first recognised in the genus one species with a cephalothecoid peridium, *C. cephalothecoides* (Malloch & Benny) Arx. Besides *C. fmeti* and *C. subfmeti*, he also accepted three other spe-
cies with a peridium of *textura angularis*, i.e. *C. pilosum* (C. Booth & Shipton) Arx, *C. spirotrichum* (R.K. Benj.) Malloch & Cain and *C. tri-
chorobustum* Seth. *Chaetomidium spirotrichum* was later recombi-
ned in *Emilmuelleria spirotrich* (R.K. Benj.) Arx. Arx et al. (1988) confirmed *Chaetomidium* as a genus and recognised *C. heteroti-
rum* R.J. Mey. and *C. arxii* Benny, the latter with a cephalothecoid peridium.

Doveri (2004) discussed *Chaetomidium* and provided a key to the species with a cephalothecoid peridium, including *C. khodense* C. Cain & Guarro & El Shafee (Cain et al., 1993) and *C. megasporum* Doveri, Guarro, Caciari & Caroti (Doveri et al., 1998), two taxa established after the Arx et al. (1988) monograph.

Stichgel et al. (2004) provided a key to all *Chaetomidium* spp. and described two new species: *Chaetomidium galalicum* Stichgel & Guarro, close to both *C. khodense* and *C. megasporum* for having fu-
siform ascospores and a cephalothecoid peridium, and *C. triangula*
re Stichgel & Guarro, the first *Chaetomidium* sp. with smooth ascocamata and triangular ascospores.

Greff & Currah (2007) recombined *Aporothielavia leptoderma* (C. Booth) Malloch & Cain in *Chaetomidium leptoderma* (C. Booth) Greff & Currah after proving by ultra-structural techniques that its cephalothecoid peridium has a development and dehiscence very similar to *C. arxii*.

Greff et al. (2009) proved that *Chaetomidium* is polyphyletic and restricted the genus to *C. fmeti* and *C. subfmeti*. They also noticed a minimal difference of gene sequences between *C. leptoderma* and *C. gallicum* and regarded them as conspecific.

GGuarro et al. (2012) accepted 11 species of *Chaetomidium*, 5 with a cephalothecoid peridium, i.e. *C. arxii*, *C. cephalothecoides*, *C. kho-
dense*, *C. leptoderma* and *C. megasporum*.

Based on Greff et al. (2009) and new personal analyses of β-tubulin and rpb2 gene sequences, Wang et al. (2016b) showed that *Chaeto-
midium fmeti* and *C. subfmeti* cluster within the *Chaetomium glo-
bsom* species complex (*Chaetomium s.s*.). So, they rejected the genus name *Chaetomidium* and regarded it as synonym of *Chaeto-
mium*.

**Characterization, relationships and ecology of Chaetomidium vicugnae and related species**

*Chaetomidium vicugnae* is characterised by a cephalothecoid pe-
idium, very pale peridial hairs, large, narrowly ellipsoid to fusiform ascospores with two large, subapical germ pores and sometimes with additional, smaller pores, and growth on dung. No other spe-
cies of *Chaetomidium s.l* shows an association of such features. The species with a cephalothecoid peridium particularly differ in having dark pigmented hairs and significantly smaller ascospores with a single germ pore. *C. arxii* further differs from *C. vicugnae* in that it has straight, usually smooth hairs and broadly ellipsoidical ascospores (Benny, 1980) and *C. leptoderma* (compared to *C. arxii* by Greff & Cur-
rah, 2007) is also distinguishable by its sparsely hairy perithecia and knob-like protrusions of the peridial cells. Unlike *C. vicugnae*, *C. ce-
phalothecoides* and *C. megasporum* have ellipsoidical to broadly fusiform ascospores (average Q < 2 versus 2.43) and almost smooth, sometimes hooked hairs (Malloch & Benny, 1973), and hairs with end branches at right angles (Doveri et al., 1998) respectively.

I also compared *C. vicugnae* with *Chaetomidium bipiculatum* Lodha and *C. hyalotrichum* Taparia & Lodha, listed in Index Fungorum but appearing almost like ghost species as they were never mentioned in other works on *Chaetomidium* and never recombined or regarded as synonyms of other taxa. According to the protologue (Lodha, 1974) *Chaetomidium bipiculatum* has morphological fea-
tures of a true *Chaetomidium*, close to the type species *C. fmeti*, but with straight peridial hairs and ascospores with two germ pores. It stands quite distant from *C. vicugnae* for having broadly ellipsoidical ascospores and a peridium of *textura angularis*. *Chaetomidium hya-
lotrichum* shares hyaline peridial hairs with *C. vicugnae* and ascospores with two germ pores (Taparia & Lodha, 1974) but, like *C. bipiculatum*, clearly differs from *C. vicugnae* in having a peridium of angular cells and broadly ellipsoidical ascospores.
### Key to sexual morph genera of Chaetomiaceae

1) Ascomata ostiolate ................................................................................................................................................................................................................... 2
2) Ascomata urniform, smooth, with a broad ostiole, up to 150 µm diam. Ascospores often dacryoid or irregular in shape ................................. Subramaniula s.str. 6
3) Ascomata hairy or setose, with a much narrower ostiole. Ascospores different in shape ........................................................................................................................................................................................................... 3
4) Ascomata with dark, coarsely warted, dichotomously branched hairs. Peridium of textura angularis. Ascospores comparatively large, 18–24 × 14–16 µm, ellipsoid to irregular, rounded at the ends, prominently pitted, with two germ pores ........................................ Chaetomiopsis 4
5) Ascomata obovate or ampulliform, covered with pale hyphal hairs. Peridium usually of textura intricata. Ascospores spherical and slightly oblate or ellipsoid-limoniform. Asexual morph unknown ........................................ Achaetomium 13
6) Ascomata with a long neck covered with lateral glandular hairs and a tuft of apical hairs. Ascospores ellipsoid with rounded ends, imperceptibly aculeate, without germ pores. ............................................... Guanomyces 5
7) Ascomata with a vestiture. Ascii 4–6-spored (4-spored in one strain of Emilmuelleria sp.). .................................................................................. Boathiella 8
8) Peridium pale and very thin. Ascii 4-spored, cylindrical. Ascospores subglobose or broadly ovoid, with one basal germ pore. Asexual morph unknown ....................................................................................................................................................................................................... Crassicippon 9
9) Ascomata very dark and opaque, hairy or covered with undifferentiated hyphae. Peridium of textura angularis. Asci subglobose or cylindrical-saccate. Ascospores subglobose to broadly ovoidal or ellipsoidal, uni- or bilaterally flattened, with one apical or lateral germ pore. Asexual morph chrysornilia-like. Meso- or thermophilic ................................................................. Melanocarpus 10
11) Ascomata dark hairy or setulose. Peridium of textura intricata. Asci 8-spored, ovoidal or broadly clavate, stalked. Ascospores ellipsoid to reniform, usually unilaterally flattened, with a thickened wall around two or more, terminal germ pores. Asexual morph unknown ................................................................. Corynascella 11
12) Peridial cells reticulate or verrucose. Ascospores with two germ pores, one at each end, ellipsoidal, broadly fusiform, or irregularly shaped. Ascii ovoidal or subglobose. Asexual morph myceliophthora-like. Mesophilic ........................................................................................................................................................................... Corynascus s. Marín-félix et al. 2015 12
13) Ascospores ellipsoid, fusiform, subclavate, sometimes broadly ovoidal and bilaterally flattened, with an apical or subapical germ pore. Ascii ellipsoidal or saccate, rarely cylindrical. Asexual morph often unknown or chrysosporium-like. Mesophilic or thermophilic ........................................................................................................................................................................................................ Thielavía 13

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Emilmuelleria (Botryotrichium p.p., s. Wang et al. 2016a)

Corynascus s. Marín-Félix et al. 2015

Thielavía

Thermothelomycetes
Finally, we have compared Chaetomidium vicugnae with Corynascella arabica Guarro, Al-Saadon, Gené & Abdullah, an atypical species of Corynascella with dark cleistothecia, short undifferentiated hairs, a cephalothecoid peridium, stalked, clavate asci, and ascospores lacking a thickened wall around the germ pores (Guarro et al., 1997). Most of these features make it similar to the group of Chaetomidium spp. with a cephalothecoid peridium, particularly to Chaetomidium vicugnae due to the presence of ascospores with two eccentric germ pores. But Corynascella arabica can be distinguished by its much shorter peridial hairs, smaller asci, and smaller, thickwalled, broadly ellipsoidal ascospores.

Coprophily is a well-known lifestyle of many Chaetomidium species (Aris et al., 1988; Guarro et al., 2012), particularly those with a cephalothecoid peridium (Dover, 2004; Guarro et al., 2012). Unfortunately, some of them are known only by single collections, i.e. C. megasporum from cattle dung (Dover et al., 1998), C. vicugnae from vicuña droppings, and C. leptoderma from soil (Booth, 1961). C. arxii was twice collected from rodent dung (Benny, 1980; Lorenzo, 1993) and once recorded from Eurygaster integriceps, the insect agent of the wheat Sunn pest (Arzanlou et al., 2012). The distribution of C. khodense is restricted to the Sultanate of Oman, where it was found on cattle (Cano et al., 1993), goat and camel dung (Elshafti, 2005), while that of C. cephalothecoides extends to North America, where it was originally isolated from mouse dung (Malloch & Benny, 1973), and Europe from sheep dung (Valldosera & Guarro, 1992; Dover, 2004; Moyne & Petit, 2006). Corynascella arabica was once isolated from donkey dung in Iraq (Guarro et al., 1997). At present, therefore, the scarce number of findings does not allow the subspecies preference and tolerance of each species to be precisely defined.

Conclusions

Cleistothecial ascomycetes, even belonging to unrelated orders and classes (Stchigel & Guarro, 2007; Lumbsch & Huhndorf, 2010) are quite frequent on dung, where they apparently behave as saprobic decomposers (Kirk et al., 2008). The cleistothelial development represents an effective defence against several environmental threats, enabling the reproductive structures to be exposed only at full maturity. Several pyrenomycetes with non-ostiolate ascocoma show a cephalothecoid peridium, consisting of plates of elongated, radiating cells, separated by lines of weakness along which the peridial frame splits at maturity (Greif & Currah, 2007). Fractures occur by means of active forces from inside (Malloch & Cain, 1970; Greif et al., 2004; Greif & Currah, 2007) or by external forcings (Bennet et al., 1988) resulting from the contact with arthropods or beetles, which also act as spore carriers and dispersers.

The cephalothecoid peridial structure is sporadically present in unrelated taxa, even belonging to different classes, such as in Cephalotheca Fuckel (Dothideomycetes O.E. Erikss. & Winka) or in Cercophora Fuckel and Chaetomidium (Sordariomycetes), proving that this feature is homoplastic, resulting from independent, parallel evolution in different lineages of ascomycetes (Sun & Blackwell, 1999; Greif et al., 2009).

The ascospores of Chaetomidium vicugnae are able to germinate even when still hyaline, proving that they reach reproductive maturity also at this stage. This striking phenomenon is typical of the genus Cercophora and sometimes occurs in Podospora Ces. sect. Podospora (Lundqvist, 1972), suggesting, perhaps, a close phylogenetic relationship with Chaetomidium vicugnae.

To my knowledge vicuña droppings have never been subjected to extensive studies or surveys on coprophilous ascomycetes. The sample of vicuña dung I examined is surprising because although numerous ascocoma were observed, only four species were recorded. Three of these were cleistothecial, two with a complete or partial cephalothecoid peridium, i.e. Chaetomidium vicugnae and a Chaetomium species of the murorum-group respectively.

I think that further studies of fungal isolates from vicuña dung can improve the knowledge of phylogenetic relationships between genera and families of Sordariaceae.

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References

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