

Published in final edited form as:

*Fungal Divers.* 2011 December 1; 51(1): 103–134. doi:10.1007/s13225-011-0145-6.

## Capnodiaceae

Putarak Chomnunti<sup>1,2</sup>, Conrad L. Schoch<sup>3</sup>, Begoña Aguirre–Hudson<sup>4</sup>, Thida W. Ko-Ko<sup>1,2</sup>, Sinang Hongsanant<sup>1,2</sup>, E.B. Gareth Jones<sup>5</sup>, Rampai Kodsueb<sup>6</sup>, Rungtiwa Phookamsak<sup>1,2</sup>, Ekachai Chukeatirote<sup>1</sup>, Ali H. Bahkali<sup>7</sup>, and Kevin D Hyde<sup>1,2,7,\*</sup>

<sup>1</sup>Institute of Excellence in Fungal Research, Mae Fah Luang University, Chiang Rai 57100, Thailand <sup>2</sup>School of Science, Mae Fah Luang University, Chiang Rai, 57100, Thailand <sup>3</sup>National Center for Biotechnology Information, National Library of Medicine, National Institutes of Health, 45 Center Drive, MSC 6510, Bethesda, Maryland 20892–6510, USA <sup>4</sup>Jodrell Laboratory, Royal Botanic Gardens, Kew, Richmond, Surrey TW93DS, UK <sup>5</sup>Institute of Ocean and Earth Sciences (IOES), C308, Institute of Postgraduate Studies Building, University of Malaya, 50603, Kuala Lumpur, Malaysia <sup>6</sup>Faculty of Science and Technology, Pibulsongkram Rajabhat University, Phisanulok, 65000, Thailand <sup>7</sup>King Saud University, College of Science, Botany and Microbiology Department, P.O. Box: 2455, Riyadh 1145, Saudi Arabia

### Abstract

In this paper we revisit the *Capnodiaceae* with notes on selected genera. Type specimens of the ascomycetous genera *Aithaloderma*, *Anopeltis*, *Callebaea*, *Capnodaria*, *Echinothecium*, *Phragmocapnias* and *Scorias* were re-examined, described and illustrated. *Leptoxyphium* is anamorphic *Capnodiaceae* and *Polychaeton* is a legitimate and earlier name for *Capnodium*, but in order to maintain nomenclatural stability we propose that the teleomorphic name should be considered for the approved lists of names currently in preparation for fungi. Notes are provided on the ascomycetous genus *Scoriadopsis*. However, we were unable to locate the type of this genus during the time frame of this study. The ascomycetous genera *Aithaloderma*, *Ceramoclasteropsis*, *Hyaloscolecostroma* and *Trichomerium* are excluded from *Capnodiaceae* on the basis of having ascostromata and trans-septate hyaline ascospores and should be accommodated in *Chaetothyriaceae*. *Callebaea* is excluded as the ascomata are thyriothecia and the genus is placed in *Micropeltidaceae*. *Echinothecium* is excluded as synonym of *Sphaerellothecium* and is transferred to *Mycosphaerellaceae*. The type specimen of *Capnophaeum* is lost and this should be considered as a doubtful genus. The coelomycetous *Microxyphium* is polyphyletic, while the status of *Fumiglobus*, *Polychaetella* and *Tripospherum* is unclear. Fourteen new collections of sooty moulds made in Thailand were isolated and sequenced. The nuclear large and small rDNA was partially sequenced and compared in a phylogeny used to build a more complete understanding of the relationships of genera in *Capnodiaceae*. Four new species are described and illustrated, while *Phragmocapnias* and *Scorias* are epitypified with fresh collections.

### Keywords

*Chaetothyriaceae*; *Micropeltidaceae*; Molecular phylogeny; Sooty moulds

## Introduction

The family *Capnodiaceae* was introduced by Höhnel (1910) with the generic type *Capnodium* Montagne (1849) and presently includes 14 genera and 117 species (Kirk et al. 2008, Lumbsch and Huhndorf 2010). *Capnodiaceae* are sooty moulds with bitunicate asci borne in ostiolate ascomata; the family however is based mostly on ecological characters (von Arx and Müller 1975). The first complete monographic review of capnodiaceous sooty moulds recognized both sexual and asexual species in *Eucapnodiaceae* (Fraser 1935). Batista and Ciferri (1963) later provided a monograph of *Capnodiaceae* in the order *Capnodiales*. Hughes (1972) reviewed and re-classified *Capnodiaceae* which was characterized by the structure of the hyphae, the presence or absence of pseudoparaphyses and by deviating conidial states. Members of this family also had superficial ascomata with ovoid asci in fascicles and hyaline to dark, one to multiseptate ascospores (see also Hughes 1976). More recently *Capnodiaceae* have been redefined by the following features: superficial mycelium of interwoven, mucilaginous, brown, cylindrical or tapering hyphae, mostly constricted at the septa, and occur as leaf epiphytes associated with the honeydew of insects (Hughes 1976; Andrew 1982; Blakeman and Fokkema 1982), the ascomata lack pseudoparaphyses and the asci are bitunicate. The fungi are also known as sooty moulds, and tend to live in complex communities, often with multiple fungal parasites, inhabiting a common sooty mass (Faull et al. 2001; Hughes 2003). They are noted for the production of darkly pigmented hyphae, often of very characteristic morphology (Hughes 1976; Reynolds 1998). Anamorphs reported in *Capnodiaceae* are *Acanthorus*, *Apiosporium*, *Conidiocarpus*, *Conidioxyphium*, *Fumagospora*, *Fumiglobus*, *Leptoxyphium*, *Mycogelidium*, *Phaeoxyphiella*, *Polychaetella*, *Polychaeton*, *Scolecoxyphium*, and *Tripospermum* (Hyde et al. 2011).

The *Capnodiaceae* should not be confused with *Chaetothyriaceae* which are also referred to as sooty moulds since they share the same ecological niche and are similar in appearance. The main differences are found in the characteristics of the ascomata, being single locules in *Capnodiaceae*, and ascostromata, often with more than one locule in *Chaetothyriaceae*. In addition, phylogenetic analyses have clearly shown them to be unrelated and they were placed in two separate classes: *Dothideomycetes* and *Eurotiomycetes* respectively (Schoch et al. 2006, 2009; Geiser et al. 2006; Chomnunti et al. 2012). The easiest character by which to distinguish these families on leaf surfaces is the form of the ascomata. In *Capnodiaceae* ascomata are subglobose to globose, with or without setae (von Arx and Müller 1975), while in *Chaetothyriaceae* they are ascostromata surrounded by a pellicle of superficial mycelium (Chomnunti et al. 2012).

The purpose of this study is to revisit the family *Capnodiaceae* by examining available generic types which are described and illustrated. We have also collected fresh specimens from Thailand and we have isolated the material in culture and sequenced the species. We incorporate 14 new taxa in the molecular analysis and provide a more complete tree than has been presented before for *Capnodiales* (Crous et al. 2009).

## Material and Methods

Generic type specimens of *Aithaloderma*, *Anopeltis*, *Callebea*, *Capnodium* *Echinothecium*, *Phragmocapnias* and *Scorias* were obtained from Herbaria S, B, NY and K, and the collections are documented morphologically. The type material of some species could not be located during the time frame of this study; however, they are discussed based on the original description and subsequent publications. The herbarium specimens were rehydrated in 5% KOH for 10 minutes and free hand sections prepared under the stereo microscope, mounted in water and later preserved in lactic acid. Microcharacters were examined and

observed under a compound microscope (Nikon 80i) fitted with DIC, and measurements made with the Tarosoft (R) Image Frame Work.

### Isolates and morphology

Sites were visited throughout the provinces of Chiang Mai and Chiang Rai in northern Thailand and leaves of various plants with sooty mould-like colonization were collected and brought to the laboratory in plastic bags. Sections of ascomata were made free hand and mounted in lacto-glycerol. Melzer's reagent was used to test the amyloidity of the apical ring and Indian ink was used for demonstrating the mucilaginous sheath (before adding the lactoglycerol). Pure cultures were obtained by single spore isolation. For that, a part of the hymenium containing ascospores was removed from 4–5 ascomata of fresh material, using a sterile needle, and placed in a drop of sterile water on a glass slide. The contents were broken up further mechanically with the sterile needle until a spore suspension was obtained. The spore suspension was then transferred with a sterile pipette onto the surface of a Petri dish with 2% Difco potato-dextrose agar (PDA) as media. The plates were left overnight to germinate and observed within 12 hours. Germinating spores were individually transferred onto a fresh Petri dish. Isolates were grown on PDA at 28 C for 12 h of light/12 h of dark for routine maintenance. Colony colour and characteristics were assessed after 4 weeks, and this material was used for molecular study.

Types of isolated new species are deposited at the Mae Fah Luang University (MFLU) Herbarium, Chiang Rai, Thailand, and the cultures in the Culture Collection of the same institution (MFLUCC) and in BIOTEC Culture Collection (BCC).

### DNA isolation, amplification and sequencing

The analysis was performed with two markers: partial sequences from the small and large subunits of the nuclear ribosomal RNA genes (SSU, LSU). The individual genes were aligned with SATé (Liu et al. 2009) using MAFFT (Katoh et al. 2009) as the external sequence alignment tool and RAxML (Stamatakis 2006) as the tree estimator. Representative sequences from *Capnodiales* were downloaded from GenBank according to Supplementary Table 1. *Dothidea insculpta* and *D. sambuci* were selected as outgroups. Phylogenetic analyses of the single genes did not yield conflicts in clades with RAxML bootstrap presence above 70% (data not shown), therefore sequences were concatenated in BioEdit (Hall 2004). This resulted in 15.5% missing and gap characters out of a total set of 1982 characters (967 obtained from SSU and 1015 obtained from LSU). The final data matrix had 51 taxa including outgroups. A phylogenetic analysis was performed at the CIPRES webportal (Miller et al. 2010) using RAxML v. 7.2.8 as part of the "RAxML-HPC2 on TG" tool (Stamatakis 2006; Stamatakis et al. 2008). A general time reversible model (GTR) was applied with a discrete gamma distribution and four rate classes. Fifty thorough maximum likelihood (ML) tree searches were done in RAxML v. 7.2.7 under the same model, each one starting from a separate randomised tree and the best scoring tree selected with a final ln value of -7912.128405. One thousand non parametric bootstrap iterations were run with the GTR model and a discrete gamma distribution. The resulting replicates were plotted on to the best scoring tree obtained previously. The phylogram with bootstrap values above the branches is presented in Fig 1 by using graphical options available in TreeDyn v. 198.3 (Chevenet et al. 2006).

We also analyzed the same data set mentioned above using the Bayesian method of Huelsenbeck et al. (2001) by implementing Markov Chain Monte Carlo (MCMC) sampling using the software MrBayes v.3.1.2 (Huelsenbeck and Ronquist 2001) at the CIPRES webportal. Data were analysed with a GTR model with gamma-distributed rate variation across sites (invariance, partitioning across genes) were applied with four discrete gamma

categories. The Bayesian prior distributions treated all trees as equally likely and two parallel runs were performed with four chains each. This was continued for 2000 000 generations and every 100th tree was saved. The two runs were verified for convergence and the first 50% of each run was discarded as burn in with the remaining two sets of 10 000 trees combined. The best scoring RAxML tree was used as a template and the percentage presence of all nodes within the combined set of 20 000 trees plotted on its nodes as Bayesian posterior probabilities. These are indicated as the second set of values (after the front slash) in Fig 1

## Results

### Molecular phylogeny

In the tree (Fig 1) we included representative sequences of *Capnodiaceae*, *Davidiellaceae*, *Dissoconiaceae*, *Mycosphaerellaceae*, *Schizothyriaceae*, *Teratosphaeriaceae* as well as uncertainly placed lineages in *Capnodiales* mainly following an earlier analysis by Crous et al. (2009). All groups agreed with this analysis. The phylogeny presented includes the biggest sampling of *Capnodiaceae* to date and includes several samples from earlier studies (Crous et al. 2009; Reynolds, 1998; Ruibal et al. 2009; Schoch et al. 2006). The 15 specimens of sooty moulds from Thailand including *Leptoxyphium cacuminum*, *Phragmocapnias betle*, *P. asiaticus*, *P. siamensis*, *Polychaeton coartatum* and *Scorias spongiosa* clustered within *Capnodiaceae* (Fig 1). The clade containing *Capnodiaceae* was only recovered in 50% of bootstrapped (BP) tree using the RAxML analysis but received a 99% posterior probability (PP) in the Bayesian analysis. This clade is recovered with high frequency in other analyses including protein coding gene markers (Schoch et al. 2009) but not well supported in other studies using only ribosomal sequence comparisons (Crous et al, 2009).

The *Capnodiaceae* comprises four clades (A–D). Clade A (100% BP and PP) comprises three *Leptoxyphium* sequences from GenBank and three new strains with characters typical of *Leptoxyphium sensu* Hughes (1976), Olejnik et al. (1999) and Cheewankoon et al. (2009) as well as *Microxiphium citri* and a rock isolate with 97% support. *Microxiphium citri* was isolated from citrus fruit in Spain and may be wrongly named. Clade B (52% BP, 92% PP 100%) comprises *Capnodium coffeae*, *Conidioxyphium gardeniorum*, *Microxiphium aciculiforme* and a new species of anamorphic *Capnodium* (= *Polychaeton*). *Conidioxyphium gardeniorum* is either wrongly named or is a synonym of *Capnodium*. Clade C are *Phragmocapnias* (= *Conidiocarpus*) species with one teleomorph species being identical to the generic type and is thus epitypified. The genus is represented by at least two morphological species which are described as new in this paper. Further collections and analyses are likely to reveal other taxa in this genus. Basal to the *Phragmocapnias* Clade C is *Polychaeton citri*, a strain of *Antennariella placitae*, *Microxiphium theae* and two ant nest wall strains. *Polychaeton citri* was isolated from a leaf of *Citrus aurantium* together with *Pseudococcus citri* (Crous et al. 2009). Because of difficulty in isolating *Capnodium* species and the fact that many species occur on the same leaf in close proximity we suspect this may be wrongly named and this will have to be verified. *Antennariella placitae* was described by Cheewankoon et al. (2009) but it is not clear if this is correctly placed and more collections would be needed to establish its familial relationships. Sister to these taxa is a putative strain of *Capnodium salicinum* which also require verification. Finally, Clade D (100% bootstrap support) comprises two isolates of *Scorias spongiosa*. The new isolate from Thailand is designated as the epitype here. Three *Microxiphium* species are included in the analysis, which in the present study show that the genus is polyphyletic. Based on morphological examination of the type species, this genus may belong in *Coccodiniaceae*.

*Capnodiaceae* (Sacc.) Höhn. ex Theiss. 1916.

*Saprobic* on honey dew excretions from insects, usually forming blackened sooty-like regions on green healthy leaves, stems, bark and even rocks (Fig 2A–E), and often in association with numerous other species and fungicolous taxa. *Thallus* comprising mycelium with black sooty growth on the host surface, producing superficial colonies with septate, cylindrical, brown hyphae. *Ascomata* arise from the mycelial mass, subglobose to globose, coriaceous, with or without setae, dark brown, with a central ostiole. *Peridium* brown, relatively thin, comprising cells of *textura angularis*. *Pseudoparaphyses* lacking. *Asci* bitunicate, saccate, with a short pedicel, lacking an ocular chamber. *Ascospores* multiseptate or muriform, hyaline to brown. Anamorph states are pycnidial, mostly elongated, with short or long narrow necks, and with or without a swelling where the conidia are produced. *Ostiole prominent* at the apex of the pycnidial neck. *Conidia* occur on typical capnodiaceous hyphae within the pycnidia and are small, one-celled, ellipsoidal, and hyaline.

**Family type:** *Capnodium* Mont. (1849) (= *Polychaeton* (Pers.) Lév. 1846). The Melbourne Botanical Congress has recently approved large scale changes to process of naming fungi, including the abolition of Article 59. Therefore, by applying the principle of priority *Polychaeton* would be the earlier and valid name for the species currently assigned to the genus *Capnodium*. However, this process is still being finalized and it was proposed that anamorph typified names should not be taken up to displace teleomorph typified names in use until each case has been reviewed by the Fungal Committee established at the Melbourne Congress (Hawksworth 2011). As the name *Capnodium* is taken up for the name of the ranks of family and order in this group of fungi, this is a prime example that the retention of the name should be proposed for approval to the Committee.

The family *Capnodiaceae* was introduced by Höhnel (1909) and validated by Theissen in 1916 according to von Arx and Müller (1975) and Hughes (1976), and is circumscribed as dothideomycetous sooty moulds with mostly pycnidial anamorphs (Reynolds 1982). The taxa of this family can be recognized by black mycelial growth spreading on the host surface which produces superficial colonies with septate, cylindrical, dark-brown hyphae (Figs 3A, B). *Ascomata* arise from the mycelial mass and are subglobose to globose (Sivanesan 1984; Barr 1987; Figs 2E, 3C). Their anamorphic states, placed mostly in *Asbolisiaceae* by Batista and Cifferi (1963) form elongated pycnidia, with short or long narrow necks, an apical ostiolar canal, and minute, one-celled and hyaline conidia (*sensu* Hughes 1976).

In the past some members of the family had been only known from anamorphic stages, and these pycnidia had been assigned to one or other teleomorphic genera and families depending on whether the researchers gave more emphasis to Saccardoan generic concepts such as spore morphology and colour, or colony hyphal development, hyphal morphology and ascomatal and pycnidial formation (as with Hughes 1976), but now the use of modern molecular techniques has enabled us to confirm their relationship in the *Capnodiaceae*.

Crous et al. (2009) used molecular methods to evaluate the monophyly of the order *Capnodiales*, yet they did not discuss the family in detail, though concluding that it probably contained diverse lineages. In the present account we illustrate genera of the group and we compare our morphological findings of some generic types examined with molecular results of taxa found in south eastern Asia.

### Key to genera accepted in *Capnodiaceae*

- |  |  |
|--|--|
| 1. <i>Pycnidia</i> with a black stalk, and an upper brown swollen region producing conidia; ascospores hyaline           | <i>Phragmocapnias</i><br>( <i>Conidiocarpus</i> ) [Fig 2F] |
| 1. <i>Pycnidia</i> without a black stalk or an upper brown swollen region producing conidia; ascospores brown or hyaline | 2  |
| 2. Pycnidia lacking a basal bulbous part; ascospores brown ( <i>Polychaeton</i> )  | <i>Capnodium</i> [Fig 2G]                                  |

- |  |                              |
|--|------------------------------|
| 2. Pycnidia with basal bulbous part; ascospores other  | 3                            |
| 3. Ascomycetous state unknown, pycnidia with narrow bulbous base, apex cup-like which produces conidia | <i>Leptoxyphium</i> [Fig 2H] |
| 3. Ascomata present, gregarious on blacked mycelial mat; pycnidia with swollen bulbous base            | 4                            |
| 4. Ascospores mostly 3-septate.  | <i>Scorias</i> [Fig 2I]      |
| 4. Ascospores mostly 1-septate.  | <i>Scoriadopsis</i>          |

*Phragmocapnias* Theiss. & Syd., Ann mycol. 15(6): 480 (1918) [1917]

*Conidioxyphium* Bat. & Cif., Quad. Lab crittogam., Pavia 31: 72 (1963)

*Podoxyphium* Speg., Physis. B. Aires 4: 294 (1918)

*Conidiocarpus* Woron., Ann mycol. 24 (3/4): 250 (1926)

*Saprobic* on sugary exudates from insects, dark mycelium forming a soot-like coating on the upper surface of leaves. *Thallus* composed of black, pelliculose, reticulately branched, dense, cylindrical, radiating, septate hyphae. *Ascomata* scattered, subglobose to broadly ellipsoidal, barely stalked, firmly attached to the basal hyphae, dark brown, thick-walled, ostiolate, with setae. *Peridium* consisting of pale to dark brown cells forming a *textura angularis*. *Asci* bitunicate, 8-spored, broadly clavate, with short pedicle. *Ascospores* cylindrical-clavate, hyaline, 4-septate and constricted at the septum. *Pycnidia* with a black stalk, with an upper brown swollen part which produces conidia, wall comprising cylindrical cells. *Ostirole* surrounded by hyaline hyphae. *Conidiogenous cells* form from inner cell surface of swollen part. *Conidia* small, ellipsoid, 1-celled, hyaline, smooth-walled.

Anamorph: *Conidiocarpus* Woron. (Hyde et al. 2011)

### Type species

*Phragmocapnias betle* (Syd. P. Syd. & E.J. Butler) Theiss. & Syd., Ann mycol. 15(6): 480 (1918) [1917]

≡ *Capnodium betle* Syd. P. Syd. & E.J. Butler., Ann Mycol 9 (4): 384 (1911)

### Description from holotype (Fig 3A–I)

*Saprobic* on sugary exudates from insects growing on the surface of living leaves (Fig 3A). *Thallus* thin, amphigenous, black, pelliculose, composed of reticulately branched, dense, cylindrical to somewhat constricted, radiating, septate hyphae (Fig 3B). *Ascomata* up to 101–110 µm diam, 99–111 µm high ( $\bar{x}$  = 106 × 105 µm, n = 5), scattered, subglobose to broadly ellipsoidal, with short stalks, firmly attached onto the radiating basal hyphae, dark brown, thick-walled, ostirole present in mature ascomata, setae with blunt apices scattered over the ascomata (Fig 3C, 3). *Peridium* 15–19 µm wide ( $\bar{x}$  = 17 µm, n = 10), composed of pale to dark brown, cells arranged in a *textura angularis* (Fig 3E). *Asci* 37–48 × 17–30 µm ( $\bar{x}$  = 42 × 22 µm, n = 5), 8-spored, bitunicate, broadly clavate, with short pedicle (Fig 3F–H). *Ascospores* 18–27 × 5 µm ( $\bar{x}$  = 21 × 5 µm, n = 5), fasciculate, cylindrical-clavate, ends rounded, upper cells slightly wider than the lower cells, hyaline, 4-septate, constricted at the septa, smooth-walled (Fig 3F–I).

### Description from epitype (Fig 4A–I)

*Saprobic* on sugary exudates from insects growing on the upper surface of living leaves (Fig 4A). *Thallus* thin, amphigenous, black, pelliculose, composed of reticulately branched, dense, cylindrical to somewhat constricted, radiating, septate hyphae (Fig 4A). *Ascomata* 82–93 × 84–105 µm diam ( $\bar{x}$  = 88 × 92 µm, n = 10), superficial, subglobose to broadly

ellipsoidal, dark brown to black, shiny, coriaceous, with 3–5 setae surround the ostiole setae  $50\text{--}75 \times 3\text{--}5 \mu\text{m}$  ( $\bar{x} = 57 \times 4 \mu\text{m}$ ,  $n = 10$ ), dark brown, septate, tapering with rounded ends (Fig 4A, B). *Ostiole* present in mature ascomata. *Peridium* thin, comprising cells arranged in a *textura angularis*. *Asci*  $43\text{--}53 \times 13\text{--}33 \mu\text{m}$  ( $\bar{x} = 24 \times 21 \mu\text{m}$ ,  $n = 10$ ), 8–spored, bitunicate, fusiform to broadly clavate, with a short pedicel, short ocular chamber observed in young asci (Fig 4D, E). *Ascospores*  $20\text{--}24 \times 4.8\text{--}5.8 \mu\text{m}$  ( $\bar{x} = 23 \times 5.3 \mu\text{m}$ ,  $n = 10$ ), fasciculate, cylindrical–clavate, ends rounded, upper cells slightly wider than the lower cells, hyaline, 4 septate, constricted at all septa, guttulate, some surrounded by a mucilaginous sheath (Fig 4F–L).

**Material examined:** BANGLADESH, Dhaka, on leaves of *Piper betle*, 5 April 1910, A.L. Som 1061 (S, **holotype** of *Capnodium betle*); THAILAND, Chiang Rai Province, Mae Fah Luang University, on living leaf of *Ixora* sp., 24 April 2009, Putarak Chomnunti, DPC 014 (MFLU09–0650, **epitype designated here**), extype living culture in MFLUCC10–0053; *Ibid.*, on living leaf of *Mimusops elengi* Linn., 14 July 2009, Putarak Chomnunti (MFLU 09–0647), living culture in MFLUCC10–0050.

*Phragmocapnias betle* has been reviewed by Reynolds (1979) who recognizes this genus as having stalked ascomata with setae and hyaline ascospores with trans–septa. In MFLU 09–0647 the ascomata are slightly bigger than in the type:  $87\text{--}137 \times 80\text{--}125 \mu\text{m}$  diam. [ $\bar{x} = 103.5 \times 94.5 \mu\text{m}$ ,  $n = 10$ ], but the size of asci and ascospores fit the range given in the above descriptions:  $42\text{--}50 \times 10\text{--}15 \mu\text{m}$  [ $\bar{x} = 41 \times 13 \mu\text{m}$ ,  $n = 10$ ] and  $20\text{--}25 \times 5\text{--}8 \mu\text{m}$  [ $\bar{x} = 22 \times 5 \mu\text{m}$ ,  $n = 20$ ] respectively. *Phragmocapnias* has been discussed fairly extensively and there are eight names listed in *Index Fungorum* of which five are given as congeneric (see <http://indexfungorum.org/Names/Names.asp>). Reynolds (1978) however, concluded that there was only one species, *P. betle* and excluded the other species based on various reasons. The anamorph of *P. betle* was reported to be *Conidiocarpus* (Hughes 1976), but Reynolds (1979) concluded that the anamorph of *Scorias* and *Phragmocapnias* were uncertain. However, the phylogenetic data presented here (Fig. 1) confirm that *Conidiocarpus* is the anamorph of *Phragmocapnias*.

In the combined gene phylogenetic analysis the epitype and second collection of *Phragmocapnias betle* clustered in *Capnodiaceae* and are basal to two species (6 strains) of anamorphic *Phragmocapnias* (= *Conidiocarpus*) confirming the anamorph–teleomorph linkage. The eight strains of *Phragmocapnias* used in this study cluster together with 75% bootstrap support with the two *Phragmocapnias* species closest with 99% bootstrap support. *Phragmocapnias asiaticus* is closest to the *Phragmocapnias* species and the five strains of *Phragmocapnias siamensis* cluster above with 81% bootstrap support indicating that they may be more than one species.

*Conidiocarpus penzigii* Woron. (*as penzigii*), Ann mycol. 24(3/4): 250 (1926).

*Saprobic* on sugary exudates from insects forming a sooty–like coating on the upper surface of living leaves, which crumbles away easily when dry. *Thallus* of blackish–gray, comprising superficial mycelia  $5\text{--}6 \mu\text{m}$  wide, with cylindrical, pale brown cells, constricted at the septum, anastomosing.

The generic type of *Conidiocarpus* is *C. penzigii* Woron. which is saprobic on sugary exudates from insects forming a sooty–like coating on the upper surface of living leaves, which crumbles away easily when dry (Woronichin 1926). Pycnidia are reported to be  $420\text{--}500 \mu\text{m}$  high, arising from mycelial mass, olive–brown, stalk  $270\text{--}335 \mu\text{m}$  long,  $23\text{--}30 \mu\text{m}$  thick, blackish, swollen part  $100 \times 33 \mu\text{m}$ , comprising short, olive–brown, angular cells, neck  $50\text{--}66 \times 13 \mu\text{m}$ , ostiole surround by hyaline hyphae up to  $20 \mu\text{m}$  long. *Conidia* are  $5\text{--}9$

× 1.5 µm, oblong–ellipsoid, hyaline, unicellular (Woronichin 1926). We have been unable to locate the type of *C. penzigii* which is described from Georgia. *Conidiocarpus* however, is a common sooty mould and we made several collections in Thailand. Presently only two species are listed in the genus, *C. penzigii* (Woronichin 1926) and *C. longicollus* Matsush (Matsushima 2003). *Conidioxyphium* (2 species) and *Podoxyphium* (16 records) are considered as synonyms and the group needs further study. Below we introduce two new species of *Phragmocapnias* as anamorphic states with molecular data which differ from existing *Conidiocarpus* species in conidia size. We also transfer *C. penzigii* (Woronichin 1926) and *C. longicollus* Matsush to *Phragmocapnias*.

***Phragmocapnias asiaticus*** Chomnunti & KD Hyde, **sp. nov.** (Fig 5A–K)

MycoBank: 563360

*Conidiocarpus penzigii* Woron. similis sed conidia 2.5–3.7 × 1–1.4 µm differt.

Etymology: ‘*asiaticus*’ in reference to its origin in Asia.

*Habit* forming a soot-like coating on the upper surface of leaves (Fig 5A). *Thallus* superficial, consisting of a network of cylindrical and septate, 2.2–3.7 µm, thick ( $\bar{x}$  = 3 µm, n = 30) hyphae, constricted at the septum, pale brown, but dark brown towards the edge (Fig 5C, D). *Pycnidia* 302–387(–471) µm high ( $\bar{x}$  = 366 µm, n = 10), arising from capnodiate type hyphae, black at the base and stalk, 17–25 µm wide ( $\bar{x}$  = 21 µm, n = 10), the conspicuous oval swelling which produces conidia is 18–24 µm wide ( $\bar{x}$  = 21 µm, n = 10) and brown, comprising of cylindrical septate cells (Fig 5E–G). *Ostiole* 4.9–6.5 ( $\bar{x}$  = 5.6 µm, n = 10), surrounded by hyaline hyphae (Fig 5H). *Conidiogenous cells* formed in the inner cells of the oval part. *Conidia* 2.5–3.7 × 1–1.4 µm ( $\bar{x}$  = 3.1 × 1.2 µm, n = 30), oblong to ellipsoid, 1-celled, hyaline, rounded ends (Fig 5I–K).

**Material examined:** THAILAND, Chiang Rai Province, Doi Tung, on living leaf of *Coffea arabica*, 15 August 2009, Jian Kui Liu, DPC 027 (MFLU09-0660, **holotype**), ex-type living culture in MFLUCC10-0062.

***Phragmocapnias longicollus*** (Matsush.) Chomnunti & KD Hyde, **comb. nov.**

≡ *Conidiocarpus longicollus* Matsush. Matsush. Mycol. Mem. 10: 85 (2003) [2001]

MycoBank: 374479

***Phragmocapnias penzigii*** (Woron.) Chomnunti & KD Hyde, **comb. nov.**

≡ *Conidiocarpus penzigii* Woron. [as penzigi], Ann mycol. 24(3/4): 250 (1926).

MycoBank: 273921

***Phragmocapnias siamensis*** Chomnunti & KD Hyde, **sp. nov.** (Fig 6A–G)

MycoBank: 563361

*Conidiocarpus penzigii* Woron. similis sed conidia 4.5–5.2 × 1.9–2.4 µm differt.

Etymology: from *siamensis* in reference to the Latin name of Thailand, where the species originated.

*Saprobic* on sugary exudates from insects growing on the upper surface of living leaves forming soot like coating. *Thallus* of 3–5 µm thick ( $\bar{x}$  = 4 µm, n = 20) hyphae, which is superficial, cylindrical, septate, constricted at the septum and pale brown (Fig 6C, D).



*Pycnidia* brown, comprised of cylindrical septate cells, 378–458  $\mu\text{m}$  high ( $\bar{x}$  = 408  $\mu\text{m}$ ,  $n$  = 10), stalk black, 22–31  $\mu\text{m}$  high ( $\bar{x}$  = 27  $\mu\text{m}$ ,  $n$  = 10) at the base, the oval part produces conidia, 36–41  $\mu\text{m}$  wide ( $\bar{x}$  = 38  $\mu\text{m}$ ,  $n$  = 10) (Fig 6E, F). *Ostiole* 9–15 ( $\bar{x}$  = 12  $\mu\text{m}$ ,  $n$  = 10), surrounded by hyaline hyphae. *Conidiogenous cells* formed on the inner cell walls of the oval part. *Conidia* 4.5–5.2  $\times$  1.9–2.4  $\mu\text{m}$  ( $\bar{x}$  = 4.8  $\times$  2.1  $\mu\text{m}$ ,  $n$  = 20), ellipsoid, aseptate, hyaline, smooth walled, ends rounded (Fig 6G).

**Material examined:** THAILAND, Chiang Rai Province, Thasud, on living leaf of *Mangifera indica*, 20 August 2009, Rungtiwa Phokhomsak, DPC 029 (MFLU09–0662, **holotype**), extype living culture in MFLUCC10-0064; *Ibid.*, Badoo, on living leaf of *Mangifera* sp., 7 June 2009, Putarak Chomnunti, DPC 026 (MFLU09-0656), living culture in MFLUCC10-006; *Ibid.*, Doi Tung, on living leaf of *Coffea arabica*, 15 August 2009, Jian Kui Liu, DPC 028 (MFLU09-0661), living culture in MFLUCC10-0063; *Ibid.*, on living leaf of *Euphorbia* sp., 15 August 2009, SC Karunarathna, DPC 030 (MFLU09-0663), living culture in MFLUCC10-0065; *Ibid.*, Mae Fah Luang University, on living leaf of *Bischofia javanica*, 9 January 2010, Putarak Chomnunti, DPC 036 (MFLU10-0003), living culture in MFLUCC10-0074.

*Leptoxyphium* Speg., Physis, B. Aires 4: 294 (1918)

*Astragoxyphium* Bat., Nascim. & Cif., in Batista & Ciferri, Quad. Lab. crittogam., Pavia 31:45 (1963)

*Caldariomyces* Woron., Ann mycol 24 (3/4): 261 (1926)

*Megaloxxyphium* Cif., Bat. & Nascim., Publcoes Inst. Micol. Recife 47:3 (1956)

*Saprobic* on sugary exudates from insects growing on the surface of living leaves. *Thallus* of superficial, grey brown to brown, septate, branched mycelium, constricted at the septa, forming an irregular network. *Pycnidia* superficial, gregarious, arising from aggregated hyphae, base bulbous, comprising parallel hyphae, straight to slightly flexuous, sometimes with helical twisting, comprised of cylindrical hyphae and expanded to become funnel-shaped, capitate at the apex. *Conidia* ellipsoidal, hyaline, 1-celled, guttulate (Woronichin 1926, Hughes 1976).

## Type species

*Leptoxyphium graminum* (Pat.) Speg., Physis, B. Aires 4:294 (1918)

$\equiv$  *Capnodium graminum* Pat., J. Bot., Paris 11: 348 (1897)

Mycelium form an irregular network which comprises cylindrical hyphae. *Pycnidia* arising from helically twisting hyphae or ropes of repent hyphae, stalk with a stout base, mostly unbranched, forming a fringe of sterile hairs at the apex. *Conidiogenous cells* formed on the inner cell walls of the swollen apex. *Conidia* usually broadly ellipsoidal, some 1-septate, and pigmented when forming a mass on the host surface (Saccardo 1899, Hughes 1976).

*Leptoxyphium cacuminum* Chomnunti & KD Hyde, **sp. nov.** (Fig 7A–7L, 8A–8L)

MycoBank 563359

*Leptoxyphium graminum* (Pat.) Speg. similis sed conidia 4.1–6.7  $\times$  2.1–2.7  $\mu\text{m}$  differt.

Etymology: from the Latin – *cacumin* meaning swollen, in relation to the pycnidia.

*Saprobic* on sugary exudates from insects growing on the surface of living leaves (Fig 7A). *Thallus* of 3.2–6.2  $\mu\text{m}$  high ( $\bar{x}$  = 4.4  $\mu\text{m}$ ,  $n$  = 20), grey brown to brown, septate, branched,

superficial mycelium, constricted at the septa, forming an irregular network. *Pycnidia* 341–446  $\mu\text{m}$  high ( $\bar{x}$  = 392  $\mu\text{m}$ ,  $n$  = 10), and 19–30  $\mu\text{m}$  base ( $\bar{x}$  = 26  $\mu\text{m}$ ,  $n$  = 10), superficial, gregarious, arising from aggregated hyphae, base bulbous, comprising parallel hyphae, straight to slightly flexuous, sometime with helical twisting (Fig. 7B–E). Stalked pycnidia comprising cylindrical hyphae expanding at the end into a funnel–shape, resembling a cupula, 27–43  $\times$  28–45  $\mu\text{m}$  [ $\bar{x}$  = 33  $\times$  35  $\mu\text{m}$ ,  $n$  = 10] (Fig 7F–H). *Conidiogenous cells* arising from the inner cell wall of the cupulate apex. *Conidia* ellipsoidal, hyaline, aseptate and guttulate, 4.1–6.7  $\times$  2.1–2.7  $\mu\text{m}$  [ $\bar{x}$  = 5.2  $\times$  2.4  $\mu\text{m}$ ,  $n$  = 20] (Fig 7I–L). *In culture* colonies reaching to 5 cm diam. after 10 days growth on PDA medium. Colony flat, irregular in the middle but radiating towards the edge, dull black, becoming olive green towards the edge (Fig 8A–C). *Mycelium* of cylindrical and septate hyphae 3.6–4.8  $\mu\text{m}$  [ $\bar{x}$  = 4.2  $\mu\text{m}$ ,  $n$  = 20], becoming aerial, branched, pale brown to deeply pigmented at the septum (Fig 8F–H). *Pycnidia* stalked, arising from a basal cell and developing a cupulate swelling towards the apex. Stalk olive–green, and deeply pigment at the base, but at the apex the hyphae are hyaline (Fig 8D, E). *Conidia* broadly ellipsoidal, unicellular and guttulated, hyaline, 4–4.9  $\times$  3.5–3.7  $\mu\text{m}$  [ $\bar{x}$  = 4.4  $\times$  3.6  $\mu\text{m}$ ,  $n$  = 20] (Fig 8I–L).

**Material examined:** THAILAND, Chiang Rai Province, Thasud, on living leaf of *Gossypium herbaceum*, 11 August 2009, SC Karunarathna, DPC 024 (MFLU09–0657, **holotype**), extype living culture in MFLUCC10–0059; *Ibid.*, Badoo, on living leaf of *Ficus* sp., 4 January 2010, KD Hyde, DPC 050 (MFLU 10–0015), living culture in MFLUCC10–0086; *Ibid.*, Mae Fah Luang University, on living leaf of *Mimosa elengi*, 24 April 2009, Putarak Chomnunti, DPC 009 (MFLU09–0646), living culture in MFLUCC10–0049.

Sequences of *Leptoxyphium fumago*, *L. madagascariense* and *L. kurandea* are available in GenBank and *Leptoxyphium cacuminum* clearly clusters with them. Nevertheless, *Leptoxyphium cacuminum* differs from the other known species in the genus because of its hyaline conidia, never becoming septated or pigmented when mature.

*Capnodium* Mont., Anns Sci. Nat., Bot., sér. 3 11: 233 (1849)

*Polychaeton* (Pers.) Lév., in Orbigny, Dict. Univ. Hist. Nat. 8: 493 (1846)

*Capnodaria* (Sacc.) Theiss. & Syd., Ann mycol. 15(6): 474 (1918) [1917]

*Capnodium* sugen. *Capnodaria* Sacc., Syll. Fung. (Abellini) 1:74 (1882)

*Capnodenia* (Sacc.) Theiss. & Syd. (1917)

*Fumago* sect. *Polychaeton* Pers., Mycol. eur. (Erlanga) 1: 9 (1822)

*Fumagospora* G. Arnaud, Annals d'École National d'Agric. de Montpellier, Série 2 10(4): 326 (1911)

*Morfea* Roze, Bull. Soc. bot. Fr. 14: 21 (1867)

*Morfea* (G. Arnaud) Cif. & Bat., in Batista & Ciferri, Saccardo 2: 153 (1963)

*Phaeoxyphiella* Bat. & Cif., Quad. Lab. crittogam., Pavia 31: 145 (1963)

*Scolecoxyphium* Cif. & Bat. Publções Inst. Micol. Recife 47: 5 (1956)

*Saprobic* on sugary exudates from insects growing on the surface of leaves, fruits, stems and other non plant objects. *Thallus* a loose or dense network of pale brown, superficial hyphae or a thick pseudoparenchymatous stromata, with sexual and asexual states often growing together. *Ascomata* superficial on mycelium of thallus, brown to dark brown or black, globose to ellipsoidal, short stalked or sessile, ostiolate at maturity, scattered or in groups, without setae. *Peridium* comprising dark brown to pale brown, thick–walled cells forming a

*textura angularis*. Asci 8-spored, bitunicate, clavate, ovoid or saccate, paraphysate, apedicellate. Ascospores brown, oblong or ovoid and some reniform, trans-septate with one or more vertical septa or without vertical septa. Pycnidia elongate, often with long stalks, dark brown. Ostiole at apex of pycnidia. hyphae continued upwards to the tapered neck, terminating in an ostiole which is surrounded by dull hyphal round ends. Conidia hyaline, 1-celled.

Anamorph: *Polychaeton* (Pers.) Lév. (Hyde et al. 2011).

*Polychaeton* was introduced by Lévillé (1847) based on Persoon's *Fumago* [subgenus] *Polychaeton*, and Hughes (1976) provides a detailed account of the choice of generic type including the reason why Spegazzini's lectotype *P. carolinense* (Berk. & Desm.) Speg. was inadmissible (not included by Lévillé at the time of description). It is not clear whether Lévillé intended to include *F. citri* in the genus or whether it was meant to represent another genus. Of the five species in Persoon's subgenus *Polychaeton*, only *P. citri* or *P. quercinum* were considered suitable to be generic types by Hughes (1976), who chose *P. quercinum* ( $\equiv$  *Fumago quercina*) as the lectotype species. However, and unlike Berkeley & Desmazieres (1849), he regarded this genus as the anamorphic stage of the genus *Scorias*, not *Capnodium*. This has been discussed by other authors, e.g. in Sutton (1977) as *Polychaeton*, see Index Fungorum (<http://www.indexfungorum.org/Names/NamesRecord.asp?RecordID=206987>) as *Capnodium*, and as type unknown in MycoBank (see <http://www.mycobank.org/MycoTaxo.aspx?Link=T&Rec=4305>), or non designated as Index Nominum Genericum (see [www.http://botany.si.edu/ing/genusSearchTextMX.cfm](http://www.botany.si.edu/ing/genusSearchTextMX.cfm)). In this study we accept *P. quercinum* as the generic type, but Persoon's original specimen was not available on loan. However, we have seen a possible type or authentic collection in herbarium K, which is part of M.J. Berkeley's herbarium.

*Capnodium* was introduced by Montagne (1849) based on *Fumago citri* Pers. and is the type genus of *Capnodiaceae* (Friend, 1965). Reynolds (1978) however, examined type material from L which only had anamorphic characters and this was similar for the supporting specimens listed in exsiccatae. Reynolds (1978) therefore chose a species where the ascus and the ascospores are known, the second species listed in the genus by Montagne (1849): *Capnodium salicinum* Mont. as the lectotype (Reynolds, 1999). Index fungorum (<http://www.speciesfungorum.org/Names/SynSpecies.asp?RecordID=164508>), however, lists this as a synonym of *C. citri* which we follow here. *Capnodium* is the teleomorph stage of *Polychaeton* (Fig 10–12), but it is the earlier name. As mentioned earlier that we advocate that *Capnodium* be considered for conservation under the “one fungus one name” concept that will be incorporated in the newly proposed Code for Algae, Fungi and Plants. In this study we provide nine sequences of ‘polychaeton-like’ *Capnodium* specimens and illustrate three species.

### Type species

- Capnodium citri* Berk. & Desm., in Berkeley, J Rl Hort Soc 4: 11 (1849) (Fig 9A–G)  
 $\equiv$  *Fumago citri* Pers., Mycol. eur. (Erlanga) 1: 9 (1822).  
 $\equiv$  *Polychaeton citri* (Pers.) Lév., in Orbigny, Dict. Univ. Hist. Nat. 8: 493 (1846)  
 $\equiv$  *Microxiphium citri* (Berk. & Desm.) Speg., Boln Acad. nac. Cienc. Córdoba 26(2–4): 399 (1924) [1923]  
 $=$  *Apiosporium citri* Briosi & Pass., Atti R. acad. Lincei, Trans., Sér. 3 7: 22 (1882).

- = *Apiosporium salicis* Kunze, in Kunze & Schmidt, Mykologische Hefte (Leipzig) 1: 8 (1817)
- = *Capnodium salicinum* Mont., *Annls Sci. Nat., Bot., sér.* 3 11: 234 (1849)
- = *Pleosphaeria salicina* (Mont.) G. Arnaud
- = *Polychaeton salicinum* (Mont.) Kuntze, *Revis. gen. pl.* (Leipzig) 3: 1–576 (1891)
- = *Teichospora salicina* (Mont.) Gäum.
- = *Limacinia citri* (Briosi & Pass.) Sacc., *Hedwigia* 36: 20 (1897)
- = *Meliola citri* (Briosi & Pass.) Sacc., *Syll. fung. (Abellini)* 1: 69 (1882)

*Saprobic* on sugary exudates from insects growing on the surface of leaves, fruits, stems and other non plant objects. *Thallus* comprising 4.2–6 µm wide, dark brown, superficial, cylindrical and septate hyphae, constricted at the septum (Fig 9A, B, F). *Pycnidia* up to 345–391 long µm, 36–40 µm wide at the base, arising from dense mycelia, elongate, often long-stalked, dark brown (Fig 9C–E). *Conidiogenous cells* formed in the swollen base. *Ostiole* 13–15 µm. *Conidia* 6.5 × 5 µm, hyaline, ellipsoidal, 1-celled (Fig 9G).

**Material examined:** France, unlocalised, ex herbarium L veill  in herbarium Berkeley (as *Capnodium citri*) [K(M) 172364 – iconotype only?, specimen missing]. *Ibid.*, on *Olea* leaf, ex herbaria C. Montagne, PC, in herbarium Berkeley (as *Fumago citri* Pers. non Turpin) [K(M) 172363 – type?].

***Capnodium coartatum*** Chomnunti & KD Hyde, **sp. nov.** (Fig 10A–K)

Mycobank 563362

*Polychaeton citri* (Pers.) L v. similis sed conidia 4.2–4.6 × 1.9–2.4 µm differt.

**Etymology:** from the Latin *coartata* meaning narrow, in reference to pycnidia.

*Saprobic* on sugary exudates from insects growing on the surface of leaves, fruits, stems and other non plant objects. *Thallus* of dark brown mycelium growing over the surface of the plant with abundant pycnidia, produced on 3–5 µm wide ( $\bar{x}$  = 4 µm., n = 20), irregularly branched, pale brown to brown, septate, sub cylindrical hyphal cells, constricted at the septum (Fig 10F–H). *Pycnidia* 332–401 × 34–56 µm ( $\bar{x}$  = 366 × 45 µm, n = 20), superficial, scattered or gregarious, blackish brown, synnematosus in structure, ovoid to flask-shaped, elongate, somewhat branched, comprising mostly cylindrical cells, with slightly swollen or flattened base, base of pycnidium forming a pseudo-parenchymatous to prosenchymatous tissue, upper cylindric region tapering to apex, 7.6–11.5 µm wide ( $\bar{x}$  = 9.8 µm, n = 10) (Fig 10A–D), ostiole surrounded by hyaline hyphae (Fig 10J, K). *Conidia* 4.2–4.6 × 1.9–2.4 µm ( $\bar{x}$  = 4.4 × 2.1 µm, n = 20), produced within the swollen base, gathering in a terminal droplet, ellipsoidal, smooth, round ends, hyaline (Fig 10L, M).

**Material examined:** THAILAND, Chiang Rai Province, Baan Du, on living leaf of *Psidium guajava* (*Myrtaceae*), 24 September 2009, SC Karunarathna DPC 040 (MFLU10–0076, **holotype**), extype living culture in MFLUCC10–0005; *Ibid.*, Mae Fah Luang University, on living leaf of *Alstonia scholaris*, 3 October 2009, P. Chomnunti DPC 041 (MFLU10–0077), living culture in MFLUCC10–0006.

***Capnodium tiliae*** (Fuckel) Sacc.. *Syll. fung. (Abellini)* 1: 74 (1882)

≡ *Capnodaria tiliae* (Fuckel) Theiss. & Syd. *Ann mycol.* 15(6): 474 (1918) (1917)

≡ *Fumago tiliae* Fuckel. Jb. Nassau. Ver. Naturk 23–24: 142 (1870) (1869–70) (Fig 11A–J)

*Saprobic* on sugary exudates from insects growing on bark (Fig 11A). *Thallus* of superficial *mycelium* comprising membranous, cylindrical, 4–6  $\mu\text{m}$  ( $\bar{x}$  = 5  $\mu\text{m}$ ,  $n$  = 20) wide, septate hyphae, constricted at the septa, dark brown at the septum and margin (Fig 11C). *Ascomata* 81–136  $\mu\text{m}$  diam, 78–141  $\mu\text{m}$  high ( $\bar{x}$  = 96  $\times$  102  $\mu\text{m}$ ,  $n$  = 10), superficial, globose, without setae, brown to dark brown (Fig 11B–D, F). *Peridium* 17–18  $\mu\text{m}$  wide ( $\bar{x}$  = 15  $\mu\text{m}$ ,  $n$  = 15), comprising dark brown cells of *textura angularis*, darker externally. *Hamathecium* comprising asci and 2.3–3.6  $\mu\text{m}$  ( $\bar{x}$  = 2.8  $\mu\text{m}$ ,  $n$  = 20) hyaline cells (Fig 11E). *Asci* 41–44  $\times$  15–18  $\mu\text{m}$  ( $\bar{x}$  = 42  $\times$  17  $\mu\text{m}$ ,  $n$  = 5), 10–spored, bitunicate, clavate, apedicellate, ocular chamber not apparent (Fig 11G–I). *Ascospores* 13–17  $\times$  5–7  $\mu\text{m}$  ( $\bar{x}$  = 15  $\times$  6  $\mu\text{m}$ ,  $n$  = 20), oblong or ovoid and some reniform, 3–5 septate, constricted at the septa, rarely with longitudinal septa, ends narrowly round, brown, dark brown at septum and margin, wall verrucose (Fig 11J).

**Material examined:** GERMANY, Biebrich, on branch of *Tilia parviflora*, Herbarium Fuckel no. 899 (1894), (G, Herbarium Barbey Boissier).

*Scorias* Fr. Syst. Orb. Veg. 1: 171 (1825)

*Algorichtera* Kuntze, Revis. gen. pl. (Leipzig) 2: 637 (1891)

*Antennella* Theiss. & Syd., Ann mycol. 15(6): 473 (1918) (1917)

*Antennellina* J.M. Mend., in Stevens, Bulletin of the Bernice P. Bishop Museum, Honolulu, Hawaii 19: 55 (1925)

*Hyalocapnias* Bat. & Cif., Saccardo 2: 114 (1963)

*Leptocapnodium* (G. Arnaud) Cif. & Bat., in Batista & Ciferri, Saccardo 2: 121 (1963)

*Paracapnodium* Speg., Anal. Mus. nac. B. Aires, Ser. 3 12: 325 (1909)

*Scolecocyphium* Cif. & Bat., Publicações Inst. Micol. Recife 47: 5 (1956)

*Xystozukalia* Theiss., Verh. zool. bot. Ges. Wien 66: 357, 358 (1916)

*Saprobic* on sugary exudates from insects growing on host. *Thallus* comprising black dense, septate mycelium with ascomata covering the surface of host. *Ascomata* dark brown to blackish, shiny, subglobose to broadly ellipsoidal, with a rounded apex, central ostiole present at maturity, with short stalk. *Peridium* composed of cells of *textura angularis*. *Asci* 8–spored, bitunicate, oblong to saccate. *Ascospores* hyaline, fusiform, with 3–4 trans–septa, the upper cells slightly wider than the lower cells. *Pycnidia* long stalked, flask–shaped, tapering to the apex, pycnidium wall showing helical twisting, synnemata–like, dark brown to black at the base, brown to pale brown towards the tapering apex. *Conidia* ellipsoidal, unicellular, hyaline.

Anamorphs: *Scolecocyphium* Cif. & Bat. (Hyde et al. 2011).

### Type species

*Scorias spongiosa* (Schwein.) Fr. Syst. mycol. (Lundae) 3(2): 291 (1832)

≡ *Botrytis spongiosa* Schwein., Schr. naturf. Ges. Leipzig 1: 127, (1822)

### Description from type (Fig 12A–P)

*Saprobic* on sugary exudates from insects growing on host (Fig 12A). *Thallus* comprising 3.8–5.5  $\mu\text{m}$  wide ( $\bar{x}$  = 4.7  $\mu\text{m}$ ,  $n$  = 20) wide, black, dense, septate mycelium. *Ascomata* 72–

88  $\mu\text{m}$  diam, 89–132  $\mu\text{m}$  high ( $\bar{x}$  = 82  $\times$  110  $\mu\text{m}$ ,  $n$  = 5), covering the surface of thallus, gregarious, dark brown to black, shiny, subglobose to broadly ellipsoidal, with a rounded apex, central ostiole present at maturity, on a stalk (Fig 12C–J). *Peridium* 14–25  $\mu\text{m}$  ( $\bar{x}$  = 18  $\mu\text{m}$ ,  $n$  = 20), composed of cells of *textura angularis* (Fig 12K). *Asci* 8-spored, bitunicate, oblong to saccate, apedicellate, with a long ocular chamber (Fig 12L–N). *Ascospores* 13–15  $\times$  2–4  $\mu\text{m}$  ( $\bar{x}$  = 13  $\times$  3  $\mu\text{m}$ ,  $n$  = 20), hyaline, fusiform, 3–4 trans-septate, the upper cells slightly wider than the lower cells (Fig 12O, P).

### Description of anamorph from Thai collection (Fig 13A–H, 14A–K)

*Saprobia* on sugary exudates from insects growing on the surface of living leaves (Fig 13A). *Thallus* comprising 3.2–4.8  $\mu\text{m}$  wide ( $\bar{x}$  = 4  $\mu\text{m}$ ,  $n$  = 20), superficial, cylindrical, septate pale brown hyphae (Fig 13A). *Pycnidia* 412–614  $\times$  40–57 ( $\bar{x}$  = 503  $\times$  47  $\mu\text{m}$ ,  $n$  = 10), long stalked, flask-shaped, tapering to the apex, pycnidial wall showing helical twisting, synnemata-like, frequency with immature ascomata, dark brown to black at the base, brown to pale brown towards the tapering apex (Fig 13B–F). *Conidia* 3.1–4.2  $\times$  1.6–2.4 ( $\bar{x}$  = 3.7  $\times$  2  $\mu\text{m}$ ,  $n$  = 20), ellipsoidal, unicellular, hyaline (Fig 13G). *Colonies* reaching upto 3 cm diam. after 10 days on PDA medium, flattened, spreading radially towards the edge, dark-brown in older parts, but olive-green towards the edge. *Mycelium* 2.6–4.4  $\mu\text{m}$  [ $\bar{x}$  = 3.5  $\mu\text{m}$ ,  $n$  = 20], consisting of cylindrical and septate hyphae, branched, thick wall, and mucilaginous in the outer layer, with numerous aerial hyphae (Fig 13A). *Pycnidia* stalked, flask-shaped, arising from the mycelium plate, comprised of hyaline hyphae helically twisting towards the apex surrounding the ostiole. Stalk pale olive-green and hyaline at the apex, swelling at base (Figs 13B–G). *Conidia* 3.5–4.4  $\times$  1.5–2.2  $\mu\text{m}$  ( $\bar{x}$  = 3.9  $\times$  1.9  $\mu\text{m}$ ,  $n$  = 20), ellipsoid, unicellular, guttulate, hyaline (Fig 14I–K).

**Material examined:** Type specimen: ‘Car. N. 1311. *Podiosoma? epiphega*. Schwein.! *In litt.*’ (UPS Fries – lectotype). USA?, unlocalised, ex herbarium Schwein., in herbarium M.J. Berkeley [K(M) 171138 – syntype]; *ibid.* Ohio, on wood, March, H.W. Ravenel 145 (as *Scorias spongiosa*) [K(M) 171139 & ? IMI 30376–authentic]; *ibid.* South Carolina, *ad ramos Alni*, Dec. H.W. Ravenel 1384 (as *Scorias spongiosa*) [K(M) 171140 – authentic]; *ibid.* Ohio, on *Fagus* sp., ex herbarium M.J. Berkeley (as *Scorias spongiosa*) [K(M) 171141 – authentic]; *ibid.* Ohio, on leaf and bark of *Fagus* sp., ex herbarium M.J. Berkeley (as *Scorias spongiosa*) [K(M) 171142 – authentic]; THAILAND, Chiang Rai Province, Khunkorn, on living leaf of *Entada* sp. (*Fabaceae*), 18 December 2009, Putarak Chomnunti, DPC048 (MFLU10–0013, **epitype designed here**), living culture in MFLUCC10–0084.

The species has been sanctioned by Fries Fr., *Syst. mycol.* 3(2): 291 (1832) with a collection from Carolina number 1311. In herbarium M.J. Berkeley at K there are five collections labeled *Scorias spongiosa* from Ohio numbered 145 found on *Fagus* leaves and twigs, and one from South Carolina collected by Ravenel on *Alnus* without a number, and a representation of these have been examined by Reynolds (1975). All of those are authentic material of *Scorias spongiosa* according to Saccardo (*Sylloge Fungorum* I: 83, 1882). Nevertheless, there is a further collection in herbarium Berkeley, originally from herbarium Schweinitz, which contains no further annotations, but maybe part of Fries’s listed 1311 specimen. From this collection we have chosen to make a slide, and the description is included above. Further to the above the IMI 230376 herbarium (now part of K herbarium’s holdings) contains several slides labeled type from Berkeley’s material, but it is not clear what specimen they used for preparing the collection.

The type illustrated contained only the teleomorph. The fresh collection from Thailand contained only the mature anamorph and immature ascomata. In the molecular analysis *Scorias spongiosa* (CBS 325.33) clustered with strain MFLU10–0084 with 100% bootstrap support and is clearly placed in *Capnodiaceae*. Nine species are currently recorded in the

genus in Index Fungorum (<http://www.indexfungorum.org/Names/Names.asp>; accessed on 12 July 2011).

### Genera of *Capnodicaceae incertae sedis*

*Scoriadopsis* J.M. Mend., in Stevens, Ann mycol. 28(5/6): 365 (1930)

*Scoriadopsis miconiae* J.M. Mend., in Stevens, Ann mycol 28(5/6): 365 (1930)

≡ *Rizalia miconiae* (J.M. Mend.) E. Müll., in Müller & von Arx, Beitr. Kryptfl. Schweiz 11 (no. 2): 597 (1962)

*Colonies* sooty black, on upper surface and closely associated with *Meliola*. *Thallus* perisporioid, slimy, loosely woven, weft-like, hyaline to straw-colored hyphae. *Ascomata* globose or ovoid, ostiolate, stalked, gelatinous, dark brown. *Asci* 40 × 14 μm, numerous, 8-spored, ovate, pseudo paraphyses lacking. *Ascospores* 16 × 4 μm, fusiform, 1-septate (Stevens 1930).

We have not seen type material of this species. The taxon is similar to *Scorias*, but it has 1-septate ascospores, while *Scorias* has 3–4 trans-septate ascospores which are pigmented when mature. We retain *Scoriadopsis* in *Capnodicaceae incertae sedis* as colonies appear like sooty moulds on the host and ascomata are globose, black, and ascospores turn brown when mature. However, the melioaceous habit would be unusual.

### Genus transferred to *Mycosphaerellaceae*

*Echinothecium* Zopf, Nova Acta Acad. Caes. Leop. –Carol. German. Nat. Cur. 70: 250 (1898)

*Thallus* superficial, composed of thick brown often anastomosing hyphae. *Ascomata* globose, ostiolate, provided with stiff, simple, appendages. *Asci* 8-spored, sessile, lacking paraphyses. *Ascospores* 2 celled, hyaline, oval, the upper cell slightly wider than the lower cell.

Anamorphs: None.

### Type species

*Sphaerellothecium reticulatum* (Zopf) Etayo, Cryptog. Mycol. 29(1): 87 (2008)

≡ *Echinothecium reticulatum* Zopf, Nova Acta Acad. Caes. Leop. –Carol. German. Nat. Cur. 70: 250 (1898) (Fig 15A–L)

*Thallus* comprising 4–6 μm thick ( $\bar{x}$  = 5 μm, n = 20), superficial, dense, brown, often anastomosing, reticulate, branching, septate hyphae (Fig 15A, F, G). *Ascomata* 32–68 μm diam, 31–69 μm high ( $\bar{x}$  = 50 × 49 μm, n = 5), spherical or depressed-globular, dark brown, surrounded by 14–18 × 4–6 μm ( $\bar{x}$  = 16 × 5 μm, n = 10) hyphal appendages (Fig 15B–E). *Asci* 23–36 × 10–13 μm ( $\bar{x}$  = 27 × 11 μm, n = 10), 8-spored, bitunicate, ovoid, apedicellate, with an ocular chamber (Fig 15H–J). *Ascospores* 8–6 × 2.5–4 μm ( $\bar{x}$  = 7 × 3 μm, n = 20), ovoid, hyaline, the upper cell slightly wider than the lower cell, 1-septate, constricted at the septum (Fig 15K, L).

**Material examined:** ITALY, South Tyrol, Fondo, Mendehof, on bark of spruce trees on *Parmelia sulcata*, 18 August 1897, Arnold exs. 1743 (K(M) 171135, 171136 syntypes!).

*Echinothecium* occurs on lichens and has been found in Europe and North America (Navarro-Rosinés and Gómez-Bolea 1989). *Lichenostigma cosmopolites* Hafellner & Calat

has been most wrongly identified and confused with *Echinothecium reticulatum* which has ascomata with septate seta-like hyphae and seems to be restricted to *Parmelia* s. str. (Calatayud et al. 2002). This is the only genus in the *Capnodiaceae* which has a lichenicolous habit. Etayo (2008) placed this species in the genus *Sphaerellothecium* and after critical study of the holotype of *Sphaerellothecium* we agree with his decision. This needs rewording. We have examined the holotype of *Sphaerellothecium* and it is similar to *Echinothecium* and thus considered a synonym. The generic type, *Sphaerellothecium araneosum* is described below.

***Sphaerellothecium araneosum*** (Rehm) Zopf, Nova Acta Acad. Caes. Leop. – Carol. German. Nat. Cur. 70: 178 (1897) (Fig 16A–L)

- ≡ *Sphaerella araneosa* Rehm, Ascomyceten Dign.: no. 133 (1872)
- ≡ *Discothecium araneosum* (Rehm) Vouaux, Bull. Soc. mycol. Fr. 29: 55 (1913)
- = *Echinothecium glabrum* M.S. Christ., Alstrup & D. Hawksw., in Alstrup & Hawksworth, Meddr Grønland, Biosc. 31: 28 (1990)
- ≡ *Endococcus araneosus* (Rehm) H. Olivier, Bull. Acad. Intern. Géogr. Bot. 17: 127 (1907)
- ≡ *Epicymatia araneosa* (Rehm) Sacc., Syll. fung. (Abellini) 1: 572 (1882)
- ≡ *Mycosphaerella araneosa* (Rehm) Lindau, Hilfsb. Sammeln Ascomyc. (Berlin): 125 (1903)
- ≡ *Phaeosphaerella araneosa* (Rehm) Sacc. & D. Sacc., Syll. fung. (Abellini) 17: 676 (1905)

*Thallus* with superficial net of dark brown, septate, vegetative hyphae on host tissue (Fig 16A). *Ascomata* 43–72  $\mu\text{m}$  diam, (42–) 45–79  $\mu\text{m}$  high ( $\bar{x}$  = 57.4  $\times$  57.3  $\mu\text{m}$ , n = 10), superficial on host surface, visible as black dots, uniloculate, individually globose to subglobose, scattered or gregarious, dark to dark brown (Fig 16A–C). *Peridium* 3–6 (–9.5)  $\mu\text{m}$  wide ( $\bar{x}$  = 4.6  $\mu\text{m}$ , n = 10), comprising 1–2 layers of dark to dark brown cells of *textura angularis* (Fig 16D). *Asci* (26–) 30–37 (–45)  $\times$  16–21.5 (–25)  $\mu\text{m}$  ( $\bar{x}$  = 35  $\times$  19  $\mu\text{m}$ , n = 10), 8-spored, bitunicate, saccate, ovoid or occasionally obclavate, non pedicellate, apically rounded with an ocular chamber (Fig 16E–G). *Ascospores* (11–)13–17.5  $\times$  6–8.5 (–9.5)  $\mu\text{m}$  ( $\bar{x}$  = 14.7  $\times$  6.8  $\mu\text{m}$ , n = 20), irregularly seriate, fusiform to ellipsoidal, both ends obtuse, 1-septate, constricted at the central septum, upper cell larger than lower cell, thick-walled, initially hyaline, becoming brown when mature (Fig 16H–K).

**Material examined:** AUSTRIA, Tyrol, Materi am Brenner, Waldrast, on the thallus and apothecia of *Ochrolechia pallescens* var. *upsaliensis* (L.), Alt. 6700', August 1872, F. Arnold (M-0044221, holotype).

### Genera transferred to *Chaetothyriaceae*

The following genera do not belong to *Capnodiaceae* and are placed in *Chaetothyriaceae*.

*Aithaloderma* Syd. & P. Syd. Ann mycol. 11: 256 (1913)

*Blastocapnias* Cif. & Bat., Saccardo 2: 67 (1963)

*Chaetopotius* Bat., Mycopath. Mycol. appl. 5: 151 (1951)

*Ciferrioxypium* Bat. & H. Maia, in Batista & Ciferri, Quad. Lab. crittogam., Pavia 31:65 (1963)

*Hypocapnodium* Speg., Physis, B. Aires 4: 287 (1918)



*Phaeochaetia* Bat. & Cif., Beih. Sydowia 3: 62 (1962)

*Vertixore* V.A.M. Mill. & Bonar, University of Calif. Publ. Bot. 19: 406 (1941)

*Saprobic* on sugary exudates from insects growing on leaves of various plants. *Thallus* comprising superficial, brown to black, septate hyphae, constricted at the septa, mostly dense and anastomosing, covering the surface of leaves, forming a dark mycelia mat.

*Ascstromata* superficial, brown to dark brown, in vertical section globose to subglobose, covered by subiculum or ascosomatal layer, consisting of brown, septate hyphae, with a circumferential space around the maturing ascomata, which results from expanding the expansion of the ascomata. Towards the upper part of the ascomata wall, the pellicles are very tightly packed, with 5–10 short black and dull setae which surround the ostiole.

*Peridium* comprising cells forming a *textura angularis*, pale brown to hyaline; without interthecial filaments. *Asci* 8-spored, bitunicate, wide fusiform to saccate, short pedicellate, lacking an ocular chamber. *Ascospores* hyaline, trans-septate, some surrounded by a mucilaginous sheath.

*Aithaloderma* was assigned to *Capnodiaceae* by Sydow and Sydow (1913) and currently includes 15 species (Kirk et al 2008). *Aithaloderma* was placed in *Chaetothyriaceae* by Spegazzini (1918) based on the dome-shaped or flattened ascostromata and pleomorphic pycnidia. Hughes (1976) suggested that *Aithaloderma* could be placed within *Capnodiaceae* because the mycelial hyphae are similar to those in *Phragmocapnias*. Recently, *Aithaloderma ferrugineum* Fraser has been reviewed by Reynolds and Gilbert (2005), who also included the species within the *Capnodiaceae* pending molecular data. The genus is characterized by globose perithecium with setae, lageniform pycnidia which produce continuous, hyaline conidia and funnel to funnel-globulose ascostromata with short setae especially around the ostiole, lack paraphyses and asci contain 8-spored, transversely septate, clavate, hyaline ascospores (Yamamoto 1954, von Arx and Müller 1975, Hughes 1976).

*Leptoxyphium* was reported to be the anamorph of *Aithaloderma* but in this study *Leptoxyphium* clusters in *Capnodiaceae*. Since there is no reported connection between *Leptoxyphium* and *Aithaloderma clavatisporum* (the generic type) we transfer *Aithaloderma* to *Chaetothyriaceae* while considering *Leptoxyphium* within *Capnodiaceae*.

Anamorphs: ?*Ciferrioxiphium* Bat. & H. Maia, *Leptoxyphium* Speg. (Hyde et al. 2011).

### Type species

*Aithaloderma clavatisporum* Syd. & P. Syd. Anns. Mycol. 11: 256 (1913) (Fig 17A–M)

≡ *Chaetothyrium clavatisporum* (Syd. & P. Syd.) Hansf., Mycol. Pap. 15 (1946)

≡ *Phaeochaetia clavatispora* (Syd. & P. Syd.) Bat. & Cif. Beih. Sydowia 3: 67 (1962)

*Saprobic* on sugary exudates from insects growing on the surface of living leaves (Fig 17A)

*Thallus* comprising 2.4–4.1 µm thick ( $\bar{x}$  = 3.5 µm, n = 20), superficial, brown to black, septate, hyphae, constricted at the septa, mostly with 90° branching, mostly dense and anastomosing, covering the surface of leaves forming a dark mycelia mat (Fig 17B, F).

*Ascstromata* 100–124 µm diam, 80–122 µm high ( $\bar{x}$  = 122 × 100 µm, n = 5), superficial, brown to dark brown, initials arising from cells of mycelium, in vertical section globose to subglobose, covered by a subiculum or a layer of brown septate hyphae, with a circumferential space around the maturing ascomata, which results from the expansion of the ascomata. Towards the upper part of the ascomata wall, the pellicles are very tightly packed, with 5–10 short black and dull setae surrounding the ostiole (Fig 17B–E). *Peridium* 4.51–9 µm wide ( $\bar{x}$  = 7 µm, n = 20), a single layer, comprising of cells forming a *textura*

*angularis*, pale brown to hyaline. *Pseudoparaphyses* not observed. *Asci* 39–69 × 10–31 μm ( $\bar{x}$  = 51 × 21 μm, n = 10), 8-spored, bitunicate, wide fusiform to saccate, short pedicellate, lacking an ocular chamber (Fig 17H–J). *Ascospores* 12–25 × 3–6 μm ( $\bar{x}$  = 19 × 4.5 μm, n = 20), overlapping triseriate, fusiform, hyaline, 4–5 septate, constricted at the septa, upper cells wider than lower cells, some surrounded by a mucilaginous sheath (Fig 17K–M).

**Material examined:** PHILIPPINES, Laguna Province, Los Baños, in living? leaves of *Voacanga globosa* (*Apocynaceae*), 1 February 1913, CF. Baker, Sydow, Fungi Exotici Exsiccata 174 (IMI 26048, isotype).

Some morphological characters of *Aithaloderma* are similar to those found in *Chaetothyriaceae* (Batista and Ciferri 1962; Chomnunti et al. 2012). These include the nature of the superficial ascostromata on a mycelial mat with a circumferential space around the subglobose maturing ascomata, with setae surrounding the ostiole, wide fusiform to saccate asci and clavate, hyaline, 5-septate ascospores. These characters indicate that *Aithaloderma* is better placed in *Chaetothyriaceae* and we follow this here.

*Ceramoclasteropsis* Bat. & Cavalc., in Batista, Perez & Bezerra, Brotéria, sér. Ci. Nat. 31(2): 101 (1962)

*Ceramoclasteropsis coumae* Bat. & Cavalc., in Batista, Perez & Bezerra, Brotéria, sér. Ci. Nat. 31(2): 101 (1962)

This species has superficial ascomata that form on superficial dark brown mycelium and appear to be ascostromata (Batista and Cavalc. 1962). Asci are bitunicate and apedicellate and ascospores are 7.5–14 × 2–4 μm, clavate, hyaline with 1–3 transverse septa. The taxon is reported to have paraphyses as in typical members of the *Chaetothyriaceae*. The ascospores appear to be typical of *Limacinula* and fresh collections are required to confirm if this is a distinct genus.

*Hyaloscolecostroma* Bat. & J. Oliveira, Atas Inst. Micol. Univ. Pernambuco 5: 448 (1967)

*Hyaloscolecostroma rondoniense* Bat. & J. Oliveira, Atas Inst. Micol. Univ. Recife 5: 449 (1967)

This genus was described from Brazil and is monotypic. This is a sooty mould with superficial ascomata, cylindrical unitunicate asci and trans-septate cylindrical-fusiform ascospores (Batista and Olivera 1967). Apparently this fungus is associated with homopteran insects. The drawing provided in Batista and Olivera (1967) this is not a convincing taxon of *Capnodiaceae* especially as it shows a thin unitunicate ascus layer. Thus we place the genus in the *Chaetothyriaceae incertae cedis*.

*Trichomerium* Speg., Physis, B. Aires 4: 284 (1918)

*Trichomerium coffeicola* (Puttemans) Speg., Physis, B. Aires 4: 284 (1918)

≡ *Limacinia coffeicola* Puttemans, Cryptog. Mycol. 20: 163 (1904)

*Trichomerium* is included in *Capnodiaceae* in Index Fungorum (<http://www.indexfungorum.org/Names/Names.asp>), but not in Lumbsch and Huhndorf (2010). The genus was introduced by Spegazzini (1918) with type species *T. coffeicola* (Reynolds, 1982) and include 23 species, mostly folicolous fungi. The ascospores are similar to *Phragmocapnias* and *Scorias* in septation and in being hyaline, but *Trichomerium* has sessile ascomata. We have made several collections of *Trichomerium* in this study which

cluster in *Chaetothyriaceae* in the phylogenetic analysis (data not shown) and will be reported in a later paper.

**Anamorphs reported for genus:** *Tripospermum* Speg. (Hyde et al. 2011).

*Tripospermum* Speg., *Physis*, B. Aires 4(no. 17): 295 (1918)

= *Pentaposporium* Bat., *Revta Biol.*, Lisb. 1(2): 106 (1957)

*Tripospermum acerinum* P. Syd., *Physis*, B. Aires 4(no. 17): 295 (1918)

*Tripospermum* was introduced by Corda in 1837 for *T. elegans* and by Spegazzini in 1918 as segregate of *Tripospermum* with type species *T. acerinum* (Hughes 1951). As the anamorph of *Trichomerium* Speg. (Hyde et al 2011) it should be transferred to *Chaetothyriaceae*.

### Genus in *Coccodiniaceae*

*Microxiphium* (Harv. ex Berk. & Desm.) Thüm., *Physis*, B. Aires 4(17): 293 (1879)

*Microxiphium footii* (Harv. ex Berk. & Desm.) Thüm., *Physis*, B. Aires 4(17): 293 (1879)

This genus is polyphyletic with species in *Coccodiniaceae* and *Capnodiaceae*. However the type of the genus is presently placed as synonym of *Dennisiella babingtonii* and thus included in the *Coccodiniaceae*. The specimen of *Microxiphium citri* used in the phylogenetic tree (see Fig. 1) is likely to be a misidentification. *Microxiphium citri*, *M. aciculiform* and *M. theae* are also dispersed amongst the *Capnodiaceae* in the tree indicating its polyphyletic nature.

### Genus transferred to *Micropeltidaceae*

Wu et al. (2011) discusses this family and the following genera are better placed therein.

*Callebaea* Bat. in Batista, Perez & Bezerra, *Brotéria*, sér. bot. 31: 100 (1962)

*Mycelium* superficial, irregularly scattered. *Thyriothecia* circular, scattered, superficial, membranous, brownish, lower peridium poorly developed easily removed from the host surface, with a central irregular ostiole; in section lenticular. *Upper wall* comprising an irregular meandering arrangement of compact hyphae. *Hamathecium* comprising asci, pseudoparaphyses not obvious. *Asci* immature and ascospores not observed.

Anamorphs: None.

### Type species

*Callebaea rutideae* (Hansf.) Bat., In Batista, Perez & Bezerra, *Brotéria*, sér. bot. 31: 100 (1962) (Fig 18A–K)

≡ *Microcallis rutideae* Hansf., *Proc. Linn. Soc. London* 158: 40 (1947)

≡ *Microcalliopsis rutideae* (Hansf.) Bat. & Cif., *Bein. Sydowia* 3: 58 (1962)

*Foliar epiphyte* on upper surface of leaves, lacking superficial mycelium (Fig 18A, B). *Thyriothecia* 83 (–196)–228  $\mu\text{m}$  diam  $\times$  41–63(–85)  $\mu\text{m}$  high ( $\bar{x}$  = 183  $\times$  59  $\mu\text{m}$ , n = 5), circular, scattered, superficial, pale brown to brown, basal peridium poorly developed, easily removable from the surface of leaves, lacking an ostiole; in section lenticular. (Fig 18E). *Upper wall* comprising an irregular meandering arrangement of compact hyphae, 2–3  $\mu\text{m}$

wide ( $\bar{x} = 2.5 \mu\text{m}$ ,  $n = 10$ ). (Fig 18C, D). *Hamathecium* comprising asci, pseudoparaphyses not obvious. *Asci* immature (Fig 18F–K) and ascospores not observed.

**Material examined:** UGANDA, Entebbe Road, in leaves of *Rutideae smithii* (*Rubiaceae*), August 1944, C.G. Hansford 3560 (K(M) 164029, holotype).

Hansford (1947) introduced *Microcallis rutidaea* as new species in *Chaetothyriaceae*. We examined type material and found a few flattened ascomata on host surface and these lacked mature asci and ascospores. The thyriotheecium however, indicate that *Microcallis rutidaea* should be transferred to *Micropeltidaceae*. However the specimen is immature and must be treated as doubtful until a better specimen or fresh collections are found.

### Doubtful genera

*Anopeltis* Bat. & Peres. Nova Hedwigia 2: 472 (1960)

*Foliar epiphyte* on leaves. *Thallus* comprising superficial, olive–brown, cylindrical, branching, irregularly reticulate, septate hyphae, lacking setae. *Ascstromata* semi–immersed, dark–brown to brown at the margin, flattened, round, scattered, surrounded with mycelium, the locule/asci produced under the stromata, hypostromata central or lateral. *Ascstromata* wall composed of angular brown cells. *Peridium* thin. *Conidia* clavate or oblong, 1–septate, deeply constricted at the septum, thick walled, wrinkled.

Anamorphs: None.

### Type species

*Anopeltis venezuelensis* Bat. & Peres, Nova Hedwigia 2: 472 (1960) (Fig 19A–J)

*Foliar epiphyte* on leaves (Fig 19A). *Thallus* superficial, 2.7–5  $\mu\text{m}$  wide ( $\bar{x} = 3.7 \mu\text{m}$ ,  $n = 20$ ), comprising olive–brown, slender, branched, septate, cylindrical hyphae, irregularly reticulate, lacking setae. (Fig 19B). *Ascstromata* 145–208  $\mu\text{m}$  diam, 74–93  $\mu\text{m}$  high ( $\bar{x} = 175 \times 84$ ,  $n = 5$ ), uniloculate, scattered, semi–immersed, dark–brown to brown, surrounded by mycelium. The wall of ascstromata composed of angular brown cells (Fig 19E, F). *Peridium* thin, 2–3  $\mu\text{m}$  wide ( $\bar{x} = 2.5 \mu\text{m}$ ,  $n = 10$ ) (Fig 19D, G). Dark brown conidia cover and surround the ascstromata. *Conidia* 9–14  $\times$  3–6  $\mu\text{m}$  ( $\bar{x} = 11 \times 4$ ,  $n = 15$ ), clavate or oblong, 1–septate, deeply constricted at the septum, thick walled and wrinkled (Fig 19H–J).

**Material examined:** VENEZUELA, Miranda, Caracas, Los Palos Grandes (above), Mt Naiguata (S slope of), c. 1200m, in the leaves of unidentified plant, 13 July 1959, R.W.G. Dennis 2321 (K(M) 171577 – holotype).

*Anopeltis venezuelensis* should be placed in *Ascomycete incertae cedis* according to its semi–immersed ascromata, lack of mycelium and peridium of *textura angularis*. The nature of this taxon is not clear from the type specimen as asci or ascospores were not observed. The taxon needs to be recollected and examined from fresh material.

*Capnophaeum* Speg. Physis, B. Aires 4: 287 (1918)

*Capnophaeum indicum* C. Bernard, Physis, Rev. Soc. Arg. Cienc. Nat. 4: 287 (1918)

We requested the type specimen from BO but was informed it is lost and therefore the genus must be considered as doubtful.

*Fumiglobus* D.R. Reynolds & G.S. Gilbert., Cryptog. Mycol. 27(3): 252 (2006)

*Fumiglobus ficina* (Bat., Nascim. & Cif.) D.R. Reynolds & G.S. Gilbert., Cryptog. Mycol. 27(3): 253 (2006)

≡ *Asbolisia ficina* Bat. Nascim. & Cif. in Batista & Ciferri, Quad. Lab. crittogam. Pavia 31: 41 (1963)

*Fumiglobus* was introduced by Reynolds & Gilbert (2006) as new genus to accommodate *Asbolisia nomen confusum*, which included nine species; typified by somewhat aerial, membraceous, superficial mycelium, comprised of dark brown septate hyphae, constricted at the septum, with pycnidia borne from several hyphae. Conidia are globose to subglobose, hyaline, single-celled, bacillate to ellipsoidal, or cylindrical. Fresh collections are needed to establish if the genus is distinct.

*Polychaetella* Speg., Physis, B. Aires 4: 295 (1918)

*Polychaetella schweinitzii* (Berk. & Desm.) Speg., Physis, B. Aires 4: 295 (1918)

≡ *Capnodium schweinitzii* Berk. & Desm. (1849)

*Polychaetella* was classified in *Capnodium* section IV by Saccardo (1882) and were anamorphs of various *Capnodium* species (Sutton 1977), and have elongated pycnidia producing dictyospetate, hyaline or chlorinous conidia (Hughes 1976). Batista and Ciferri (1963) added *Polychaetella* in *Asbolisiaceae* and accepted *P. araucariaceae* (Thüm) Speg. as type species. Hughes (1976) observed the DAOM syntype of *Capnodium araucariae* but could not find the hyaline dictyospetate conidia. Therefore the genus must be treated as uncertain.

## Discussion

We examined nine generic types and sequenced 15 taxa of *Capnodiaceae*. Phylogenetic analysis show *Capnodium*, *Leptoxyphium*, *Phragmocapnias* and *Scorias* to be well defined genera in *Capnodiaceae*, while *Aithaloderma*, *Anopeltis*, *Callebaea*, *Echinothecium* and *Trichomerium* are removed to other families or are doubtful. This study thus provides an expansion in the documentation of capnodiaceous sooty molds. This group now comprise three easily recognized genera, i.e. *Phragmocapnias* = *Conidiocarpon*, *Capnodium* = *Polychaeton* and *Scorias*, comprising of both sexual and asexual states, and the exclusively anamorphic *Leptoxyphium*. It is not clear whether the genera *Anopeltis*, *Capnophaeum* and *Scoriadopsis* however, are acceptable in *Capnodiaceae* yet.

The present study has shown that the general term “sooty molds” encompasses a broad set of species within the families *Antennulariellaceae*, *Capnodiaceae*, *Chaetothyriaceae* and *Metacapnodiaceae* (Hughes 1976, Reynolds 1986, Reynolds 1998, Chomnunti et al. 2012) which often grow in close association on a single leaf. This had posed considerable challenges to taxonomists since the mid-19<sup>th</sup> century (Friend 1965, Hughes 1976, Reynolds 1986, 1998, Chomnunti et al. 2012). Pycnidiaceous sooty moulds were placed in the generally unaccepted family *Asbolisiaceae* (Batista 1963) and Hosagoudar (2011) recently treated them in a new family *Schifferulaceae*, as black mildews, which he termed “saprobic sooty moulds”. The *Schifferulaceae* may well be synonymous with *Asterinaceae* but this cannot be corroborated without DNA sequence comparisons. DNA sequence data remains rare in other families too. Only one putative species of *Antennulariellaceae* (*Antennariella placitae*) has however, been sequenced and clustered in *Capnodiaceae* (Cheewangkoon et al. 2009).

This study and that of Chomnunti et al. (2012) clearly shows that *Capnodiaceae* and *Chaetothyriaceae* consist of unrelated taxa belonging to different classes and yet they can

hardly be distinguished by morphology and growth habit. It seems clear that the similar morphological characters in these groups evolved under selection pressures unique to their shared niche to utilise sugary insect exudates on leaf surfaces.

Besides the species associated with leaf surfaces and particularly with honey dew produced by insects, our analysis indicates other possible environmental niches in *Capnodiaceae*. One sequence in our analysis was obtained from a member of an ecological guild of rock-inhabiting fungi (Ruibal et al. 2009). Members of this found interspersed throughout the classes *Dothideomycetes* and *Eurotiomycetes*, can tolerate extreme conditions found on rock surfaces. It would be interesting to establish if capnodiaceous species grew on proximity to honey dew on rocks surfaces. Another group of sequences were isolated from a species found in ant nest walls. This undescribed species act as mutualists by aiding in reinforcing the nest walls. They are cultivated by the ants which nourishes them with honeydew (Schlick–Steiner et al. 2008). Finally, there are several pathogenic species which occur on *Capnodiaceae* and include species in the genera *Rhombostilbella* (Pohlad 1988). It will be important that these taxa are considered carefully when studying sooty moulds to avoid confusion in future.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

## Acknowledgments

This work was supported by the Thailand Research Fund BRG528002. The Global Research Net work for Fungal Biology and King Saud University are also thanked for support. Library staff from the Royal Botanic Gardens, Kew are thanked for their support locating obscure literature and providing access to their collections. The curators from herbaria G, NY, S are thanked for loaning specimens. The second author acknowledges support by the Intramural Research Program of the NIH, National Library of Medicine.

## References

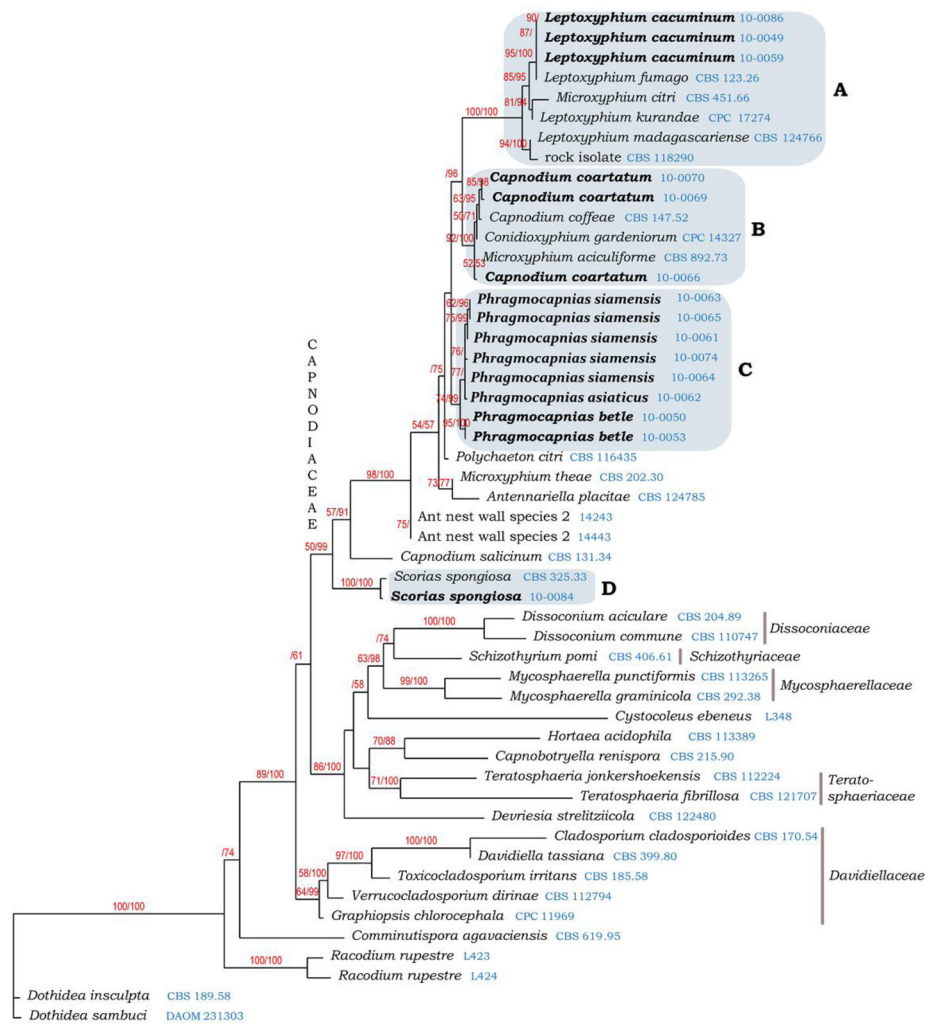
- Andrew JH. Biological control in the phyllosphere. *Ann Rev Phytopathol.* 1982; 30:603–635.
- Barr, ME. Amherst. University of Massachusetts; Massachusetts: 1987. Prodomus to class *Loculoascomycetes*.
- Batista AC, Ciferri R. Capnodiales. *Saccardo.* 1963; 2:1–296.
- Batista AC, Ciferri R. The Chaetothyriales. *Sydowia.* 1962; 3:1–129.
- Batista AC, Ciferri R. The sooty-molds of the family Asbolisiaceae. *Quad Ist Bot Univ Lab Crittogam Pavia.* 1963; 31:1–229.
- Batista AC, da Silva JO. *Hyaloscolecostroma* Batista & J. Oliveira, um novo gênero de *Phaeosaccardinulaceae*. *Atas Inst Micol Univ Recife.* 1967; 5:447–452.
- Batista AC, Peres GEP, Bezerra JL. Novos fungos de fumagina, da família *Phaeosaccardinulaceae*. *Brotéria, SérTrim Cienc Nat.* 1962; 31(2):93–118.
- Berkeley MJ, Desmazières JBHJ. On some moulds referred by authors to *Fumago* and to certain allied or analogous forms. *J Hort Soc London.* 1849; 4:3–19.
- Blakeman JP, Fokkema NJ. Potential for biological control of plant diseases on the phylloplane. *Annu Rev Phytopathol.* 1982; 20:162–192.
- Calatayud V, Navarro-Rosinés P, Hafellner J. A synopsis of *Lichenostigma* subgen. *Lichenogramma* (Arthoniales), with a key to the species. *Mycol Res.* 2002; 106(10):1230–1242.
- Cheewangkoon R, Groenewald JZ, Summerell BA, Hyde KD, To-anun C, Crous PW. *Myrtaceae*, a cache of fungal biodiversity. *Persoonia.* 2009; 23:55–85. [PubMed: 20198162]
- Chevenet F, Brun C, Banuls AL, Jacq B, Christen R. TreeDyn: towards dynamic graphics and annotations for analyses of trees. *BMC Bioinformatics.* 2006; 7:439. [PubMed: 17032440]

- Chomnunti P, Ko Ko TW, Cai L, Jones EBG, Chukeatirote E, Kodsueb R, Bahkali AH, Hang C, Hyde KD. Phylogeny of *Chaetothyriaceae* in northern Thailand including three new species. *Mycologia*. 2012 In press.
- Crous PW, Schoch CL, Hyde KD, Wood AR, Gueidan C, de Hoog GS, Groenewald JZ. Phylogenetic lineages in the Capnodiales. *Stud Mycol*. 2009; 64:17–47. [PubMed: 20169022]
- Faull JL, Olejnik I, Ingrouille M, Reynolds D. A Reassessment of the taxonomy of some tropical sooty moulds. *Trop Mycol*. 2002; 2:33–40.
- Fraser L. An investigation of the sooty mould of New South Wales IV The species of the Eucapnodieae. *Proc Linn Soc New South Wales*. 1935; 40:159–178.
- Friend RJ. What is *Fumago vagenae*? *Trans Brit Mycol Soc*. 1965; 48:371–375.
- Geiser DM, Gueidan C, Miadlikowska J, Lutzoni F, Kauff F, Hofstetter V, Fraker E, Schoch CL, Tibell L, Untereiner WA, Aptroot A. Eurotiomycetes: Eurotiomycetidae and Chaetothyriomycetidae. *Mycologia*. 2006; 98(6):1053–1064. [PubMed: 17486980]
- Hall TA. BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. *Nucleic Acids Sym Ser*. 1999; 41:95–98.
- Hansford CG. New or interesting tropical fungi I. *Proc Linn Soc London*. 1947; 158(1):28–50.
- Hawksworth DL. A new dawn for the naming of fungi: impacts of decisions made in Melbourne in July 2011 on the future publication and regulation of fungal names. *MycKeys*. 2011; 1:7–20.
- von Höhnelt F. Fragmente zur Mykologie VIII. Sitzungsberichten der kaiserlichen Kaiserl. Akad Wiss Math-Naturwiss Cl Abt1. 1909; 118:1157–1246.
- von Höhnelt F. Fragmente zur Mykologie (Xi Mitteilung, Nr. 527 bis 573). Sitzungsber, Kaiserl. Akad Wiss Math-Naturwiss Cl Abt 1. 1910; 119:618–679.
- Hosagoudar VB, Riju MC. Some interesting Meliolaceae members from Western Ghats Region of Kerala State. *Plant Pathology & Quarantine*. 2011; 1(2):121–129.
- Huelsenbeck JP, Ronquist F. MRBAYES: Bayesian inference of phylogenetic trees. *Bioinformatics*. 2001; 17:754–755. [PubMed: 11524383]
- Huelsenbeck JP, Ronquist F, Nielsen R, Bollback JP. Bayesian inference of phylogeny and its impact on evolutionary biology. *Science*. 2001; 294:2310–2314. [PubMed: 11743192]
- Hughes SJ. Studies on micro-fungi X. *Zygosporium*. *Mycol Pap*. 1951; 44:1–18.
- Hughes SJ. New Zealand Fungi 17. Pleomorphism in Cuantennariaceae and Metacapnodiaceae, two new families of sooty moulds. *N Z J Bot*. 1972; 10:225–242.
- Hughes SJ. Sooty moulds. *Mycologia*. 1976; 68:693–820.
- Hughes SJ. *Capnofrasera dendryphioides*, a new genus and species of sooty moulds. *N Z J Bot*. 2003; 41:139–146.
- Hyde KD, McKenzie EHC, KoKo TW. Towards incorporating anamorphic fungi in a natural classification-checklist and notes for 2010. *Mycosphere*. 2011; 2(1):1–88.
- Katoh K, Asimenos G, Toh H. Multiple alignment of DNA sequences with MAFFT. *Meth Mol Biol*. 2009; 537:39–64.
- Kirk, PM.; Cannon, PF.; Minter, DW.; Stalpers, JA. *Dictionary of the Fungi*. 10. CABI Bioscience; UK: 2008.
- Léveillé JH. *Mycologie, Mycétologie*. D'Orbigny, Dictionnaire univ d'Hist nat. 1847; 9:261–303.
- Liu K, Raghavan S, Nelesen S, Linder CR, Warnow T. Rapid and accurate large-scale coestimation of sequence alignments and phylogenetic trees. *Science*. 2009; 324:1561–1564. [PubMed: 19541996]
- Lumbsch HT, Huhndorf SM. Outline of Ascomycota—2009. *Fieldiana, Life and Earth Sciences*. 2010; 1:1–60.
- Matsushima T. *Matsushima Mycological Memoirs* 9. *Mats Mycol Mem*. 2003; 10:1–214.
- Miller, MA.; Pfeiffer, W.; Schwartz, T. Creating the CIPRES Science Gateway for inference of large phylogenetic trees. *Proceedings of the Gateway Computing Environments Workshop (GCE)*; 14 Nov. 2010; New Orleans, LA. 2010. p. 1–8.
- Montagne C. *De Capnodio. novum fungorum genus*. *Ann Sci Nat Bot sér 3*. 1849; 11:233–234.
- Müller E, von Arx JA. Die Gattungen der didymosporen Pyrenomyceten. *Beitr Kryptogamenfl Schweiz*. 1962; 11(2):1–992.

- Navarro–Rosines P, Gomez–Bolea A. *Rhagadostoma–Lichenicola* (D. Not.) Keissler i *Echinothecium reticulatum* (Zopf) dos fongs liquenícoles nous per a la Península Ibèrica. *Folia Bot Misc Barcelona*. 1989; 6:61–64.
- Olejnik IM, Ingrouille M, Faull JL. Numerical taxonomy of the sooty moulds *Leptoxiphium*, *Caldariomyces* and *Aithaloderma* based on micromorphology and physiology. *Mycol Res*. 1999; 103:333–346.
- Pohlrad BR. *Rhombostilbella* parasitizing Chaetothyriaceae and Capnodiaceae. *Mycologia*. 1988; 80(5):757–759.
- Reynolds DR. Observation on growth forms of sooty mold fungi. *Nova Hedwigia*. 1975; 26:179–193.
- Reynolds DR. Foliicolous ascomycetes 2: *Capnodium salicinum* Montagne emend. *Mycotaxon*. 1978; 7:501–507.
- Reynolds DR. Foliicolous ascomycetes: 3. The stalked capnodiaceous species. *Mycotaxon*. 1979; 8(2): 417–445.
- Reynolds DR. Foliicolous Ascomycetes: 4. The capnodiaceous genus *Trichomerium* Spegazzini emend. *Mycotaxon*. 1982; 14:189–220.
- Reynolds DR. Foliicolous ascomycetes 7. Phylogenetic systematics of the *Capnodiaceae*. *Mycotaxon*. 1986; 27:377–403.
- Reynolds DR. Capnodiaceous sooty mold phylogeny. *Can J Bot*. 1998; 76:2125–2130.
- Reynolds DR. *Capnodium citri*: The sooty mold fungi comprising the taxon concept. *Mycopathologia*. 1999; 148:141–147. [PubMed: 11189765]
- Reynolds DR, Gilbert GS. Epifoliar fungi from Queensland, Australia. *Aust Syst Bot*. 2005; 18:265–289.
- Ruibal C, Gueidan C, Selbmann L, Gorbushina AA, Crous PW, Groenewald JZ, Muggia L, Grube M, Isola D, Schoch CL, Staley JT, Lutzoni F, de Hoog GS. Phylogeny of rock-inhabiting fungi related to Dothideomycetes. *Stud Mycol*. 2009; 64:123–133. [PubMed: 20169026]
- Saccardo PA. *Sylloge fungorum* 14. Patavii. 1899:1–1316.
- Schlick–Steiner BC, Steiner FM, Konrad H, Seifert B, Christian E, Moder K, Stauffer C, Crozier RH. Specificity and transmission mosaic of ant nest–wall fungi. *Proc Nat Acad Sci*. 2008; 105:940–943. [PubMed: 18195358]
- Schoch CL, Shoemaker RA, Seifert KA, Hambleton S, Spatafora JW, Crous PW. A multigene phylogeny of the Dothideomycetes using four nuclear loci. *Mycologia*. 2007; 98:1041–1052. [PubMed: 17486979]
- Schoch CL, Crous PW, Groenewald JZ, Boehm EW, Burgess TI, de Gruyter J, de Hoog GS, Dixon LJ, Grube M, Gueidan C, Harada Y, Hatakeyama S, Hirayama K, Hosoya T, Huhndorf SM, Hyde KD, Jones EB, Kohlmeyer J, Krays A, Li YM, Lucking R, Lumbsch HT, Marvanova L, Mbatchou JS, McVay AH, Miller AN, Mugambi GK, Muggia L, Nelsen MP, Nelson P, Owensby CA, Phillips AJ, Phongpaichit S, Pointing SB, Pujade–Renaud V, Raja HA, Plata ER, Robbertse B, Ruibal C, Sakayaroj J, Sano T, Selbmann L, Shearer CA, Shirouzu T, Slippers B, Suetrong S, Tanaka K, Volkmann–Kohlmeyer B, Wingfield MJ, Wood AR, Woudenberg JH, Yonezawa H, Zhang Y, Spatafora JW. A class-wide phylogenetic assessment of Dothideomycetes. *Stud Mycol*. 2009; 64:1–15. [PubMed: 20169021]
- Sivanesan, A. *The bitunicate ascomycetes*. Cramer; Vaduz, Germany: 1984.
- Spegazzini C. *Notas Micológicas*. Physis (Buenos Aires). 1918; 4:281–295.
- Stamatakis A. RAxML–VI–HPC: maximum likelihood-based phylogenetic analyses with thousands of taxa and mixed models. *Bioinformatics*. 2006; 22:2688–2690. [PubMed: 16928733]
- Stamatakis A, Hoover P, Rougemont J. A rapid bootstrap algorithm for the RAxML Web Servers. *Syst Biol*. 2008; 57:758–771. [PubMed: 18853362]
- Stevens FL. Parasitic fungi of British Guiana, Trinidad and Costa Rica. *Ann Mycol*. 1930; 28 (5/6): 346–371.
- Sutton BC. Coelomycetes VI. Nomenclature of generic names proposed for Coelomycetes. *Mycol Pap*. 1977; 141:1–253.
- Sydow H, Sydow P. *Novae fugorum species–X*. *Ann Mycol*. 1913; 11:254–271.



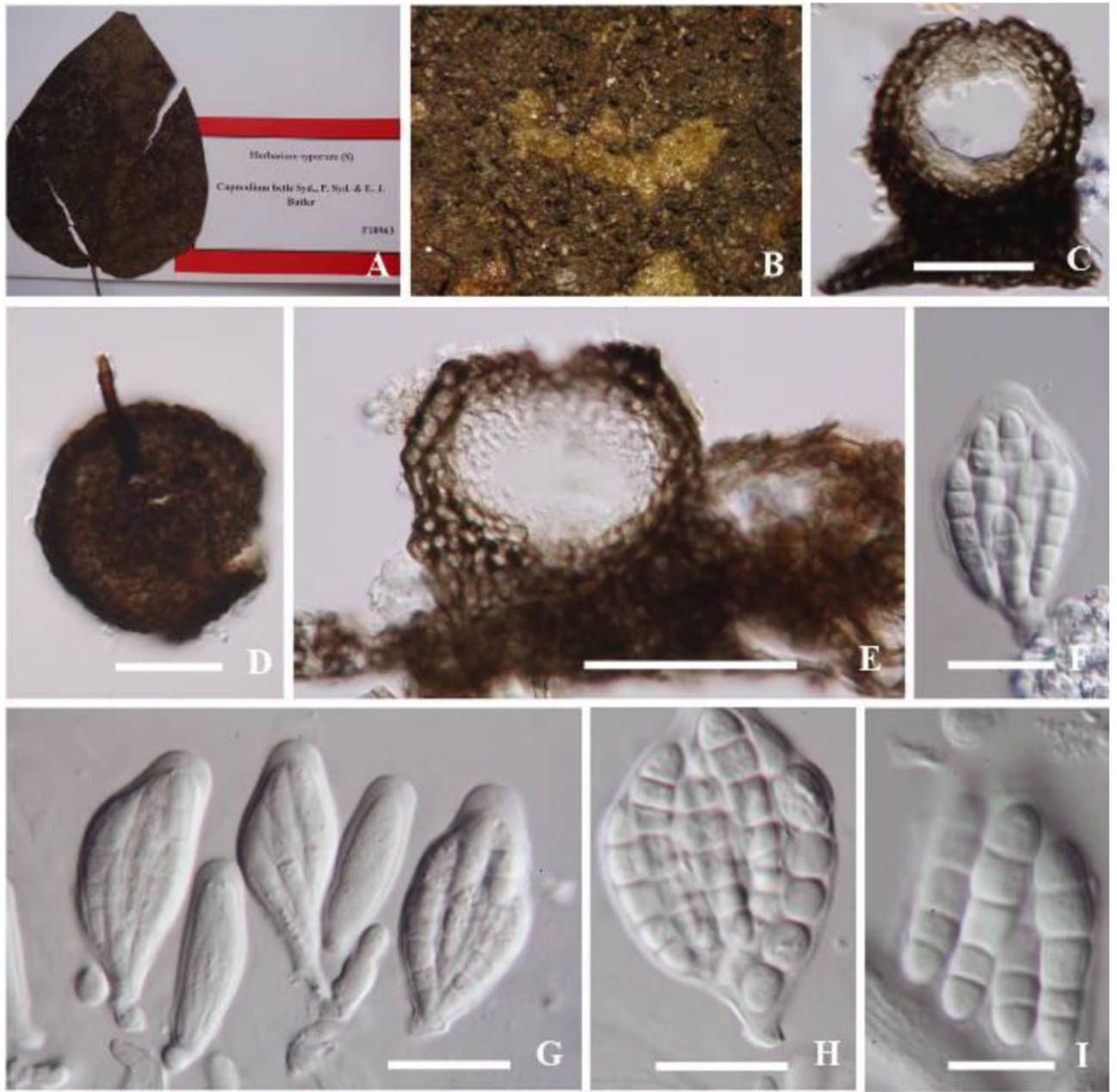
- Von Arx JA, Müller E. A re-evaluation of the bitunicate ascomycetes with keys to families and genera. *Stud Mycol.* 1975; 9:1–159.
- Woronichin NN. Zur Kenntnis der Morphologie und Systematik der Russtaupilze Transkaukasiens. *Ann Mycol.* 1926; 24 (3/4):231–264.
- Yamamoto W. Taxonomic studies on the *Capnodiaceae* 2 On the species of the Eucapnodiaceae. *Ann Phytopath Soc Japan.* 1954; 19(1–2):1–5.



**Fig. 1.** A RAxML maximum likelihood tree from obtained from a data set of 51 taxa including representatives of *Capnodiales*, focused on *Capnodiaceae*, comparing two genes (SSU, LSU). The first set of numbers above the nodes are bootstraps from 1000 pseudorepetitions and the second represent Bayesian posterior probabilities expressed as percentages. Only values above 50% are shown. Culture and voucher numbers are indicated after species names and names of isolates with newly obtained sequences for this study are bolded.

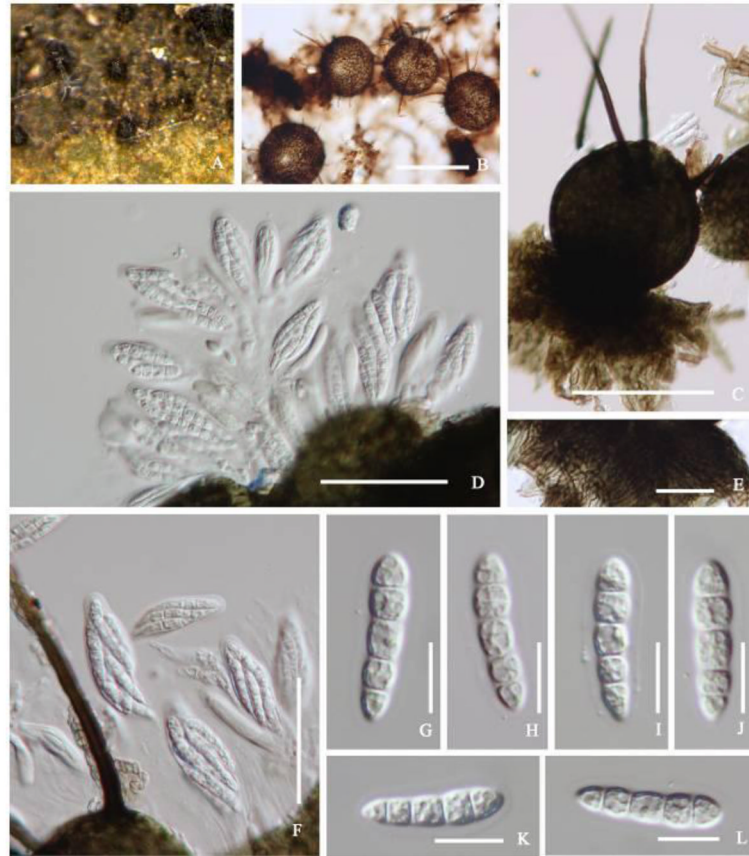


**Fig. 2.**  
**A–E** Sooty moulds growing on host leaves. A. Unidentified tree. B. *Bischofia javanica*. C. *Euphorbia* sp. D. *Psidium guajava*. E. *Cestrum diurnum*. **2F–I** Representative pycnidia of *Capnidiaceae* genera accepted in this paper. F. *Phragmocapnias*. G. *Capnodium*. H. *Leptoxyphium*. I. *Scorias*.



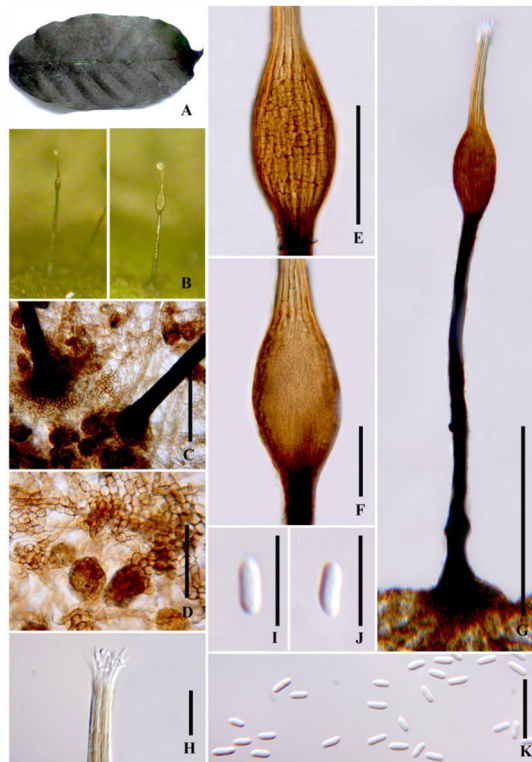
**Fig. 3. A–I** *Phragmocapnias betle* (holotype of *Capnodium betle*)

A, B. Ascomata on leaves. C, E. Vertical section through stalked ascoma. D. Ascomata exterior wall with setae. F–H. Asci with short pedicel. I. Cylindric–clavate ascospores. Bars: E = 100  $\mu\text{m}$ , C, D = 50  $\mu\text{m}$ , F, H, G = 20  $\mu\text{m}$ , I = 10  $\mu\text{m}$ .



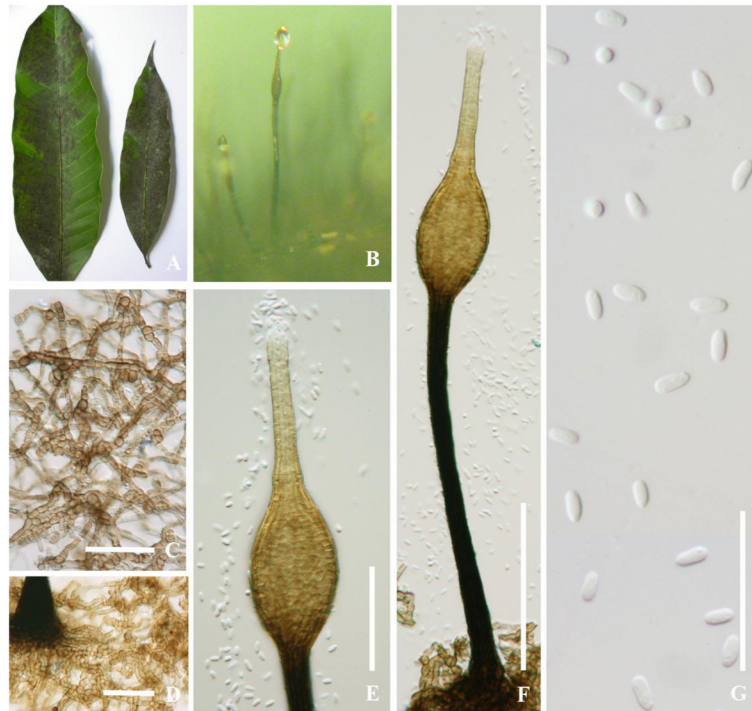
**Fig. 4. A–L** *Phragmocapnias betle* (epitype)

A. Ascomata on living leaf. B, C. Ascomata which are subglobose with setae. D, F. Bitunicate asci. E. Mycelium beneath ascomata. G–L. Ascospores surrounded by a mucilaginous sheath. Bars: B, C = 100 μm, D, F = 50 μm, E = 20 μm, G–L = 10 μm.



**Fig. 5. A–K *Phragmocapnias asiaticus* (holotype)**

A. Black mycelium covering the leaf surface. B. Pycnidium with long stalks on the host. C, D. Mycelial network. E, F. Conical pycnidium and pycnidium wall. Note the conidia in the swollen part in F. G. Pycnidia. H. Ostiole. I–K. Conidia. Bars: C, E = 50  $\mu\text{m}$ , D–F = 20  $\mu\text{m}$ , H, K = 10  $\mu\text{m}$ , I, J = 5  $\mu\text{m}$ .



**Fig. 6. A–G *Phragmocapnias siamensis* (holotype)**

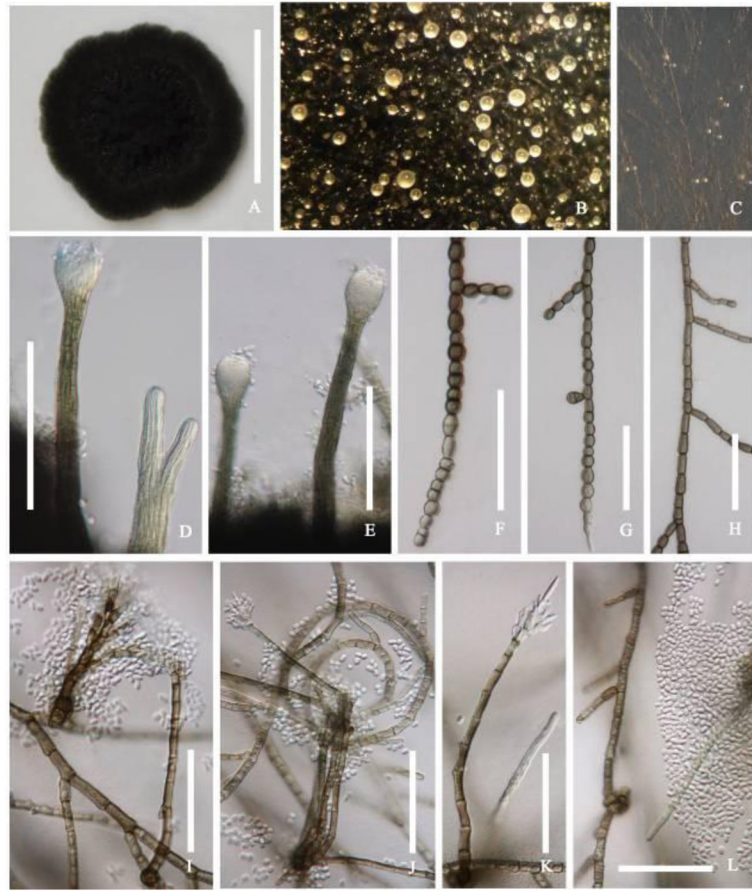
A. Black mycelium covering the leaf surface. B. Pycnidia on host. C, D. Mycelial network. E, F. Conical pycnidia and pycnidia wall. G. Conidia. Bars: F = 100 μm, C–E = 50 μm, G = 20 μm.



**Fig. 7. A–L***Leptoxyphium cacuminum* (holotype)

A. Gregarious pycnidia on host surface. B, D, G. Stalked pycnidia with wider base. E. Formation of pycnidia from aggregated hyphae. C, F. Black stalked funnel cupulate apex. H–L. Conidia, conidiogenous boundary with hyaline hyphae surrounding the ostiole. Bars: B, D, E, G = 200  $\mu$ m, C–F = 50  $\mu$ m, H–L = 20  $\mu$ m.





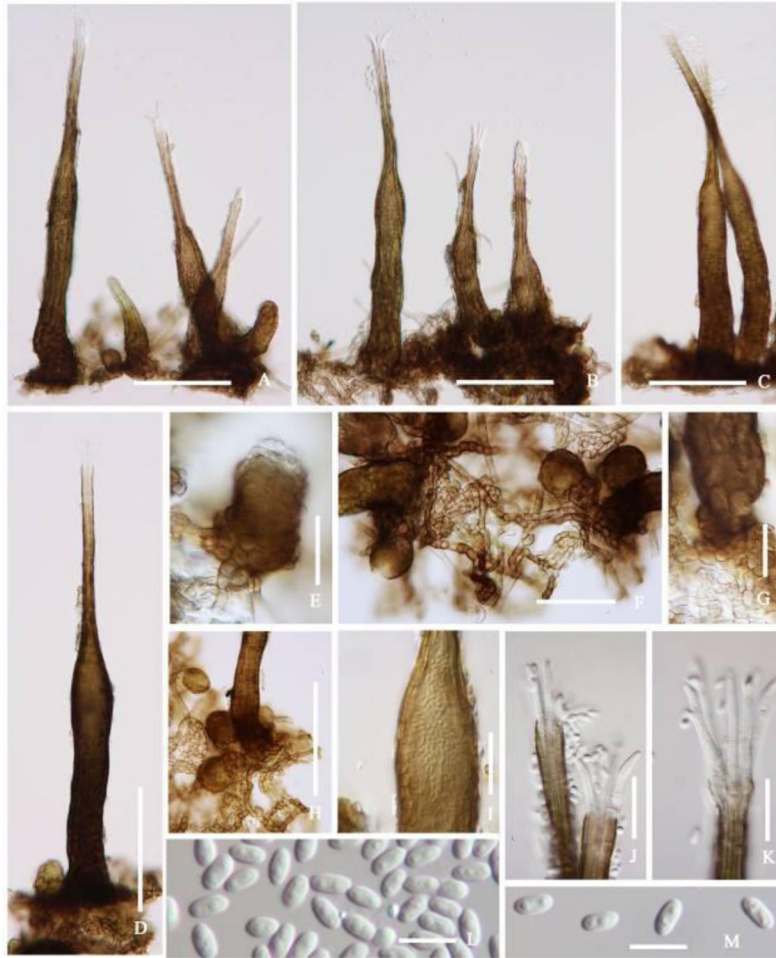
**Fig. 8. A–L *Leptoxyphium cacuminum* (holotype) in culture**

A. Colony on PDA. C, D. Conidial mass at the apex of conidia. D, E. Olive–green stalked funnel shaped at apex. F–H. Septate hyphae. I–L. Conidia produced from the apex of conidiophores. Bars: A = 2 cm, D = 200  $\mu$ m, E–L = 50  $\mu$ m.



**Fig. 9. A–G***Capnodium citri* (type?)

A. Superficial mycelium on host. B, F. Cylindrical, septate mycelium. C–E. Elongate pycnidia. G. Conidia. Bars: B, C = 200 µm, D, E = 100 µm, F = 50 µm, G = 20 µm.

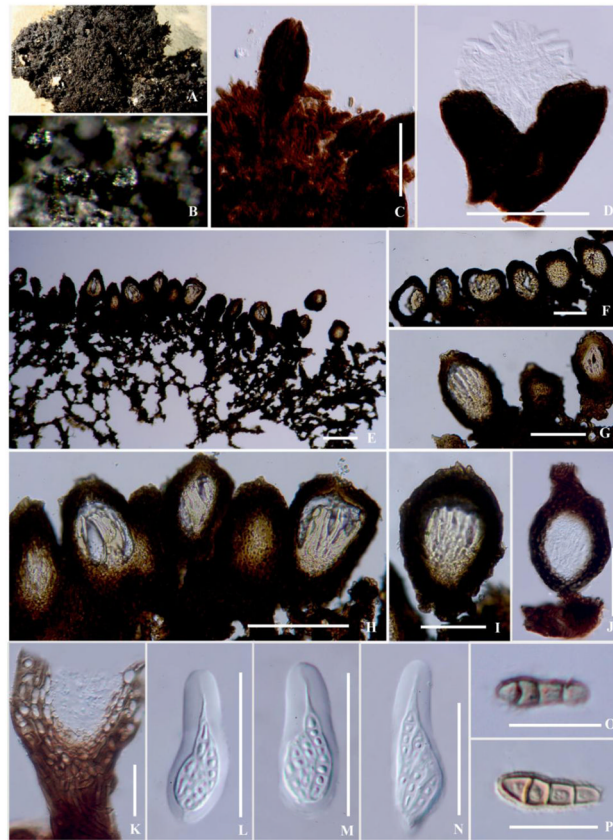


**Fig. 10. A–M** *Capnodium coartatum* (holotype)

A–D. Stalked pycnidia. E. Immature pycnidia. F. Mycelia. G, H. Pycnidia rising from mycelium. I. Abundant conidia at apex pycnidia and pycnidia wall. J, K. Ostiole surround by hyaline hyphae. L, M = Conidia. Bars: A–D = 200  $\mu\text{m}$ , F = 100  $\mu\text{m}$ , E, G, I–K = 50  $\mu\text{m}$ , L, M = 20  $\mu\text{m}$ .

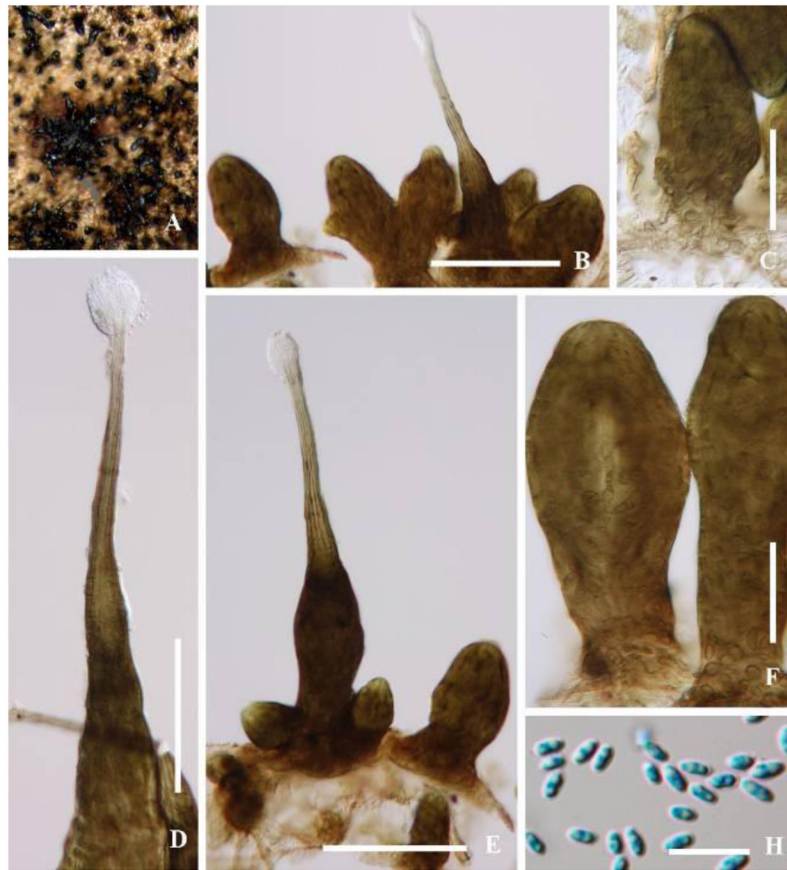


**Fig. 11. A–J***Capnodium tiliae* (exsicata of *Fumago tiliae*)  
 A. Label data. B. Vertical section through ascoma. C. Dark brown mycelium. D. Peridium.  
 E. Peridium with cells of *textura angularis*. G–I. Cylindrical to cylindric-clavate asci. J.  
 Ascospores 3–4 septate. Scale bars: F = 200  $\mu\text{m}$ , B–D = 100  $\mu\text{m}$ , E, G–I = 50  $\mu\text{m}$ , J = 20  $\mu\text{m}$ .



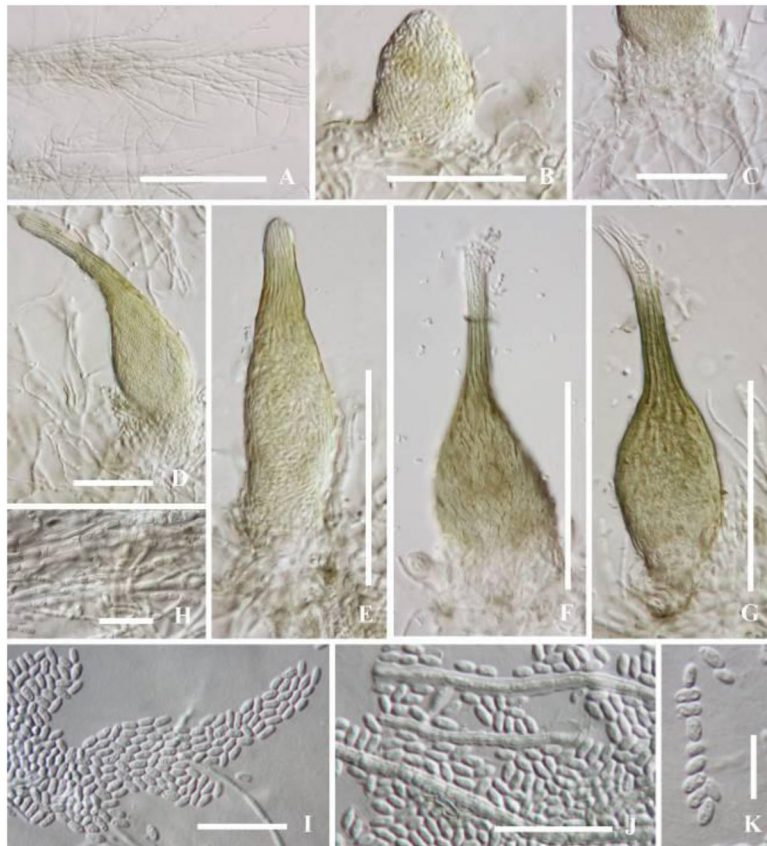
**Fig. 12. A-*Scorias spongiosa* (syntype)**

A, B. Ascomata on hyphal mass on host. C, D. Squash of ascomata. E–J. Vertical section through ascomata on hyphal mass. K: Stalked ascomata. L–N: Asci with thick wall. F, G. Pale brown ascospores. Bars: D–H, J = 100  $\mu\text{m}$ , C, I = 50  $\mu\text{m}$ , K–N = 20  $\mu\text{m}$ , O, P = 10  $\mu\text{m}$ .



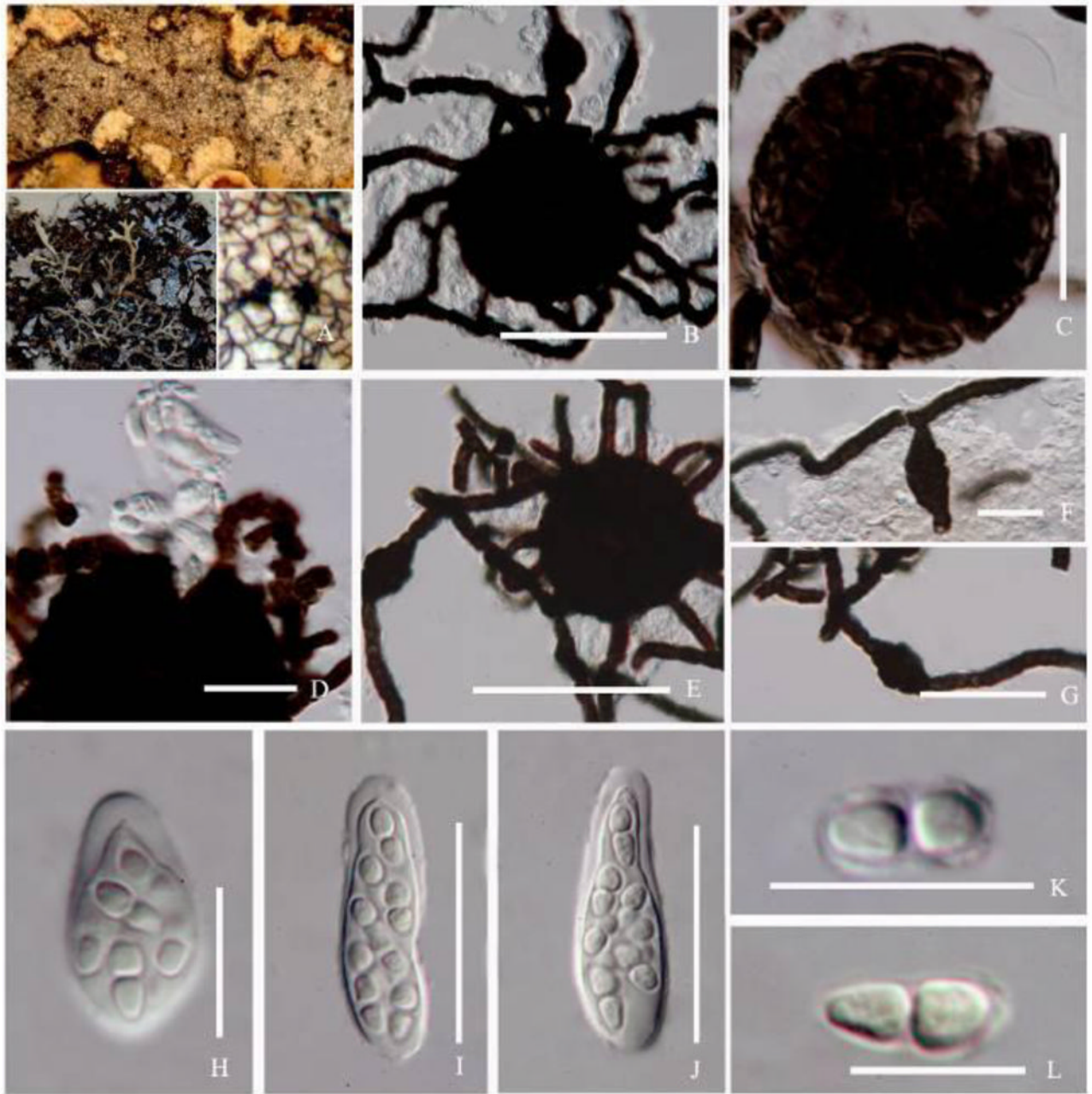
**Fig. 13. A–H***Scorias spongiosa* (epitype)

A. Ascomata and pycnidia on surface of leaf. B, D–F. Immature ascomata and pycnidia. C. Pycnidia arising from mycelium. H. Conida. Bars A = 200  $\mu\text{m}$ , D, E = 100  $\mu\text{m}$ , B, F = 50  $\mu\text{m}$ , H = 20  $\mu\text{m}$ .



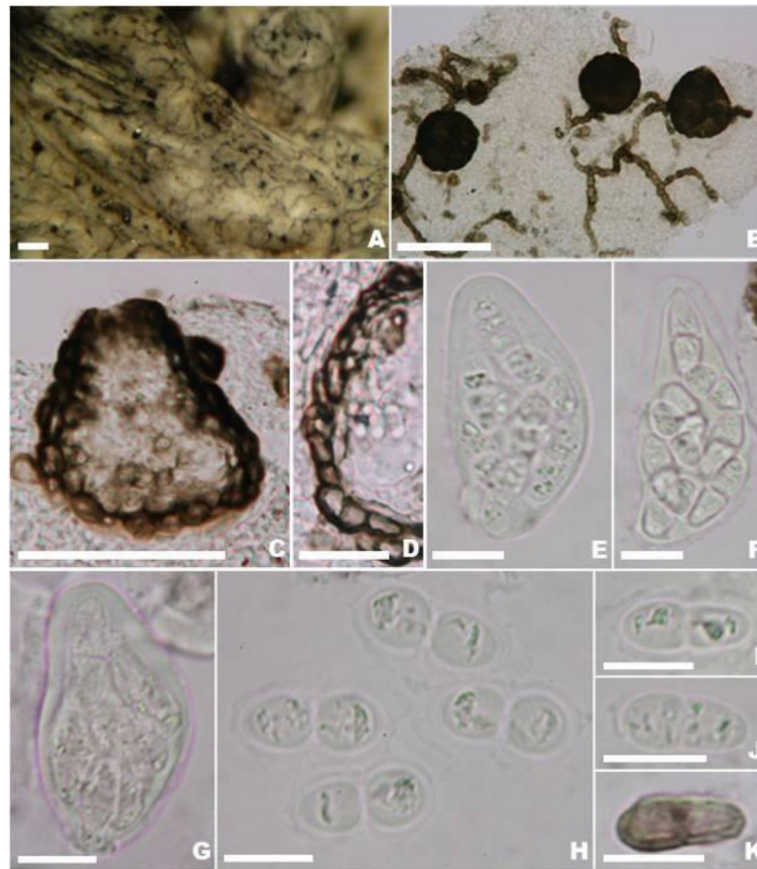
**Fig. 14. A–K** *Scorias spongiosa* (epitype)

A. Hyphae. B. Immature pycnidia. C. Mycelium bearing pycnidium. D–G. Mature pycnidia. H. Septate hyphae. I–K. Hyaline conidia. Bars: A = 200 μm, E–G = 100 μm, B–D = 50 μm, H–J = 20 μm, K = 10 μm.

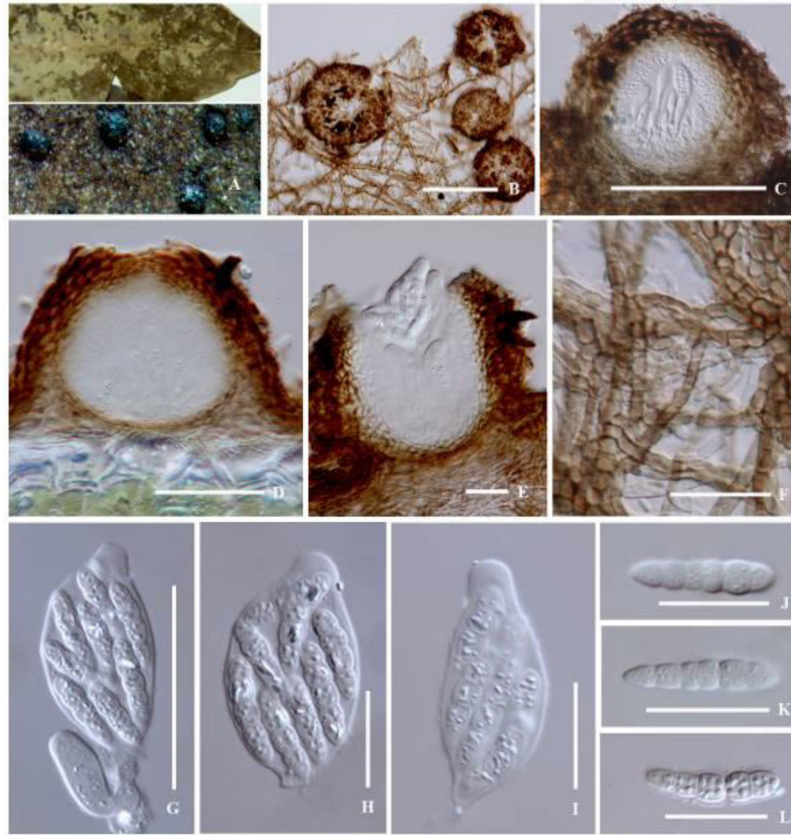


**Fig. 15.** A–L *Sphaerellothecium reticulatum* (syntype of *Echinothecium reticulatum*)  
 A. Ascomata on *Parmelia sulcata*. B–E. Ascoma with eternal hyphal appendages. F, G.  
 Mature hyphae. H–J. Bitunicate asci. K, L. Ascospores. Bars: A, C, D, F = 50  $\mu\text{m}$ , B, E, G–I  
 = 20  $\mu\text{m}$ , J, K = 10  $\mu\text{m}$ .



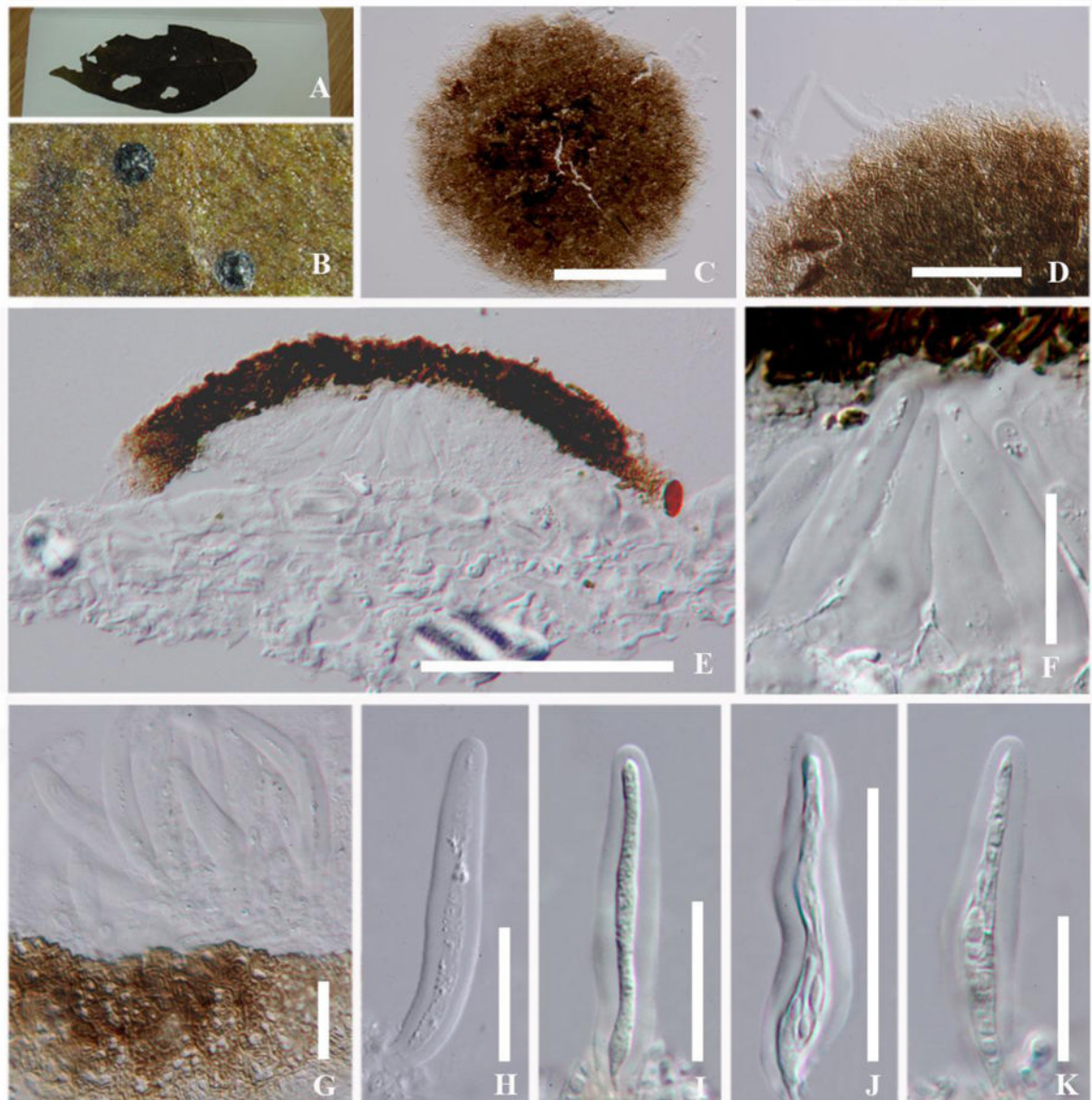


**Fig. 16. A–K** *Sphaerellothecium araneosum* (holotype of *Sphaerella araneosa*)  
 A. Fruiting bodies on host tissue. B. Ascomata with hyphae. C. Section through ascoma. D.  
 Section through peridium. E–G. Ascus. H–J. Ascospores. K. Mature ascospore. Bars: A =  
 200  $\mu\text{m}$ , B = 100  $\mu\text{m}$ , C = 50  $\mu\text{m}$ , D = 20  $\mu\text{m}$ , E–K = 10  $\mu\text{m}$ .



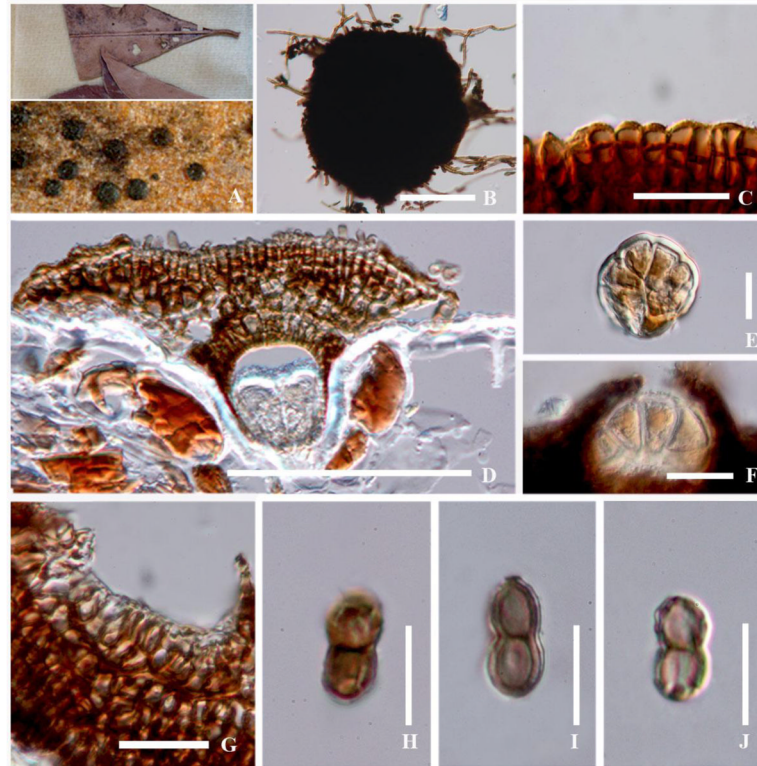
**Fig. 17. A–L** *Aithaloderma clavatisporum* (isotype)

A. Sooty mold and ascostromata on surface of host. B. Ascostromata with short setae. C–E. Section through ascostromata. F. Network of hyphae. G–I. Asci. J–L. Ascospores. Bars: B–D= 100  $\mu\text{m}$ , E–G= 50  $\mu\text{m}$ , H–L= 20  $\mu\text{m}$ .



**Fig. 18. A–K** *Microcallis rutideae* (holotype)

A, B. Ascomata on leaf surface. C, D. Circular ascomata comprising meandering hyphae. E. Vertical section of ascostomata. F–K. Young asci. Bars: C, E = 100  $\mu\text{m}$ , D, J = 50  $\mu\text{m}$ , F–I, K = 20  $\mu\text{m}$ .



**Fig. 19. A–J**–*Anopeltis venezuelensis* (holotype)

A. Appearance of leaves colonized by the fungus. B. Ascostromata with mycelium and conidia. C. Pale brown angular cells of ascostromata edge. D. Section of ascostromata with angular cells. E. Young locule/asci. F. Vertical section of ascostromata with young asci. G. Angular cells of ascostromata. H–J. Brown conidia with 1-septa. Bars: B–D = 100  $\mu\text{m}$ , C, E–G = 20  $\mu\text{m}$ , H–J = 10  $\mu\text{m}$ .