Coprophilous ascomycetes of northern Thailand

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The distribution and occurrence of coprophilous ascomycetes on dung of Asiatic elephant, cattle, chicken, goat and water buffalo in Chiang Rai Province, northern Thailand was investigated between March and May, 2010. A moist chamber culture method was employed. Species from eleven genera in Sordariales, Pleosporales, Pezizales, Thelebolales and Microascales were identified. Some of the species examined are new records for Thailand. The most common species were *Saccobolus citrinus*, *Sporormiella minima*, *Ascobolus immersus* and *Cercophora kalimpongensis*. Most fungal species were found on cattle dung. Chicken dung, a rarely reported substrate for coprophilous fungi, had the least fungal species.

Key words – *Ascobolus* – *Cercophora* – dung types – moist chamber – *Saccobolus* – *Sporormiella* – substrate.

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Introduction

Many studies have contributed to the knowledge of Thai fungal biodiversity. These studies have mainly focused on insect fungi, marine fungi, plant pathogens, disease pathogens, dung fungi, fungi morphology and taxonomy (Somrithpol et al. 2002, Jones et al. 2004, Manoch et al. 2009, Piasai et al. 2009a). The occurrence and distribution of coprophilous fungi in Thailand (Somrithipol et al. 2002, Jeamjitt et al. 2007, 2008, Piasai et al. 2009a) compares well with studies elsewhere e.g. Africa (Eberson et al. 1992, 1997, Caretta et al. 1998), Australia and New Zealand (Bell 1983, 2005), the Middle East (Elshafie 2005) and South America (Richardson 2001, 2008). These studies have shown that species richness and diversity in coprophilous ascomycetes is similar for tropical areas of the world.

The objectives of this survey were: (1) to study the taxonomy of ascomycetes found on various dung types in northern Thailand and, (2) to record the species diversity and distribution of ascomycetes associated with different dung types in Chiang Rai Province, northern Thailand. These coprophilous ascomycetes are described and illustrated in this paper.

Material and methods

Dung was collected from locations near Chiang Rai in northern Thailand and the collection sites mapped using a Global Positioning System (GPS) device. The criteria for sampling and site selection were mainly dung type (animal diversity) and land use. Parameters such as

sample number, moisture condition of dung, animal species voiding the dung, vegetation type, location (site), weather details, collector's name and collection date were recorded in a field datasheet. Very dry dung was moistened with sterile water taking into account that too much water may inhibit fungal sporulation (Bell 2005). Dung from Asiatic elephant, cattle, chicken, goat and water buffalo was collected in the field, labeled, placed in sterile polythene containers and returned to the laboratory for culturing. The dung was examined for signs of fungal sporulation prior to incubation. The dung samples were incubated at room temperature under natural light to induce sporulation of coprophilous ascomycetes (Cain 1934, Brummelen van 1967, Lundqvist 1972, Bell 2005).

Sporulation of ascomycetes started after about one week of incubation. Thorough examinations commenced immediately thereafter and continued on a regular basis thereby ensuring that fungal sporulation and the development of ascomycete fruiting was well monitored (Lundqvist 1972, Doveri 2004, Bell 2005).

The examination of coprophilous ascomycetes was carried out by picking individual fruiting bodies with a pair of fine forceps or a sharp needle and transferring them directly on a drop of sterile water placed on a glass slide. Gentle pressure was applied on the mount using the rubber of a pencil to extrude the asci and ascospores for microscopic examination (Brummelen van 1967, Bell 2005). Each species was examined in detail and its sample number, date of incubation, date of examination, tentative name, notes on reactions with stains, habit and colour, photograph number and the age of dung were recorded in a laboratory data sheet. Herbarium material was prepared by placing small pieces of dung in envelopes and cryotubes. These specimens were deposited in the Mae Fah Luang University herbarium for preservation. Low resolution digital images of ascomata growing on the substrate were taken to enhance taxonomy while photomicrographs of the micro characters were taken on a Nikon® eclipse 80i camera and a Sony® digital camera. In addition, a Nikon® compound microscope with advanced computer software (Image Framework®) was used to measure the sizes of fungi structures observed. These digital images were preserved for future reference.

Morphological features including mycelium, ascomata, hairs, setae, ascomal wall, paraphyses, asci and ascal apical apparatus; ascospore characters such as their shapes and sizes, presence or absence of germ pores, germ slits, de Bary bubbles, colour and ornamentation as seen under phase contrast microscopy, were used for species diagnosis (Brummelen van 1967, Lundqvist 1972, Bell 1983, 2005).

Staining of squashed slide mounts of fungi tissues was done to enable clear observation of morphological features and also note any fungal tissue-stain reactions that could aid species delimitation. Detailed examinations of all micromorphological characters of living materials were carried out and the features photographed and described. Identification keys provided by Cain (1934), van Brummelen (1967), Mirza et al. (1969), Korf 1972, Richardson et al. (1997), Bell (1983, 2005) and Doveri (2008a, 2008b) were extensively used. At least ten spores, asci and other important structures were measured and the lowest and highest measurement taken for each.

Taxonomy

Ascobolus immersus Pers., Neues Mag. Bot. 1:115 (1794). **(Fig. 1A-H)**

Ascomata cleistothecioid in the early stages, immersed or superficial, 1000–1500 µm high, 600–800 µm diam., gregarious or scattered, sessile, receptacle yellowish brown, without margin, a few ripe asci protruding above the upper surface of the hymenium, disc pale yellow, subglobose to turbinate. *Ectal excipulum* thick, of somewhat horizontally elongated *textura angularis* cells, 8–20 × 10–40 µm, yellowish brown. *Paraphyses* filiform, exceeding the asci, septate, 2–4 µm broad, simple or rarely branched, embedded in yellowish mucus, sometimes curved and slightly clavate at the tips. *Asci* 310–550 × 42–115 µm, 8-spored, unitunicate, broadly clavate to sacciform, short stipitate, rounded above, operculate, wall turning deep blue in Meltzer reagent, apical ring ca. 25 µm diam. *Ascospores* 30–60 × 17–34 µm, single-celled, subcylindrical, hyaline at first, violet later, purple-brown at maturity, uniseriate to biseriate, smooth or with few anastomosed cracks, a gelatinous sheath on each, broader on sides and narrow on polar region.

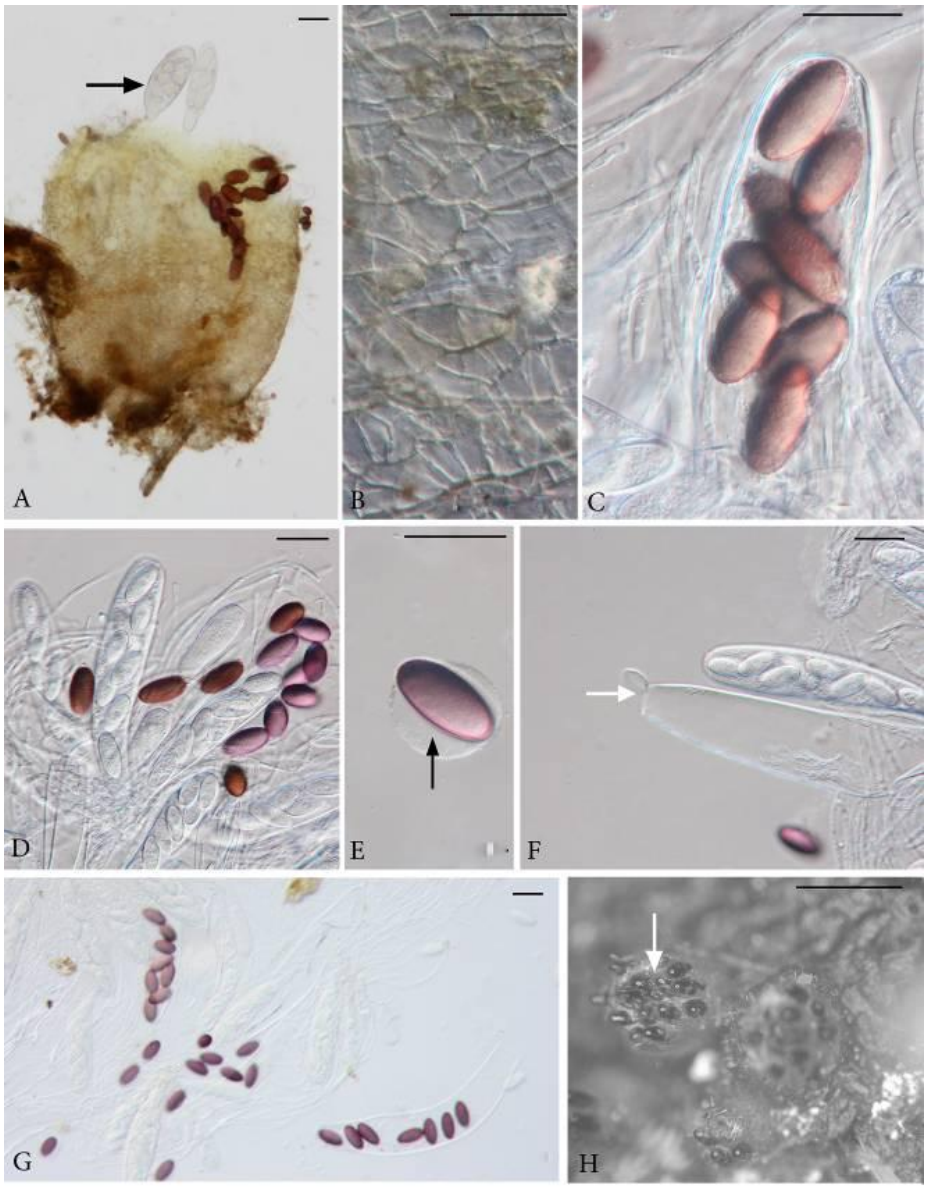

Fig. 1 – *Ascobolus immersus* (from MFLU10 0192). **A** Ascoma showing protruding asci (arrowed). **B** Cells of ectal excipulum. **C** Apical part of an 8-spored ascus. **D** Details of hymenium. **E** Mature ascospore with a patent perisporium (arrowed). **F** Immature asci and one dehiscing ascus with on open operculum (arrowed). **G** Asci and ascospores. **H** Ascomata on dung, note protruding asci (arrowed). **Scale bars**: **A =** 500 µm, **D**, **E**, **G** = 40 µm, **B** = 20 µm, **C** = 50 µm, **F** = 30 µm.

Material examined

THAILAND, Chiang Rai Province, Muang District, Thasud Sub-District, Fah Thai Market, GPS N20°02.8582 E099°52.0498, alt. 417m, cattle dung, 6 March 2010, P. Mungai, MFLU100192; GPS N20°02.9407 E099°52.21 35, alt. 418m, cattle dung, 6 March 2010, P. Mungai, MFLU100187; GPS N20°02.8582 E099°2.0498, alt. 417m, cattle dung, 6 March 2010, P. Mungai, MFLU100190; GPS N20°02.8582 E099°2.0498, alt. 417m, cattle dung, 6 March 2010, P. Mungai, MFLU100193; GPS N20°02.8582 E099°52.0498, alt. 417m, cattle dung, 6 March 2010, P. Mungai, MFLU100191.

Notes: *Ascobolus siamensis* Brumm., *A. demangei* Pat., *A. albidus* H. Crouan & P. Crouan and an *Ascobolus* sp. have been recorded in previous coprophilous fungi studies in Thailand (Brummelen 1967, 1969, 1977, Somrithipol et al. 2002, Jeamjitt et al. 2008, Piasai et al. 2009a). *A. immersus* is easily differentiated from the other *Ascobolus* species of sect. *Dasyobolus* (Sacc.) Brumm. (cleistothecioid ascomata, opening at late maturity

only, or not opening at all) by its comparatively large ascomata, asci and ascospores, the latter typically smooth or with thin crevices (Brummelen van 1967, Doveri 2004). *A. immersus* appears to be a very common coprophilous species that sporulates very early on the incubated dung.

Ascodesmis sphaerospora W. Obrist**,** Can. J. Bot. 39: 948 (1961). (**Fig. 2A-F)**

Ascomata apothecioid, rudimentary, superficial, 70–200 µm diam., gregarious, formed of clusters of asci and paraphyses, hyaline to light brown, hemisphaerical to globose. Subhymenium of *textura angularis* cells, 6 × 6.5 µm. *Paraphyses* filiform, exceeding the asci and mixed with them, septate, 3–6 µm broad, numerous, not branched, slightly swollen at the tips. *Asci* 60–100 × 25–30 µm, 8-spored, rounded above, opening by a somewhat obliquely placed operculum, unitunicate, broadly clavate to saccate, short stipitate. *Ascospores* 10–12 µm diam. (ornamentations excluded), 10-15 µm diam. (ornamentations included), single-celled, thick walled at first, becoming thin walled at maturity, globose to subglobose, hyaline at first, becoming pale brown, biseriate or irregularly arranged in the ascus, without perisporium, ornamented with spines and ridges forming a more or less complete reticulum.

Material examined

THAILAND, Chiang Rai Province, Muang District, Thasud Sub-District, Fah Thai Market, GPS N20°02.9776 E099°2.1176, alt. 418m, on cattle dung, 6 March 2010, P. Mungai, MFLU10 0189.

Notes: Jeamjitt et al. (2007) and Piasai et al. (2009a) recorded *Ascodesmis macrospora* W. Obrist, *A. porcina* Seaver and *A. sphaerospora* W. Obrist in Thailand. *Ascodesmis sphaerospora* usually grows on carnivore dung but has occasionally been isolated from soil and vegetable debris (van Brummelen 1981). In this study *A. sphaerospora* was isolated from cow dung, an unusual substrate for the species. This Thai collection has characteristics very close to previous descriptions for *A. sphaerospora* (van Brummelen 1981, Hanlin 1998a, Doveri 2004, Jeamjitt et al. 2007). According to Doveri's key (2004) it is characterized by globose to subglobose ascospores with a reticulate ornamentation. *A. microscopica* (H. Crouan & P. Crouan) Seaver can easily be confused with *A. sphaerospora* but the ascospores of the latter are broadly ellipsoidal with an irregular reticulation (van Brummelen 1981). *A. sphaerospora* also resembles *A. nana* Brumm., but it differs in having smaller ascospores ornamented with tubercles or minute roundish warts (Doveri 2004).

Cercophora kalimpongensis Mukerji, R.N. Kumar & N. Singh, Phytomorphology 45: 94 (1995). (**Fig. 3A-H)**

Perithecia semi-immersed, scattered to gregarious, 670–810 µm high, 470–600 µm diam., obpyriform; *neck* cylindrical, opaque 140–150 × 90–125 µm, with brown, hyaline ended, septate one-sided tufts of fascicled hairs 60–70 × 2–2.5 µm; perithecial contents usually hyaline. *Peridium* membranaceous, 3-layered, almost bare, brown, semi-transparent. *Exoperidium* of *textura angularis* cells 10–25 × 7–15 µm, semi-transparent. *Paraphyses* simple, filiform, longer than the asci and mixed with them, septate, hyaline, evanescent, tips not swollen. *Asci* ca. 95 × 20 µm, 8-spored, unitunicate, non-amyloid, narrowly clavate, costate after dehiscence, apical apparatus thickened, a round smooth sub apical plasma globulus, with a long slender stipe. *Ascospores* 14–21 × 8.5–10 µm, ellipsoidal, slightly sigmoid or bent only below, bi- to tri-seriate, at first vermiform, one-celled, hyaline, many guttules, finally two-celled, smooth, claviform, with one large guttule, swollen at the apex; *pedicel* cylindric-sigmoid, 26.5–34 × 1–2 µm, hyaline, collapsing at maturity; equipped with a single solid lash-like gelatinous cauda on each end of spore; *apical cauda* 21–32 × 3–4 µm, cylindric, hyaline; *basal cauda* hyaline, evanescent; germ pore, apical, eccentric.

Material examined

THAILAND, Chiang Rai Province, Muang District, Thasud Sub-District, Chiang Rai Elephant Camp, GPS N19°57.5680 E099° 42.5561, alt. 429m, Asiatic elephant dung, 10 March 2010, P. Mungai, MFLU100210;

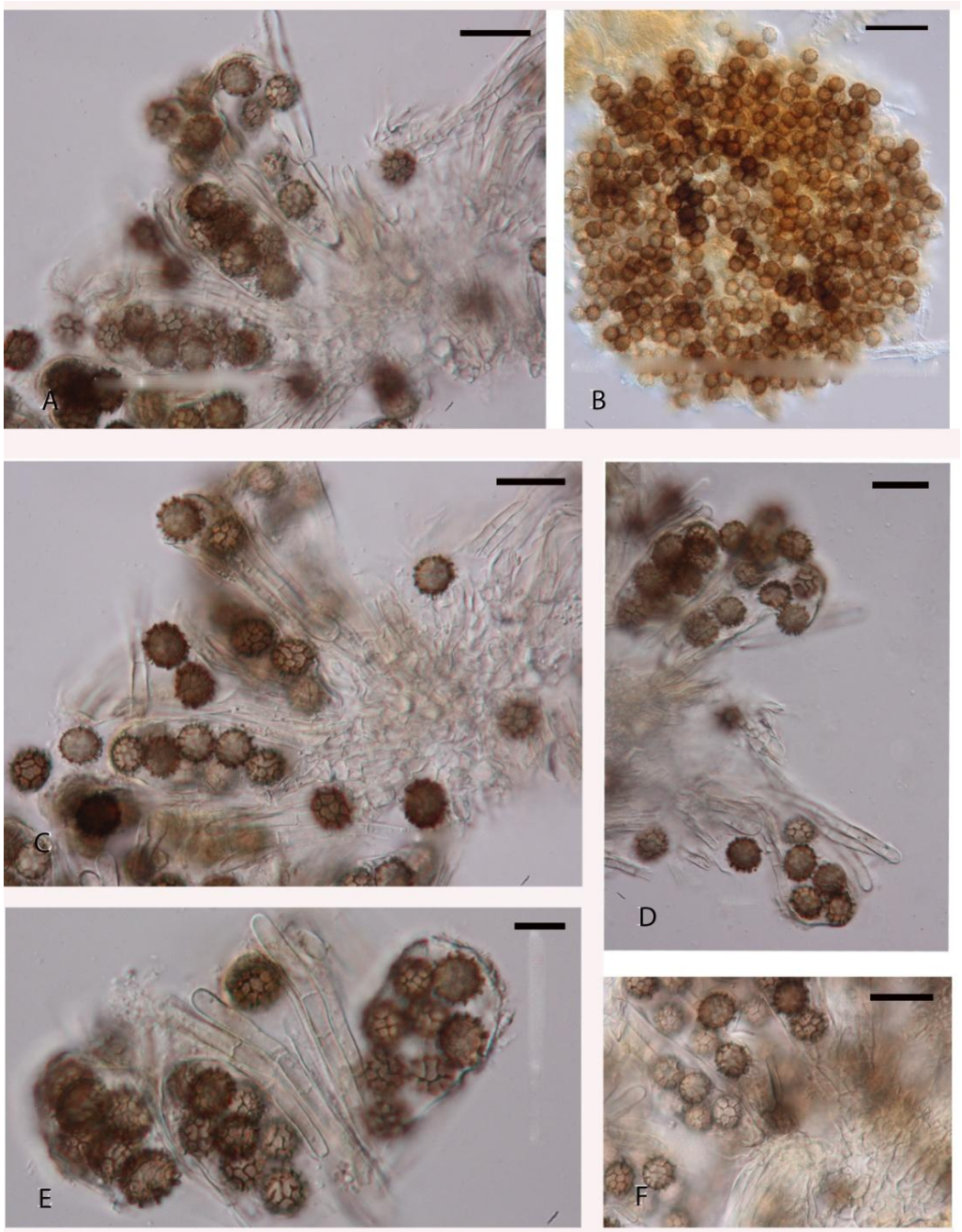

Fig. 2 – *Ascodesmis sphaerospora* (from MFLU10 0189). **A** Asci and ascospores showing attachment to basal cells. **B** Ascoma water mount. **C**–**D** Asci, paraphyses and ascospores. **E** Asci. **F** Ascospores. **Scale bars: A, C, D, F =** 20 µm, **B** = 50 µm, **E** = 10 µm.

Fah Thai Market, GPS N20°02.9776 E099° 2.1176, alt. 417m, cattle dung, 6 March 2010, P. Mungai, MFLU100189; Bandoo Market, GPS N19°57.3415 E099°51.4509, alt. 415m, water buffalo dung, 8 March 2010, P. Mungai, MFLU100209.

Notes: *Cercophora silvatica* N. Lundq. and *Cercophora* sp. have previously been recorded in Thailand from elephant and barking deer dung (Jeamjitt et al. 2007, Piasai et al. 2009a). *Cercophora* species have very similar morphological characteristics making it very difficult for correct species delimitation. According to Lundqvist (1972) the asci and ascospore shape and colour are not unique to any of the species. The ascomatal wall structure is, however, a very important diagnostic character for these species and has been used extensively by many investigators in taxonomy (Lundqvist 1972).

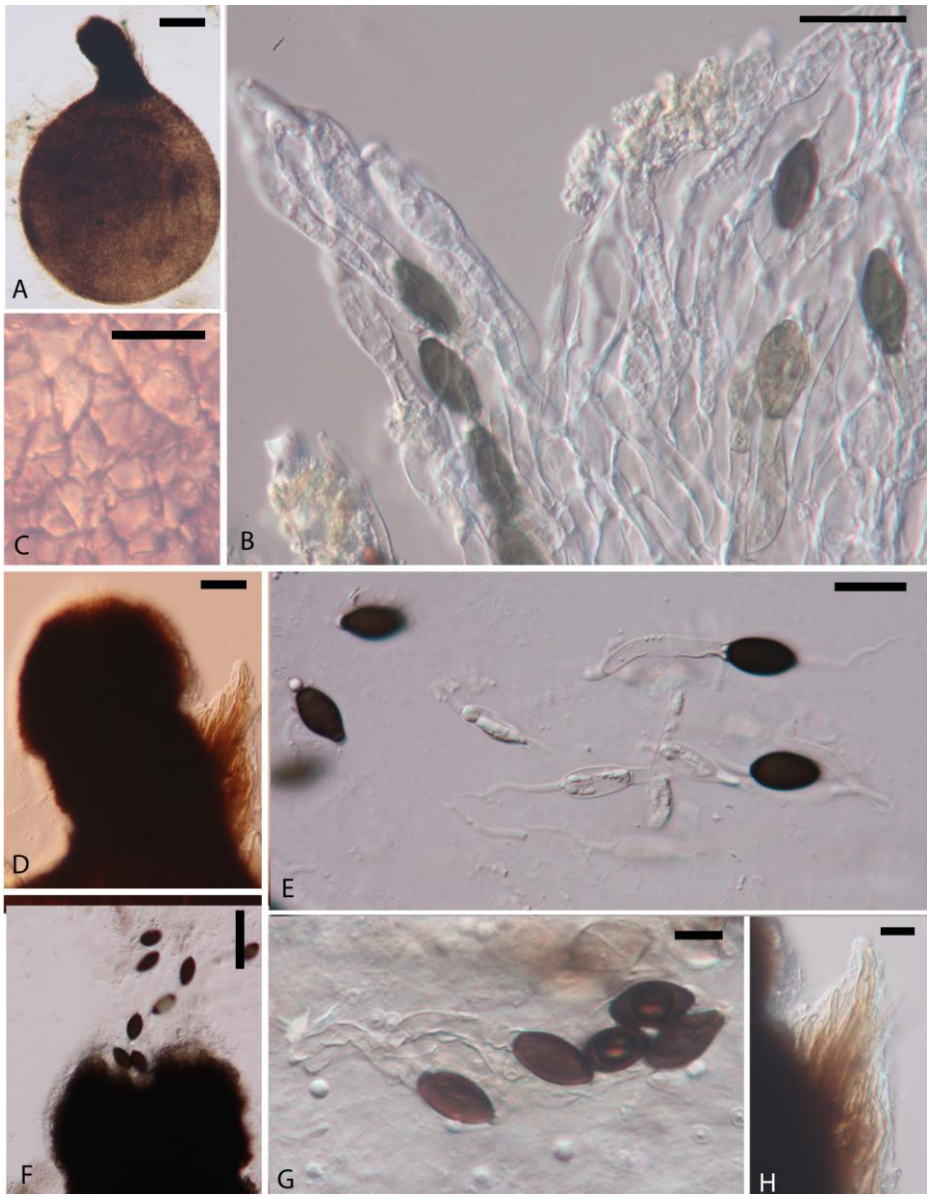

Fig. 3 – *Cercophora kalimpongensis* (from MFLU10 0210). **A** Ascoma water mount. **B** Asci with pigmented ascospores. **C** Detail of exoperidium. **D** Neck showing one-sided fasciculate hairs. **E** Mature dark and immature hyaline ascospores. **F** Free ascospores outside the ostiole. **G** Mature ascospores with large guttulae on each dark cell. **H** Neck hairs at high magnification.
Scale bars: **A** = 200 µm, **B, C, E = 20** µm, **D** = 50 µm, **F** = 100 µm, **G, H** = 10 µm.

Recent molecular phylogenetic studies have helped clarify the correct taxonomic placement of some species of this genus (Chang et al. 2010).

Chaetomium bostrychodes Zopf. Abhand. Botan. Ver.Prov. Brandenburg 19: 173 (1877). **(Figs. 4A–B & 5A–F)**

Ascomata gregarious**,** 600–800 µm high, 200–350 µm diam., superficial, ostiolate, steel grayish to pale metallic in reflected light, turning dark grey to black at maturity, usually ovoidal or ellipsoidal, sometimes turbinate, ampulliform or cylindrical. *Peridium* ochraceous or brown, composed of *textura angularis*, rather thick walled cells surrounded by pale green exudates, ostiolar pore 35–40 µm diam., often with a darkened collar. *Terminal hairs* arising from the apical collar, entangled, unevenly spiralled circinate ends, brown, thick walled, septate, warty, 4–6 µm thick, tips not enlarged. *Lateral hairs* seta-like, straight but tapering, septate, warty, brown, ends straight. *Asci* 25–38 × 8.5–11 µm, 8-spored, unitunicate, clavate, fasciculate, numerous, with a relatively long evanescent stalk, 13 × 3 µm; mixed with

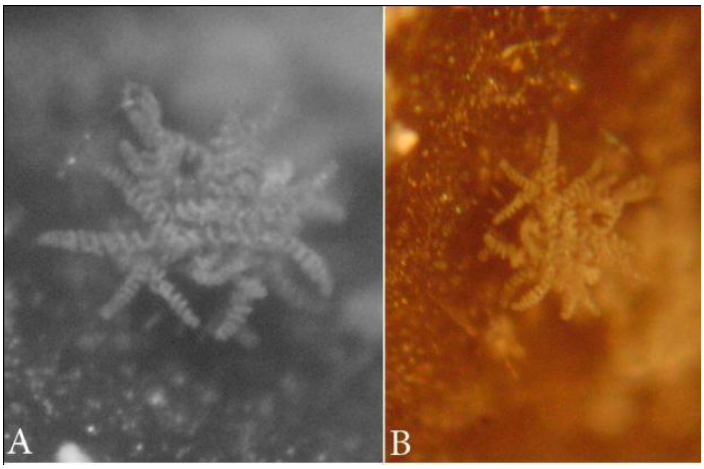

Fig. 4 – *Chaetomium bostrychodes* (from MFLU10 0195). **A**–**B** Spirally coiled terminal hairs from top of ascoma.

paraphyses-like structures, clavate, numerous, broad, finely warted, evanescent, non-septate, non-vacuoled. *Ascospores* 5.5–6.5 × 5–6 µm, irregularly placed inside the asci, single celled, limoniform to subglobose in frontal view, usually biapiculate, hyaline and dextrinoid at first, greyish at maturity, with a central germ pore at one end, containing air bubbles.

Material examined

THAILAND, Chiang Rai Province, Muang District, Bandoo Market, GPS N19° 57.3415 099°51.4509, alt. 415m, goat dung, 8 March 2010, P. Mungai, MFLU10 0195.

Notes: This species has not been previously recorded in Thailand. *C. bostrychodes* is easily confused with *C. convolutum* Chivers. The latter is differentiated by having larger ascospores (von Arx et al. 1986, Bell 2005, Doveri 2008b). This collection is morphologically similar to the collections described by von Arx et al. (1986) and Bell (2005) but has slightly smaller ascospores than the Italian collection (Doveri 2008b).

Coprotus niveus **(**Fuckel) Kimbr., Luck-Allen & Cain, Can. J. Bot. 50: 967 (1972).

(Fig. 6A–F)

Ascomata scattered or gregarious, apothemcioid, barrel to cup-shaped at maturity, superficial, 200–600 µm diam., sessile, glabrous, attached to substrate by rooting hyphae, soft and fragile, hymenial surface flat to slightly depressed, dotted due to the protruding asci, at first whitish or translucid, yellowish at maturity. Margin fairly distinct due to the fringe of smooth appendages exceeding the hymenium; outer surface smooth, whitish. Subhymenium indistinct from the medullary excipulum. *Medullary excipulum* of *textura globulosa-angularis* with hyaline thin-walled globular or polygonal cells, 10–15 × 5–7 µm, forming a fringe of smooth appendages exceeding the hymenium resembling the excipular cells, but elongated and subcylindrical towards the margin and perpendicular to it. *Paraphyses* filiform, often longer than asci by at least 20 µm, 2–3 µm broad, septate, sparingly branched, curved and enlarged at the apex, wall hyaline, contents hyaline or yellowish. *Asci* 130–200 × 45–60 µm, 64-spored, unitunicate, non-amyloid, with round and central operculum, cylindric-clavate, persistent, short stipitate, slightly protruding above hymenium at maturity. *Ascospores* 8.5–10.3 × 5.7–6.5 µm, more or less ellipsoidal, single-celled, irregularly placed in apical portion of mature ascus, or occupying the whole volume of immature ascus, smooth, hyaline, thin-walled, without perisporium.

Material examined

THAILAND, Chiang Rai Province, Muang District, Thasud Sub-District, Fah Thai Market, GPS N20°02.8582 E099°52.0498, alt. 418m, cattle dung, 6 March 2010, P. Mungai, MFLU10 0191.

Notes: Piasai et al. (2009b) reported two unidentified *Coprotus* spp. in Thailand. *Coprotus* species look very similar, particularly the group with whitish ascomata and 8-spored asci

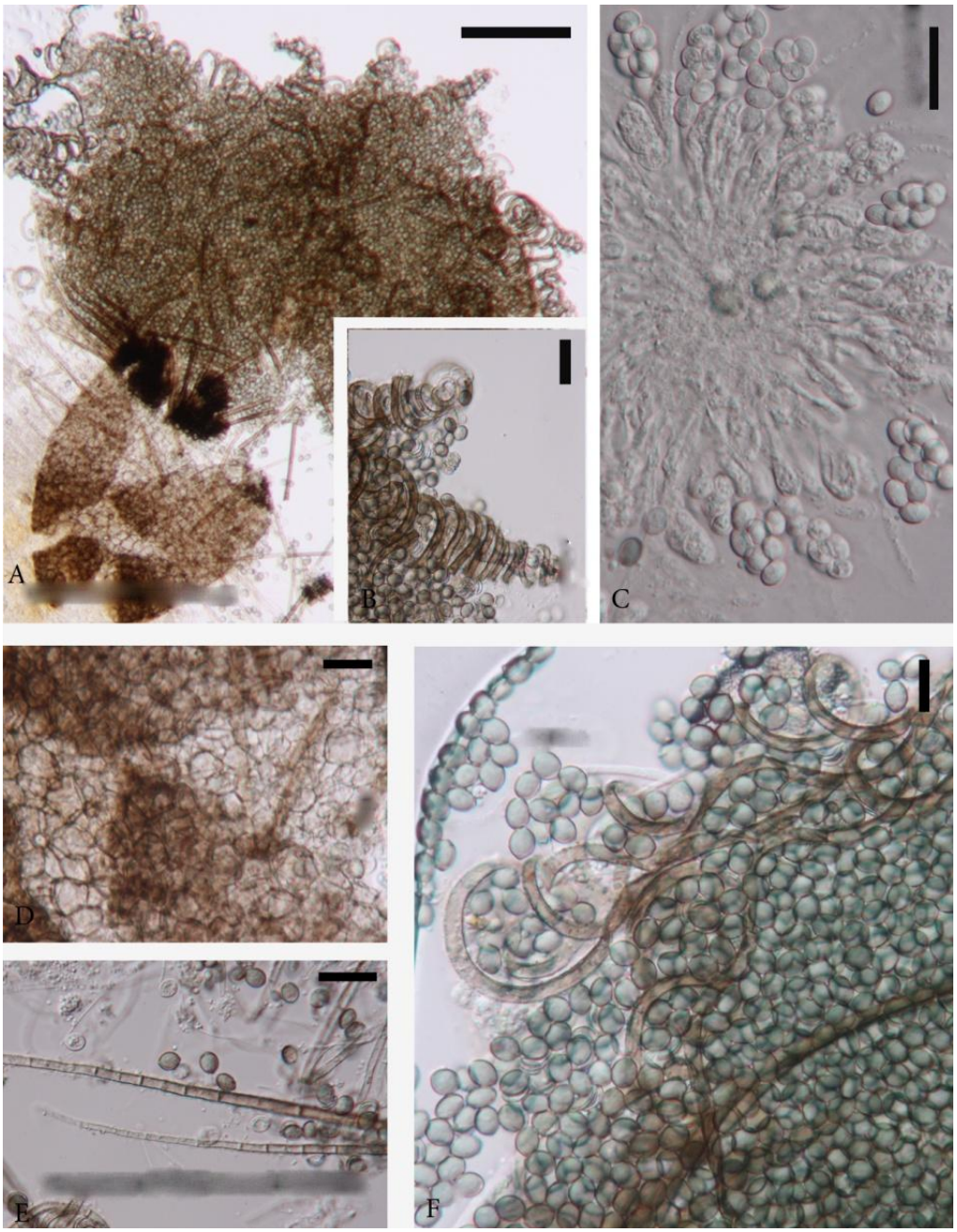

Fig. 5 – *Chaetomium bostrychodes* (from MFLU10 0195). **A** Squashed ascoma showing spirally coiled terminal hairs and black collar around an ostiole. **B** Tips of terminal hairs. **C** Centrum with asci and ascospores. **D** Peridial cells. **E** Lateral hairs. **F** Mass of free ascospores amongst terminal hairs. **Scale bars**: **A** = 100 µm, **B, C, E =** 20 µm, **D, F** = 10 µm.

(Kimbrough et al. 1972). The genus does not have truly distinctive morphological or cultural features and is confused with other similar genera (Kimbrough 1970a, 1972, Korf 1972, Bell 2005, Dokmetzian et al. 2005, Suarez et al. 2006). This has brought about many, apparently, invalid taxonomic arguments and a lot of ambiguity in species delimitation (Kimbrough 1967, 1970a, 1972, Doveri 2004, Bell 2005). There is, therefore, a need to conduct phylogenetic studies to conclusively revise and clear confusion in the taxonomy of this genus. *C. niveus* is similar to *C. winteri* but the latter has 256 ascospores.

Iodophanus* aff. *helotinus Cain, Am. J. Bot., Suppl. 56(10): 1199 (1969). **(Fig. 7A–F)**

Apothecia gregarious, superficial, sessile, 0.5–1.8 mm diam., appears arachnoid due to presence of hyaline hyphae cover, white to pale

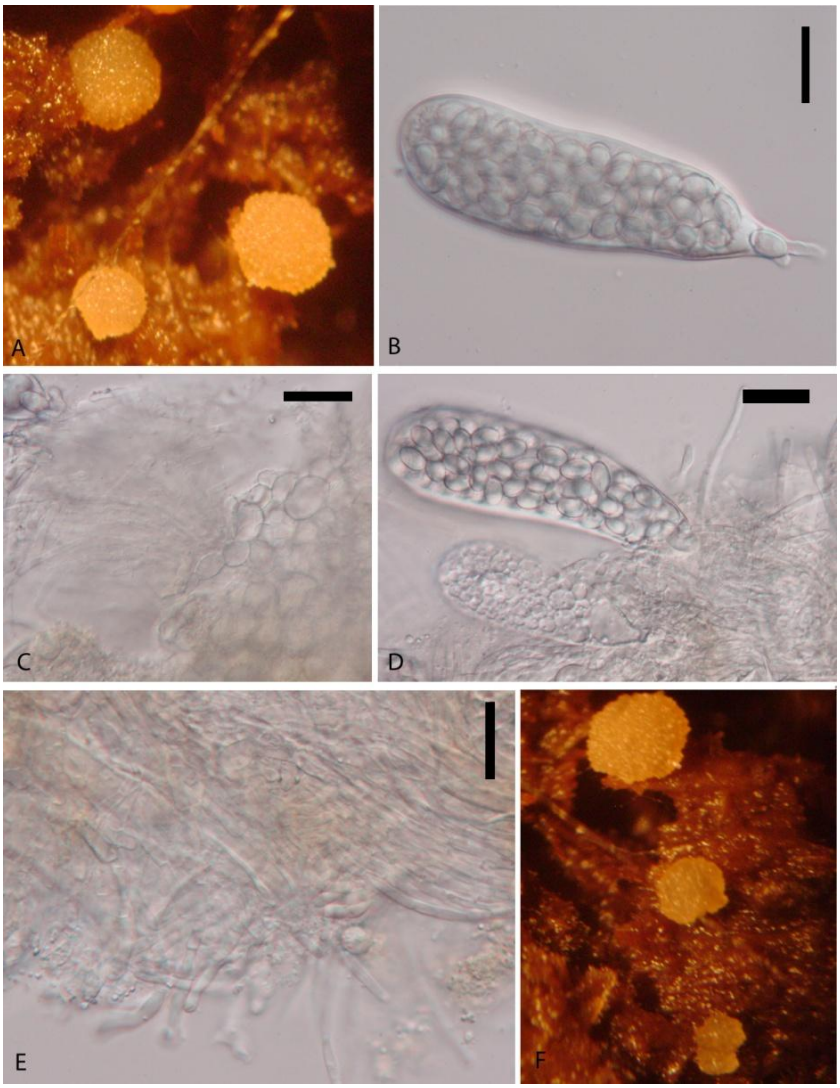

Fig. 6 – *Coprotus niveus* (from MFLU10 0191). **A**, **F** Ascomata on dung. **B** Ascus with ascospores. **C** Cells of ectal excipulum. **D** Mature and immature ascus with ascospores. **E** Paraphyses. **Scale bars: B** = 20 µm, **C** = 20 µm, **D** = 20 µm, **E** = 20 µm.

salmon or light buff, becoming yellow on drying; protruding asci render the hymenial surface papillose, globose in the initial stages, becoming lenticular and discoidal; *ectal excipulum* of *textura angularis* to *globulosa*, hyaline to light brown cells, 8–10 µm diam., with elongate marginal cells, adorning isolated flexuous hyaline, septate hairs, rounded at apices, with a light brown pigmented outer basal zone; *medullary excipulum* usually thin-walled *textura intricata*, interwoven tightly in the hypothecium. *Paraphyses* stout, numerous, simple, exceeding the asci, apex containing numerous oil guttules, 6–8.5 µm broad, hyaline, septate, orange pigmented guttules concentrated at the basal part. *Asci* 170–223 × 26–30 µm, 8-spored, unitunicate, diffusely amyloid, subclaviform, rounded or slightly truncate above, attenuated below in a short stipe, operculum 16–25 µm wide, apex with a ring. *Ascospores* 21–26 × 13–15 µm, ellipsoidal, broadly rounded ends, single-celled, hyaline, thick walled at first, thinner walled at maturity, uniseriate to irregularly biseriate, clustering towards the apical portion of the ascus, ornamented with numerous tack-head like warts, ca.1 µm high, each spore surrounded by a thin mucilaginous sheath.

Material examined

THAILAND, Chiang Rai Province, Muang District, Bandoo Market, GPS N19° 57.3415 E099°51.4509, alt. 415m, on goat dung, 8 March 2010, Mungai, MFLU10 0149.

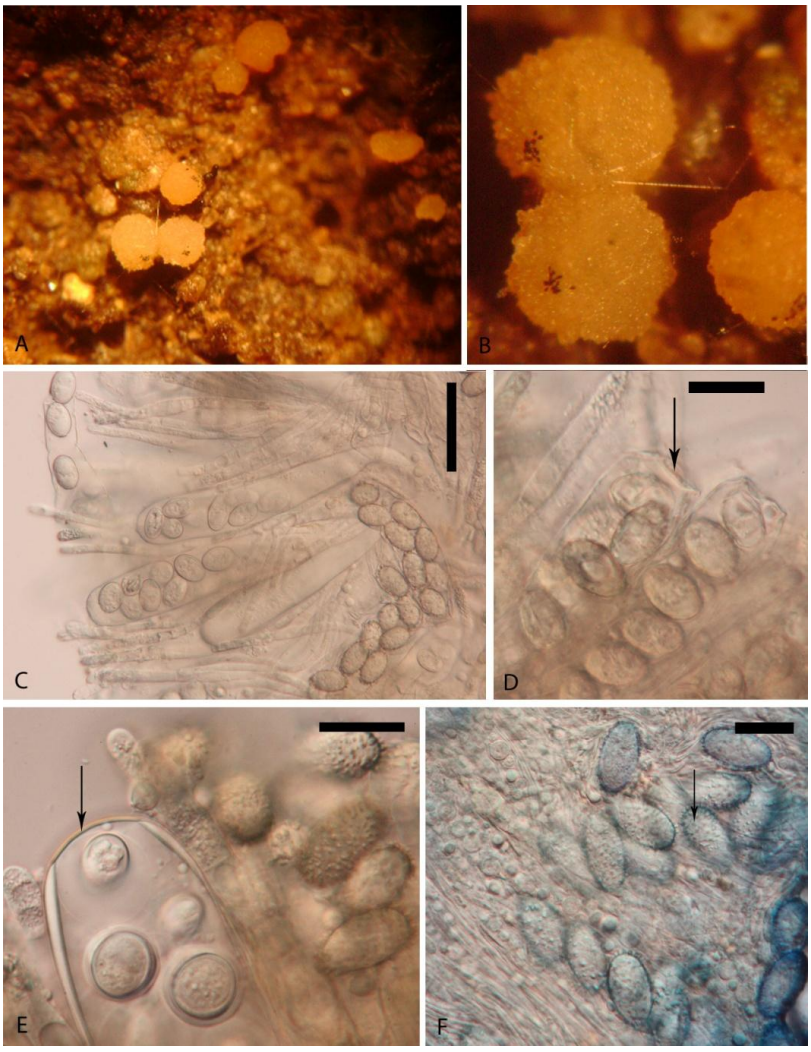

Fig. 7 – *Iodophanus* aff. *helotinus* (from MFLU10 0194). **A**–**B** Ascomata on dung. **C** Asci, ascospores and paraphyses. **D** Operculate asci. Note an open operculum. **E** Ascus apex showing a closed operculum and free ascospores. **F** Ascospores in lactic-cotton blue, note the cyanophilic ornamentations. **Scale bars: C =** 100 µm, **D-F** = 20 µm.

Notes: The genus *Iodophanus* has not been previously recorded in Thailand. The identity of our collection is not definite because it has warts that are tack-head like and more than 1µm in length, a feature that according to the monograph of Kimbrough et al. (1969) and Doveri's key (2004) is typical of both *I. helotinus* and *I. crystallinus*. According to Kimbrough (1969, 1970a) the former mostly prefers dung of various herbivores as its substrate, while the latter usually sporulates on straw and has orange-yellowish apothecia. According to Kimbrough et al. (1967) and Cinto et al. (2007) the morphology of spores and asci usually overlap in different species of *Iodophanus*. In addition, highly variable spore and ascus sizes have been reported by different authors studying the same species. It has also been observed that biotic and abiotic conditions impart significant influence on ascus and spore sizes thus rendering these elements highly unreliable and inadequate on their own to delimit species of *Iodophanus* (Cinto et al. 2007). Employing the morphological and cytochemical properties of the asci and ascospores, and to a lesser extent the developmental pattern of the ascocarp as a means of species delimitation has not been very successful (Kimbrough et al. 1967, Cinto et al. 2007). To be able to properly identify species of *Iodophanus* and to complement the study by Cinto et al. (2007) it is important that this genus be subjected to phylogenetic studies to help make accurate and conclusive species delimitation.

Kernia* cf. *retardata Udagawa & T. Muroi, Trans. Mycol. Soc. Japan 22:18 (1981).

(Fig. 8A–G)

Cleistothecia superficial, abundant, gregarious, globose, 200–400 µm, outer wall at first dark brown, finally black at maturity, rather thick, opaque, with scattered, hyaline, setate, almost straight hairs, 22–57 × 2–2.5 µm, with pointed apices. *Exoperidium* dark brown, *textura angularis* polygonal cells 3.5–5 × 3–4.5 µm. *Paraphyses* not distinct. *Asci* 13–17 × 8.5–9 µm, 8-spored, ovoid to broadly clavate, unitunicate, stipe indistinct, evanescent, short. *Ascospores* 4–5.5 × 4–4.5 µm, ovoid, limoniform or broadly ellipsoidal, at first hyaline, then light brown or grayish, irregularly arranged, smooth, single-celled, at first with a small and a large de Bary bubble, finally one prominent de Bary bubble at maturity, dextrinoid when young, without a perisporium, each with a single germ pore at the acute end.

Material examined

THAILAND, Chiang Rai Province, Muang District, Thasud Sub-District, Fah Thai and Bandoo Markets, banana gardens and roadside paddocks, GPS N20°02.8582 E099° 52.0498, alt. 418m, cattle dung, 6 March 2010, P. Mungai, MFLU10 0203; GPS N20° 02.6116 E099°52.6314, alt. 419m, chicken dung, 6 March 2010, P. Mungai, MFLU100206; GPS N19°57.3415 E099°51.4509, alt. 415m, water buffalo dung, 8 March 2010, P. Mungai, MFLU100209.

Notes: There are no previous records of *Kernia* spp in Thailand. The ascospores of this Thai collection are narrower and longer than those of *K. retardata* and *K. cauquensis* Calviello in Doveri's key (2004) cf. 4.5–7 × 3.5–5 µm. According to the cited key, the morphological differences between *K. retardata* and *K. cauquensis* are largely insignificant. Overall, this genus has species with a lot of overlapping characters hence, only molecular techniques can satisfactorily help resolve the challenges in species delimitation.

Podospora hyalopilosa (R. Stratton) Cain, Can. J. Bot. 40: 460 (1962).

(Figs. 9A–J & 10A–D)

Ascomata perithecioid, pyriform, superficial or semi-immersed, 450–875 µm high, 375–450 µm diam., scattered, thin, membraneceous, semi-transparent, light olivaceous-brown, exposed part of perithecium usually smooth or with short, straight or somewhat flexuous, hyaline, septate hairs measuring 12–80 × 1.5–2 µm, more abundant on the neck. *Neck* cylindric to cylindric-conical. *Ostiole* ca. 66.5 µm diam. *Endoperidium* of *textura angularis* cells 20–24 × 15–20 µm; *exoperidium* of *textura angularis* thin-walled, brownish cells, 3–8 × 3–5 µm. *Paraphyses* ventricose, septate, hyaline, tapering upwards exceeding the asci, 15–20 µm broad at their base. *Asci* 220–250 × 26–34 µm, 8-spored, unitunicate, clavate, swelling rapidly in water, broadly rounded above, tapering below into a stipe 80–90 µm long, apical ring indistinct. *Ascospores*, biseriate at first, becoming clustered below apex before dehiscence, single-celled, hyaline, clavate at first, becoming two-celled as subdivided by a transverse septum into a pigmented apical dark cell (head) and a hyaline basal cell (pedicel); *spore head* 20–30 × 10–15 µm, ellipsoidal, somewhat flattened at their base, olivaceous to dark brown and opaque, thin-walled, greatly variable in size even in the same ascus, germ pore apical, ca. 1.5 µm diam. *Primary appendage* obclavate, characteristically constricted at base, 18–31 × 6–9 µm, smooth, one long lash-like basal cauda arising from the distal end, 22–30 × 2–3 µm; 4 apical caudae arising from sides of the apex 9–18 × 3.5–4 µm, covering the germ pore.

Material examined

THAILAND, Chiang Rai Province, Muang District, Thasud Sub-District, Fah Thai Market, N20°02.9407 E099°52.2135, alt. 418m, cattle dung, 6 March 2010, P. Mungai, MFLU10 0196.

Notes: *Podospora communis* (Speg.) Niessl, *P. curvicolla* (G. Winter) Niessl, *P. setosa* (G. Winter) Niessl and *Podospora* sp. were recorded previously in Thailand (Somrithipol et al. 2002, Jeamjitt et al. 2007, 2008, Piasai et al. 2009b). *Podospora hyalopilosa* sporulates very

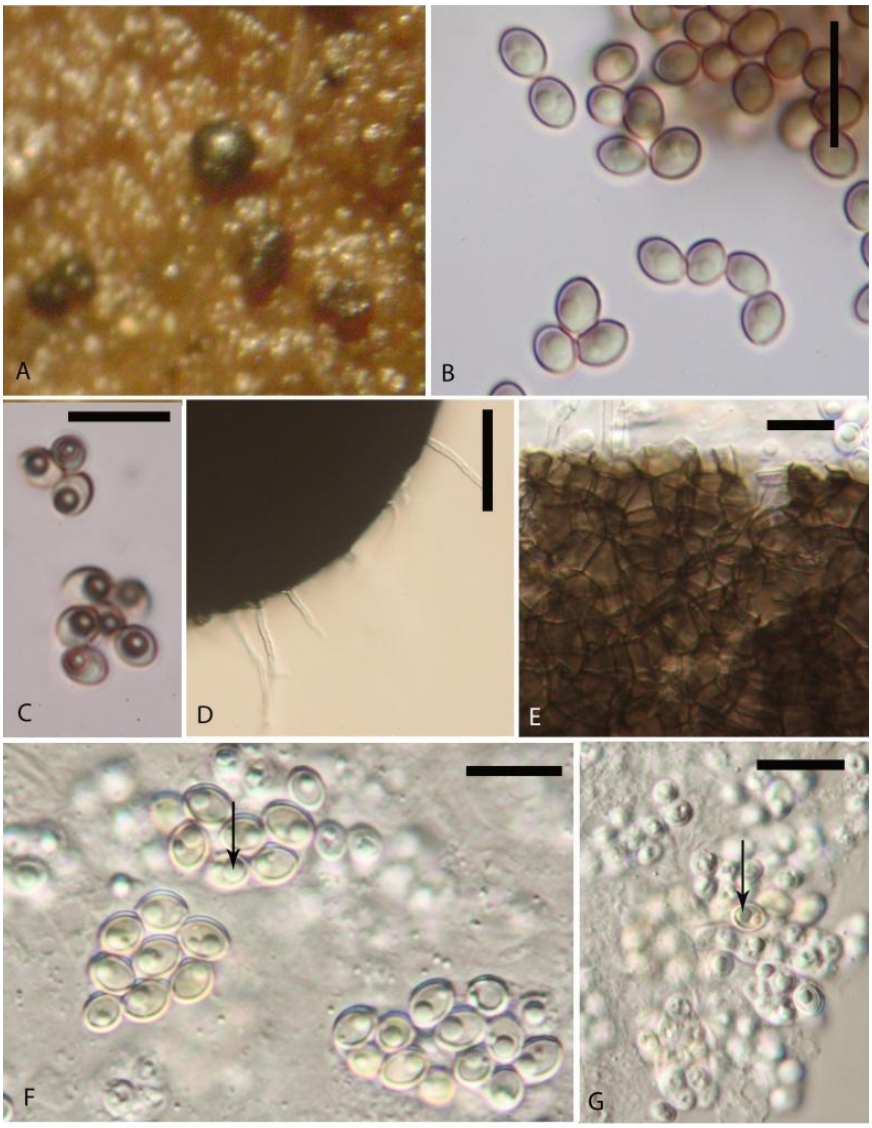

Fig. 8 – *Kernia* cf. *retardata* (MFLU10 0203). **A** Ascoma on dung. **B** Ascospores. **C** Ascospores treated with Meltzer reagent, note single de Bary bubble (arrowed). **D** Ascomal hairs. **E** Details of exoperidium. **F-G** Immature asci and ascospores, note the double de Bary bubbles (arrowed). **Scale bars: B-G** = 10 µm.

late in incubation and is most likely to be missed. This collection constitutes a new record in Thailand. Our Thai *P. hyalopilosa* has characters that agree closely with the descriptions made for the same species by Cain (1934) and Mirza et al. (1969). The shape and arrangement of the gelatinous appendages of the Australian species is slightly different from our collection (Bell 2005). *P. hyalopilosa* is similar to *P. communis* (Speg.) Niessl, however, the ascospores of the latter have a single long secondary appendage at the tip of the pedicel while the former has 3 or 4 short, stout, curved appendages (Cain 1934, Mirza 1969, Lundqvist 1972). On the other hand the ascoma of *P. hyalopilosa* is usually hairy, has smaller ascospores of varying sizes and a narrower primary appendage (Cain 1934, Mirza 1969).

Saccobolus citrinus Boud. & Torrend, Bull. Soc. mycol. Fr. 27: 131 (1911).

(Fig. 11A–F)

Apothecia scattered or gregarious, superficial, sessile, 200–360 µm high, 200–450 µm diam. Receptacle smooth, ochraceous to lemon yellow, hymenial surface yellow, margin not differentiated pulvinate or almost lenticular at maturity. Disc convex same colour but darker than receptacle, dotted with brownish to almost black protruding tips of ripe asci. *Ectal and*

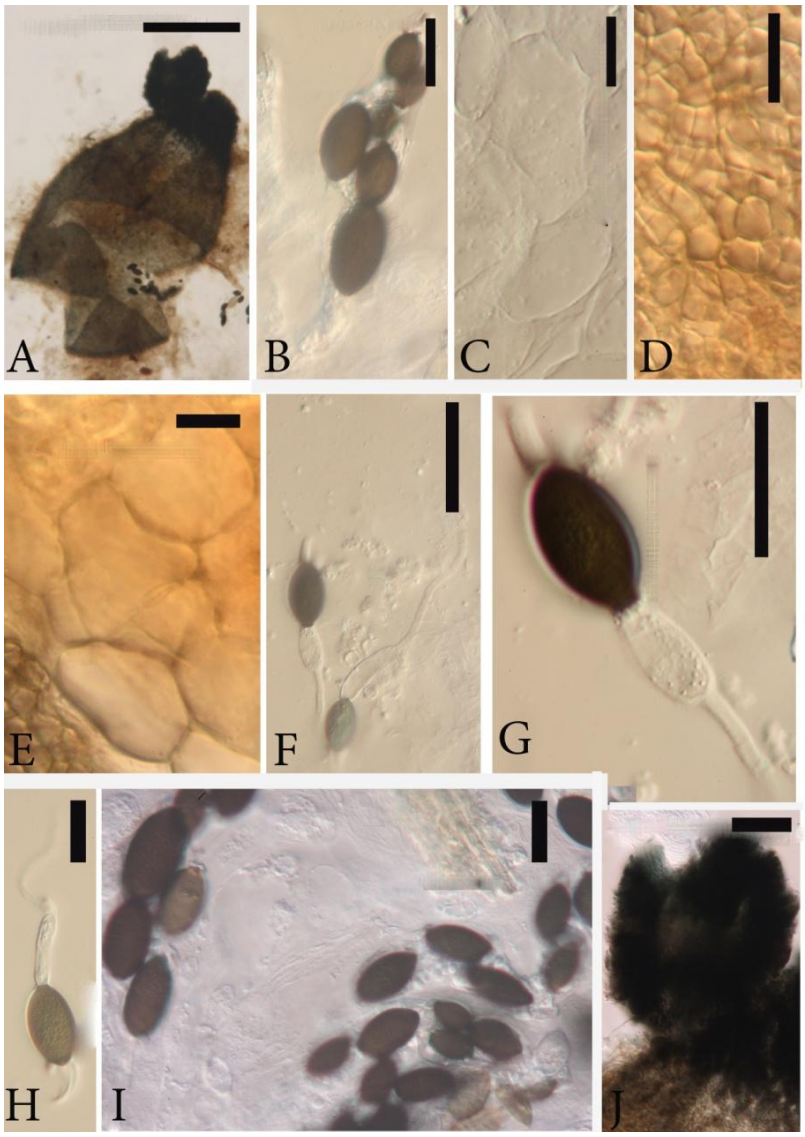

Fig. 9 – *Podospora hyalopilosa* (from MFLU10 0196). **A** Squashed perithecium. **B** Ascus with mature ascospores very different in size. **C** Bases of paraphyses intergrading with cells of endoperidium. **D** Cells of ectal excipulum. **E** Cells of the ectal excipulum on the left and bases of paraphyses on the right. **F-I** Mature ascospores. **J** Perithecial neck. **Scale bars**: **A** = 500 µm, **B, J** = 50 µm, **C, D, E, G** = 10 µm, **F =** 40 µm, **H, I** = 20 µm.

medullary excipulum thin, of *textura globulosa* hyaline to roundish, light yellowish small cells. *Paraphyses* cylindric-filiform, septate, exceeding the asci, 1.5–4 µm broad, simple or furcate at the base, slightly curved or straight, apices yellow and slightly swollen. *Asci* 125–150 × 25–28 µm, 8-spored, unitunicate, thick walled, broadly clavate, with truncate apices, gradually tapering into short stalks, operculum ca. 8 µm wide, opening partly to one side like a lid, amyloid. *Ascospores* arranged in clusters according to van Brummelen pattern I, broad ellipsoidal to ellipsoidal-fusiform, violet to purple-brown, usually slightly asymmetrical or ventricose, truncate at the ends, enveloped by a bilateral, broad granulated gelatinous sheath; *individual spore* 18–22.5 × 7–9 µm, ornamented with fine scattered warts; *spore clusters* 33–55 × 17–19 µm, not shortening with maturity, always ejected as an aggregate, not easily separable.

Material examined

THAILAND, Chiang Rai Province, Muang District, Thasud Sub-District, Fah Thai Market, GPS N20°02.9407 E099°52.2135, alt. 418m, cattle dung, 6 March 2010, P. Mungai, MFLU10 0187; GPS N20°02.8582 E099°

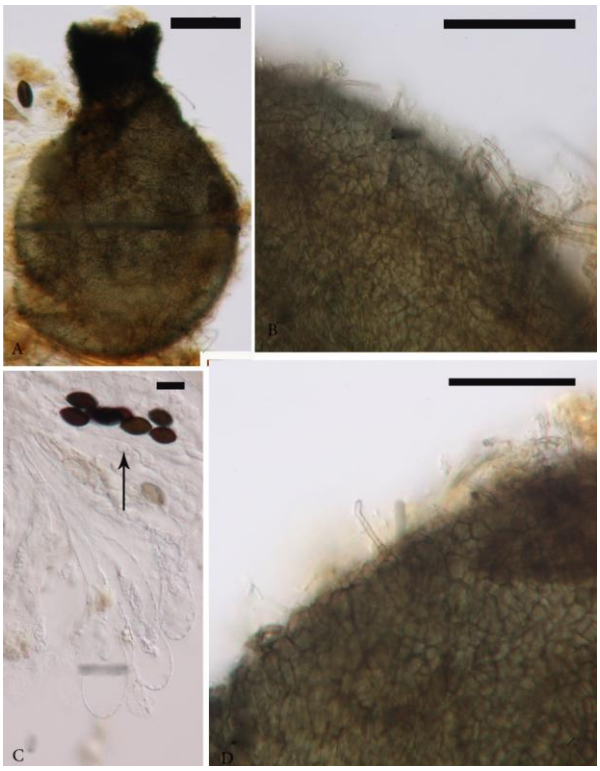

Fig. 10 – *Podospora hyalopilosa* (from MFLU10 0196). **A** Whole perithecium with a cylindric neck. **B**, **D** Details of exoperidium with hairs. **C** Immature ascospores (arrowed). **Scale bars**: **A** = 100 µm, **B, D** = 5µm, **C** = 40 µm.

2.0498, alt. 417m, cattle dung, 6 March 2010, P. Mungai, MFLU10 0190; GPS N20°02.9407 E099°52.2135, alt. 418m, cattle dung, 6 March 2010, P. Mungai, MFLU100188; GPS N20°02.8582 E099°2.0498, alt. 417m, cattle dung, 6 March 2010, P. Mungai, MFLU10 0188; GPS N20°02.8582 E099°52.0498, alt. 417m, cattle dung, 6 March 2010, P. Mungai, MFLU10 0191; GPS N20°02.9776 E099° 2.1176, alt. 417m, cattle dung, 6 March 2010, P. Mungai, MFLU10 0189 and Bandoo Market, GPS N19°57.3415 E099°51.4509, alt. 415m, water buffalo dung, 6 March 2010, P. Mungai, MFLU10 0209.

Notes: *Saccobolus citrinus* Boud. & Torrend, *S. glaber* (Pers.) Lambotte, *S. minimus* Velen., *S. truncatus* Velen., *S. succineus* Brumm., *S. thaxteri* Brumm. and a *Saccobolus* sp. were previously recorded in Thailand (Brummelen van 1967, 1969, Somrithipol et al. 2002, Jeamjitt et al. 2007, 2008, Piasai et al. 2009b). This species is characterized by a lemon-yellow apothecium, ascospores with truncate ends and episporium with isolated round warts (van Brummelen 1969, Doveri et al. 2000). Our Thai *S. citrinus* is similar to the descriptions given for the Italian and Australian collections (Doveri et al. 2000, Bell 2005). This species closely resembles *S. succineus* Brumm. but the latter has pale yellow or amber apothecia with dotted broader ascospores (van Brummelen 1969, Doveri 2004). *S. citrinus* is also close to *S. diffusus* S.C. Kaushal & Virdi, which, however, can be distinguished by having larger smooth ascospores and larger apothecia (Kaushal et al. 1986, Doveri 2004). *S. citrinus* seems to be a very common species in northern Thailand.

Sporormiella minima (Auersw.) S.I. Ahmed & Cain, Can. J. Bot. 50: 449 (1972).

(Fig. 12A–G)

Pseudothecia, semi-immersed to nearly superficial at maturity, 150–190 µm high, 75–100 µm diam., scattered or in sparingly crowded groups, dark-brown, glabrous, subglobose to nearly pyriform. *Neck* 55–60 × 35–45 µm, papilliform to somewhat elongated, smooth, bare, dark-brown. *Exoperidium* thin,

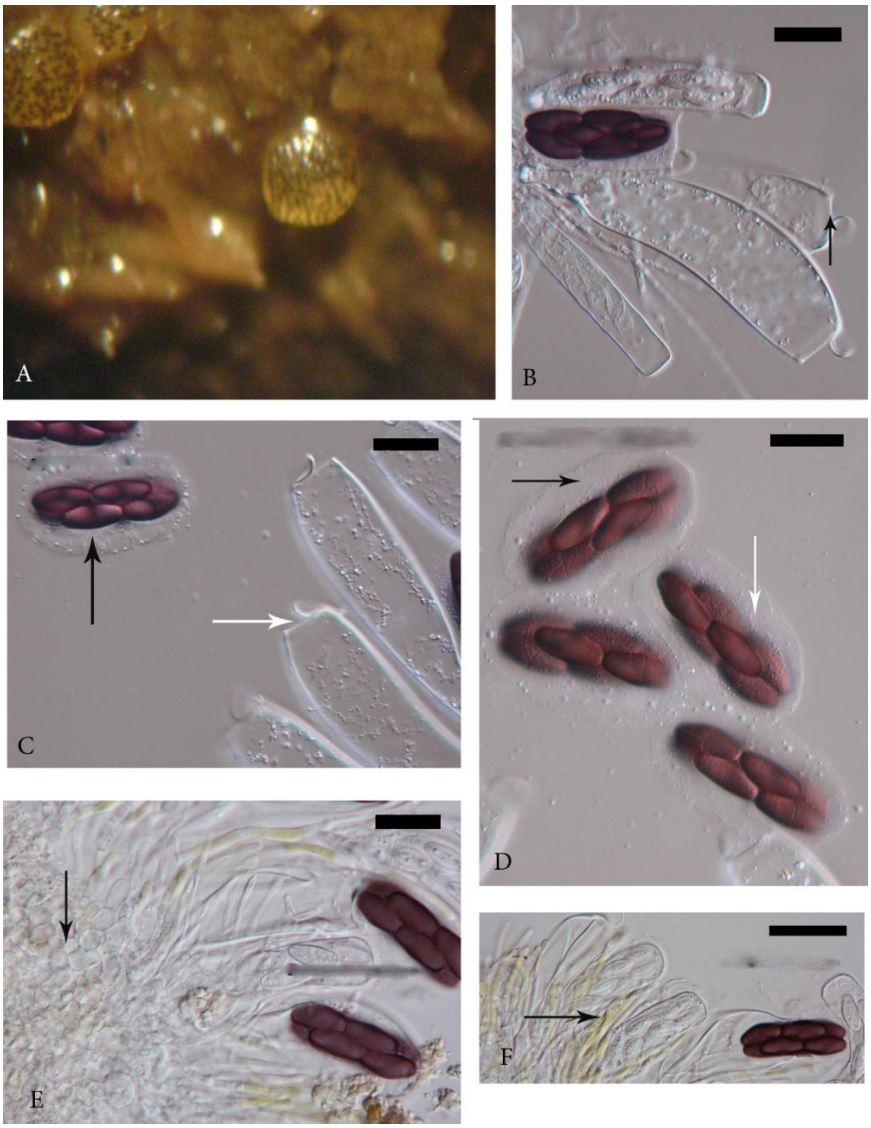

Fig. 11 – *Saccobolus citrinus* (from MFLU10 0192). **A** Apothecia on dung. **B**–**C** Asci with open opercula and spore clusters (arrowed). **D** Free spore clusters, note the sheath and warted epispore (arrowed). **E**–**F** Paraphyses, note the yellow pigmentation and roundish cells of subhymenium and medullary excipulum (arrowed). **Scale bars**: **B, C** = 10 µm, **D**, **E** = 20 µm, **F** = 40 µm.

membraneceous, semi-transparent, brown, composed of *textura angularis* cells 9–13 × 7–11 µm. *Endoperidium* consisting of small *angular* cells. *Pseudoparaphyses* filiform, 2–2.5 µm diam., scanty, septate, equaling the asci and mixed with them, simple, slightly swollen at the tips. *Asci* 80–140 × 15–18 µm, 8-spored, fissitunicate, relatively short, broadly cylindrical, broadly rounded above, widest in the middle, reducing abruptly into a short stipe 4–5 × 4.5–6.5. *Ascospores* 26–34 × 4–6 µm, 4-celled, cylindrical, straight or curved, hyaline when young, becoming yellowish-brown, dark-brown when mature, uniseriate near the stipe, obliquely bi- or tri-seriate in the middle of ascus, gently and slightly tapering ends, transversely septate, septal constrictions broad, deep, cells more or less equal in size; terminal cells notably narrower towards their ends, germ slit almost parallel with a kink in the middle, gelatinous sheath hyaline, narrow, cells readily separable at central septum, easily separable at other septa.

Material examined

THAILAND, Chiang Rai Province, Muang District, Thasud Sub-District, Fah Thai Market, near Mae Fah Luang University, fallow rice fields and grazing, GPS N20° 02.9776 E099°2.1176, alt. 417m, cattle dung, 6 March 2010, P. Mungai, MFLU10 0189; GPS N20°02.9407 E099°52.2135, alt. 418m,

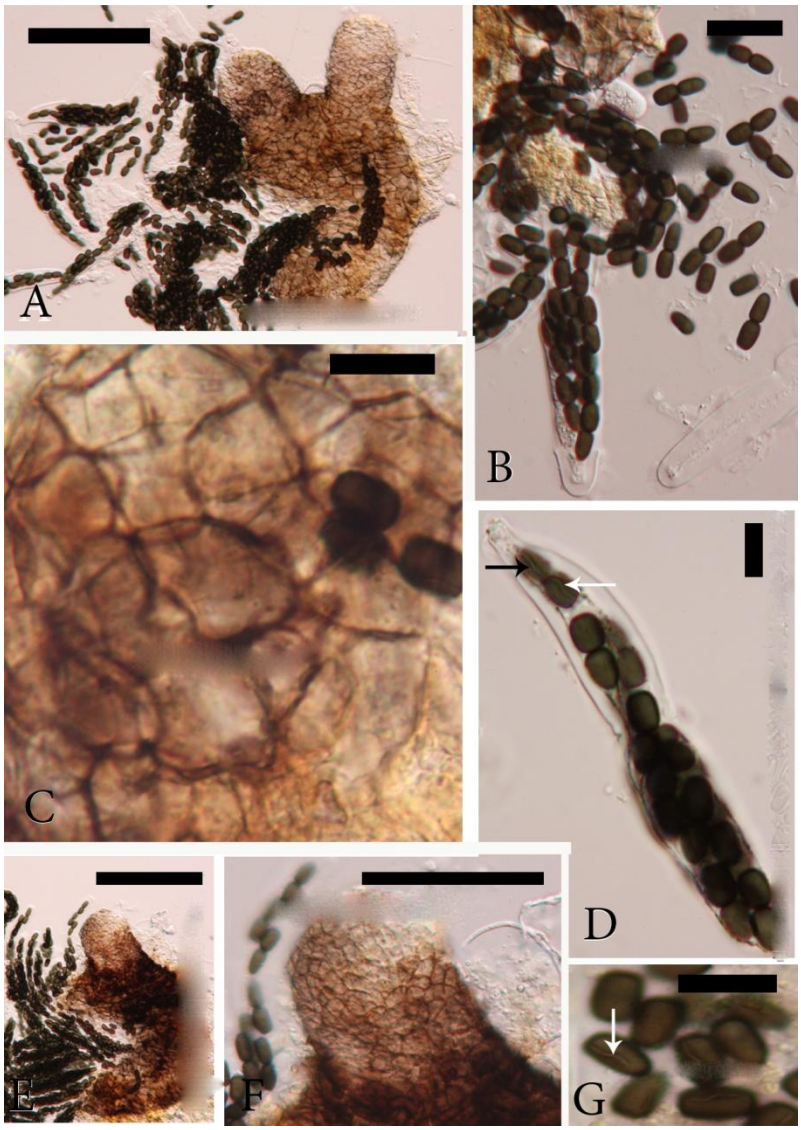

Fig. 12 – *Sporormiella minima* (from MFLU10 0201). **A** Squashed ascoma, note the twin neck (arrowed). **B** Asci and ascospores showing the triseriate arrangement towards ascus tip. **C** Cells of exoperidium. **D** Ascus with ascospores, note germ slit on spores nearest stipe (white and black arrow). **E** Ascoma and ascospores. **F** Ascoma neck. **G** Free mature ascospores, with kinked germ slit (arrowed). **Scale bars: A** = 100 µm, **B** = 20 µm, **C** = 10 µm, **D** = 10 µm, **E** = 100 µm, **F** = 100 µm, **G** = 10 µm.

cattle dung, 6 March, 2010, P. Mungai, MFLU10 0188; GPS, N20°02.8582 E099° 2.0498, alt. 417m, cattle dung, 6 March, 2010, P. Mungai, MFLU10 0193; GPS, N20°02.8582 E099°52.0498, alt. 417m, cattle dung, 6 March, 2010, P. Mungai, MFLU10 0190 and from Bandoo Market near Chiang Rai City, GPS N19°57.3415 E099°51.4509, alt. 415m, goat dung, 8 March, 2010, P. Mungai, MFLU10 0195.

Notes: Jeamjitt et al. (2007) and Piasai et al. (2009b) recorded the genus *Sporormiella* in Thailand. *Sporormiella minima* is one of the most common species on dung (Furuya et al. 1972, Doveri 2004). Some *Sporormiella* species are very similar in morphology, for instance, *S. minima* closely resembles *S. minimoides* S.I. Ahmed & Cain (Doveri 2004, Bell 2005). However, *S. minimoides* has somewhat longer and broader ascospores with oblique or diagonal germ slits. It does not have a central kink and is not as commonly seen on dung as *S. minima* (Ahmed et al. 1972, Doveri 2004). In addition, *S. minimoides* has a preference to grow on carnivore dung (Ahmed et al. 1972). This Thai collection has morphological features that agree with the descriptions of *S. minima*

from Japan, Italy and Australia (Furuya et al.1972, Doveri 2004, Bell 2005). Except for having longer asci our Thai collection also has features that agree closely with the description of material examined by Ahmed et al. (1972). In view of the prevailing uncertainties in the circumscription of species in Sporormiaceae, it is important to carry out molecular phylogenetic studies to complement Kruys & Wedin's (2009) work on this family to conclusively and concisely revise the taxonomy of its genera.

Zygopleurage zygospora (Speg.) Boedijn., Persoonia 2: 316 (1962). **(Fig. 13A–H)**

Ascomata perithecioid, immersed to semi-immersed, 600–750 µm high, 400–500 µm diam., scattered or in small groups, olivaceous brown, pyriform, with a venter usually covered with long, brown, septate, flexuous hairs. *Neck* 200–370 × 115–185 µm, cylindrical, covered with short hairs, darker, ostiole 105–115 µm diameter. *Peridium* 3-layered; *Exoperidium* thin, semi-translucent, of *textura angularis* cells, 6–8 µm. *Mesoperidium* of smaller vertically elongated *textura angularis* cells. *Endoperidium* consisting of subhyaline to light brown *textura angularis* cells. *Paraphyses* filiform, simple, hyaline, septate, evanescent and indistinct. *Asci* 210–24 × 33–40 µm, 8-spored, clavate, unitunicate, long-stipitate, rounded apex. *Ascospores* 32–38.5 × 14.5–19 µm, 3-celled, composed of two, dark brown end cells that are usually smooth, pigmented when mature, ellipsoidal, with an indistinct apical germ pore, joined by a long subhyaline intercalary cell, cylindrical, 110–170 long, 6–7 µm broad, narrowing to 3–4 µm at the point of insertion to end cell, slightly inflated centrally, staining blue in lacto-phenol cotton blue, usually parallel or coiled, each end cell with 4 distinct short claw-shaped hyaline apical gelatinous appendages, 11–15 × 3–4 µm long and 4 short gelatinous caudae arising at the septa of the intercalary cell, 10–13 × 3–4 µm.

Material examined

THAILAND, Chiang Rai Province, Muang District, Thasud Sub-District, Fah Thai Market, GPS N20°02.9407 E099°52.2135, alt. 418m, cattle dung, 6 March 2010, P. Mungai, MFLU10 0187; GPS N20°02.8582 E099° 2.0498, alt. 417m, cattle dung, 6 March, 2010, P. Mungai, MFLU10 0190.

Notes: *Z. zygospora* has not been recorded in Thailand in previous studies. The genus *Zygopleurage* is diagnosed from other genera in pyrenomycetes by the mode of development and morphology of the ascospores (Abdullah et al. 1978). The ascospores develop an intermediate hyaline structure that is usually observed as an intercalary cell, notably absent from other pyrenomycetes. Currently there are only three species recorded in this genus globally. The size and shape of the intercalary cells, spores, gelatinous sheath, and claw-shaped appendages vary in *Zygopleurage* and are very useful in species delimitation. For instance, *Z. zygospora* has ascospores with longer intercalary cells and 4 distinct, short claw-shaped hyaline gelatinous processes on the end cells (Abdullah et al. 1978). In addition, the colour of the ascoma also varies in the genus with *Z. zygospora* having an olivaceous brown perithecium. The ascospores of *Z. zygospora* are intermediate in size between those of *Z. multicaudata*, which are smaller and *Z. fayumensis*, which are bigger (Abdullah *et al*. 1978). *Z. zygospora* is truly a unique species and therefore not easy to confuse with any other known species (Lundqvist 1969, 1972, Abdullah et al. 1978).

Discussion

This study was conducted in March to May 2010 when northern Thailand was exceptionally dry. Fourteen dung samples were incubated and examined for ascomycetes between the 6th and 46th day of incubation. Forty-eight isolates that comprised 11 species were found; cattle dung had nine species, goat had six, water buffalo had three and chicken and Asiatic elephant dung had one each. *Saccobolus citrinus* was the most frequent species occurring mostly on cattle dung. This was followed by *Ascobolus immersus*, *Cercophora kalimpongensis* and *Kernia* cf. *retardata* (Table 1). The results show that *Sporormiella minima* is a very common coprophilous ascomycete in Thailand. *Ascodesmis sphaerospora*, *Chaetomium bostrychodes*, *Iodophanus* aff. *helotinus*,

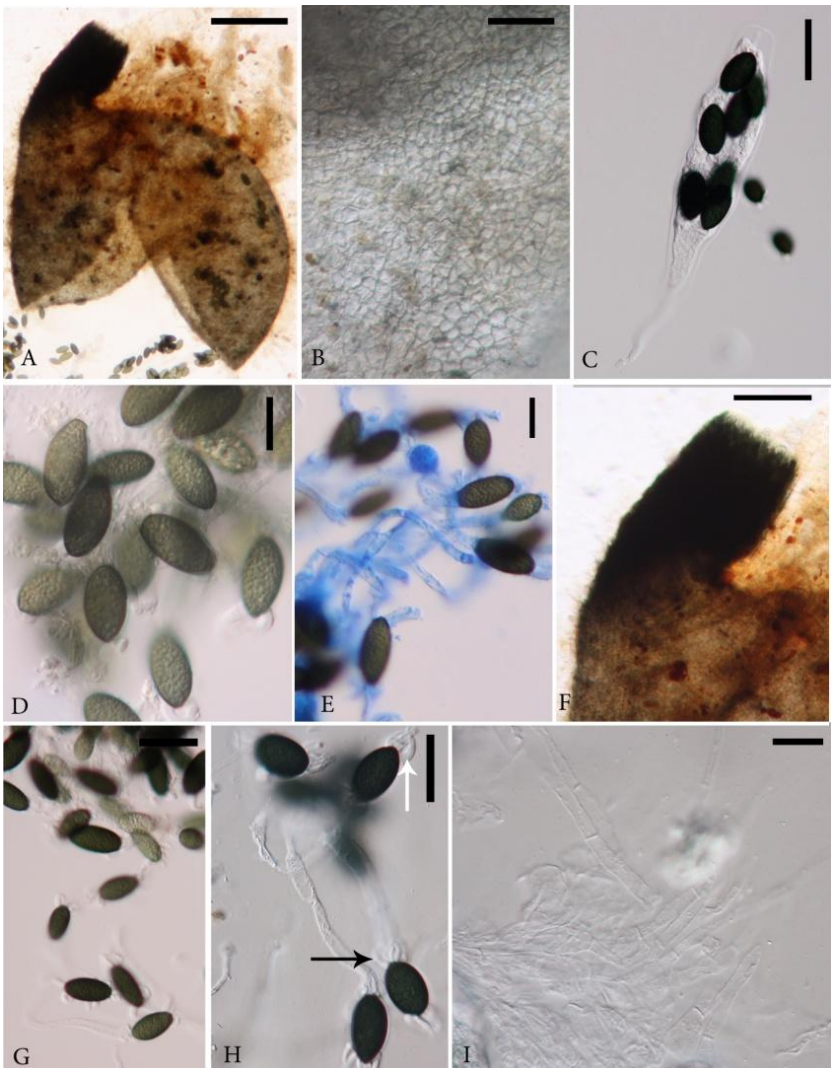

Fig. 13 – *Zygopleurage zygospora* (MFLU10 0187). **A** Squashed perithecium. **B** Details of exoperidium. **C** Ascus with ascospores. **D-E**, **G** Free ascospores in different stages. **F** Peridial neck **H** Mature ascospores joined by intercalary cells, note the short claw-like gelatinous appendages on the end cells (white arrow) and the short caudae at the septa of intercalary cells (black arrow). **Scale bars**: **A** = 400 µm, **B, D** = 20 µm, **C, E G, H** = 40 µm, **F** = 100 µm.

Podospora hyalopilosa and *Zygopleurage zygospora* were found on one dung type each. Of the species found, *Cercophora kalimpongensis*, *Kernia* cf. *retardata*, *Iodophanus* aff. *helotinus*, *Podospora hyalopilosa* and *Zygopleurage zygospora* are new records for Thailand (Table 2).

Biodiversity surveys mainly serve to elucidate the general biodiversity status of an area under study which in turn may be used as a baseline for more detailed studies. Fourteen dung samples is a very small number for any statistical analysis. However, it does give an indication of the diversity of coprophilous fungi from the sampling sites.

Acknowledgements

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Table 1. Occurrence of coprophilous ascomycetes on different dung types.

Species \ Dung type	Chicken (2)	Water buffalo (1)	Cattle (8)	Goat (1)	Asiatic elephant (2)	Freq. %*	Rel. Freq. %*
Saccobolus citrinus, Boud. & Torrend		1	8	1		21.4	20.8
Ascobolus immersus Pers.			7	1		14.3	16.7
Cercophora kalimpongensis Mukerji, R.N. Kumar & N. Singh		2	2		4	14.3	16.7
*Sporormiella minima (*Auersw.) S.I. Ahmed & Cain			6	1		14.3	14.6
Zygopleurage zygospora (Speg.) Boedijn			5			7.1	10.4
Kernia cf. *retardata* Udagawa & T. Muroi	1	1	1			21.4	6.3
Chaetomium bostrychodes Zopf.				2		7.1	4.2
Coprotus winteri (Marchal) Kimbr.			1	1		14.3	4.2
Iodophanus aff. *helotinus* Cain				1		7.1	2.1
Podospora hyalopilosa (R. Stratton) Cain			1			7.1	2.1
Ascodesmis sphaerospora W. Obrist			1			7.1	2.1
Total (isolated individuals)	1	4	32	7	4	100	
#Total (different species)	1	3	9	6	1		

The frequency and relative frequency (Table 1) of each species was computed using the formulae below:

$$\text{Frequency (\%)} = \frac{\text{Sample units on which fungal species occurred}}{\text{Total number of sample units examined}} \times 100$$

$$\text{Relative frequency (\%)} = \frac{\text{Number of isolates for each species}}{\text{Total number of isolates}} \times 100$$

Source: Zak et al. 2004.

Table 2 Coprophilous fungi known from Thailand.

Name	Dung type	Province/Locality	Reference
Ascobolus albidus H. Crouan & P. Crouan	Elephant (2)	1) Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Province 2) unknown.	Piasai et al. 2009 Jeamjitt et al. 2007
Ascobolus demangei Pat.	Not known	Rachaburi	Brummelen 1969
Ascobolus siamensis Brumm.	Burmese goat	Pha Nok Khao	Brummelen van 1967
Ascodesmis macrospora W. Obrist	1) Wild boar 2) Mouse	1) Ko Samaesarn in Chonburi Province 2) Not known	Piasai et al. 2009 Jeamjitt et al. 2007
Ascodesmis sphaerospora W. Obrist	Toad	Not known	Jeamjitt et al. 2007
Aspergillus clavatus Desm.	Barking deer	Ko Samaesarn	Piasai et al. 2009
Aspergillus flavus Link	Dusky langur, bird	Mu Ko Angthong in Surat Thani Province	Piasai et al. 2009
Aspergillus fumigatus Fresen.	Wild boar, buffalo and dusky langur	Ko Samaesarn and Mu Ko Angthong	Piasai et al. 2009
Aspergillus fumigatus Fresen.	Wild boar buffalo, dusky langur	Ko Samaesarn	Piasai et al. 2009
Aspergillus niger sensu auct. pro parte, pre 2007,	Barking deer	Ko Samaesarn	Piasai et al. 2009
Aspergillus terreus Thom.	Dusky langur and bird	Mu Ko Angthong	Piasai et al. 2009
Cercophora silvatica N. Lundq.	Elephant	Not known	Jeamjitt *et al.* 2007
Cercophora sp.	Elephant, Barking deer	Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces	Piasai et al. 2009
Chaetomium cupreum L.M. Ames	Deer, eld's deer, elephant, rabbit, cow	Not known	Jeamjitt et al. 2007
Chaetomium globosum Kunze	1) Barking deer, deer, eld's deer, gaur, rabbit, camel, buffalo, cow, goat, horse. 2) Barking deer	1) Not known 2) Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces	Jeamjitt et al. 2007 Piasai et al. 2009
Chaetomium crispatum (Fuckel) Fuckel	Elephant, cow	Not known	Jeamjitt et al. 2007
Coprinus sp.	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai National Park in Nakhon Ratchasima Province	Somrithpol *et al.* 2002
Coprotus sp.1	Elephant, barking deer, cow	Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces	Piasai et al. 2009
Coprotus sp.2	Barking deer	Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces.	Piasai et al. 2009
Cunninghamella echinata Pišpek	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai National Park in Nakhon Ratchasima Province	Somrithpol et al. 2002
Delitschia pachylospora Luck-Allen & Cain	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai National Park in Nakhon Ratchasima Province	Somrithpol et al. 2002
Emericella nidulans (Eidam) Vuill.	1) Eld's deer, gaur, cow, goat 2) Barking deer, buffalo	1) Not known 2) Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces	Jeamjitt et al. 2007 Piasai et al. 2009

Table 2 (Continued) Coprophilous fungi known from Thailand.

Name	Dung type	Province/Locality	Reference
Emericella rugulosa (Thom & Raper) C.R. Benj.	Cow, mouse	Not known	Jeamjitt et al. 2007
Emericella variecolor Berk. & Broome	Cow, mouse, toad	Not known	Jeamjitt et al. 2007
Eupenicillium parvum (Raper & Fennell) Stolk & D.B. Scott	1) Deer, elephant, camel, buffalo, cow, goat, horse, mouse, toad 2) Barking deer, elephant	1) Not known 2) Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces, Thailand.	Jeamjitt et al. 2007 Piasai et al. 2009
Eupenicillium sp.	Barking deer	Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces	Piasai et al. 2009
Eurotium amstelodami L. Mangin	1) Barking deer 2) Barking deer, elephant, gaur, rabbit, camel, buffalo, cow, horse, mouse, toad	1) Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces 2) Not known	Piasai et al. 2009 Jeamjitt et al. 2007
Gelasinospora brevispora R.S. Khan & J.C. Krug	Cow	Not known	Jeamjitt et al. 2007
Gelasinospora indica (J.N. Rai, Wadhwani & J.P. Tewari) Arx	Barking deer, elephant	Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces	Piasai et al. 2009
Gelasinospora sp.	Barking deer	Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces	Piasai et al. 2009
Hamigera avellanea Stolk & Samson	1) Elephant, cow, goat 2) Elephant	1) Not known 2) Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces	Jeamjitt et al. 2007 Piasai et al. 2009
Idriella lunata P.E. Nelson & S. Wilh.	Sambar deer, common barking deer, Asian elephant, cattle	Not known	Jeamjitt et al. 2007
Leptokalpion albicans Brumm.	Not known	Not known	Brummelen van 1977
Mucor spp.	Buffalo, bird	Mu Ko Angthong	Piasai et al. 2009
Myrothecium verrucaria (Alb. & Schwein.) Ditmar	Wild boar,, buffalo	Ko Samaesarn and Mu Ko Angthong	Piasai et al. 2009
Neosartorya fischeri (Wehmer) Malloch & Cain	1) Barking deer, wild boar, buffalo 2) Deer, eld's deer, elephant, gaur, buffalo, cow, goat, mouse, toad 3) Cow, buffalo, barking deer	1) Ko Samaesarn and Mu Ko Angthong 2) Not known 3) Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces	Piasai et al. 2009 Jeamjitt et al. 2007 Piasai et al. 2009
Neosartorya fumigata O'Gorman, H.T. Fuller & P.S. Dyer	Cow, mouse	Not known	Jeamjitt et al. 2007
Paecilomyces lilacinus (Thom) Samson	Barking deer, wild boar,buffalo, dusky langur, bird	Ko Samaesarn and Mu Ko Angthong	Piasai et al. 2009
Penicillium claviforme Bainier	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai N.P. in Nakhon Ratchasima Province	Somrithipol et al. 2002

Table 2 (Continued) Coprophilous fungi known from Thailand.

Name	Dung type	Province/Locality	Reference
Phialophora sp.	Barking deer,buffalo and dusky langur	Ko Samaesarn and Mu Ko Angthong	Piasai et al. 2009
Pilobolus sp.	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai N.P. in Nakhon Ratchasima Province	Somrithipol et al. 2002
Podosordaria leporina (Ellis & Everh.) Dennis	Deer	Not known	Jeamjitt et al. 2007
Podospora communis (Speg.) Niessl.	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai N.P. in Nakhon Ratchasima Province	Somrithipol et al. 2002
Podospora curvicolla (G. Winter) Niessl	Deer, barking deer,	Not known	Jeamjitt et al. 2007
Podospora setosa (G. Winter) Niessl	Elephant	Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces	Piasai et al. 2009
Podospora sp.	Deer, eld's deer, gaur, rabbit	Not known	Jeamjitt et al. 2007
Podospora sp.	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai N.P. in Nakhon Ratchasima Province	Somrithipol et al. 2002
Poronia gigantea Sacc.	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai N.P. in Nakhon Ratchasima Province	Somrithipol et al. 2002
Rhizopus stolonifer (Ehrenb.) Vuill.	Bird	Ko Samaesarn and Mu Ko Angthong	Piasai et al. 2009
Saccobolus thaxteri Brumm.	1) Sambar deer, common barking deer, cattle, Asian elephant 2) Burmese goat	1) Not known 2) Pha Nok Khao	Brummelen 1969 Brummelen 1969
Saccobolus citrinus Boud. & Torrend.	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai N.P. in Nakhon Ratchasima Province	Somrithipol et al. 2002
Saccobolus glaber (Pers.) Lambotte	1) Elephant 2) Camel 3) Not known	1) Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces 2) Not known 3) Khao Dai Kuad, Surat	Piasai et al. 2009 Jeamjitt et al. 2007 Brummelen 1969
Saccobolus succineus Brumm.	Elephant	Not known	Brummelen 1969
Saccobolus truncatus Velen.	Culture	Pha Nok Khao	Brummelen 1969
Saccobolus minimus Velen.	Goat	Khao Dai Kuad, Surat	Brummelen 1969
Scopulariopsis brumptii Salv.-Duval	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai N.P. in Nakhon Ratchasima Province	Somrithpol et al. 2002
Scytalidium lignicola Pesante	Barking deer, dusky langur, bird	Ko Samaesarn and Mu Ko Angthong	Piasai et al. 2009
Sordaria fimicola (Roberge ex Desm.) Ces. & De Not.	1) Barking deer, cow, elephant 2) Barking deer, buffalo 3) Buffalo, cow, goat	1) Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces 2) Ko Samaesarn and Mu Ko Angthong 3) Not known	Piasai et al. 2009 Piasai et al. 2009 Piasai et al. 2009

Table 2 (Continued) Coprophilous fungi known from Thailand.

Name	Dung type	Province/Locality	Reference
Sporormiella minima (Auersw.) S.I. Ahmed & Cain	1) Barking deer, buffalo 2) Barking deer, dusky langur 3) Deer, rabbit, buffalo, cow, goat, mouse, toad	1) Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces 2) Ko Samaesarn and Mu Ko Angthong 3) Not known	Piasai et al. 2009 Piasai et al. 2009 Piasai et al. 2009
Stilbella sp.	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai N.P. in Nakhon Ratchasima Province	Somrithpol et al. 2002
Syncephalastrum racemosum Cohn ex J. Schröt.	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai N.P. in Nakhon Ratchasima Province	Somrithpol et al. 2002
Talaromyces flavus (Klöcker) Stolk & Samson	1) Barking deer, buffalo cow 2) Wild boar 3) Barking deer, deer, elephant, gaur, camel, buffalo, cow, goat, horse, mouse, toad	1) Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces 2) Ko Samaesarn and Mu Ko Angthong 3) Not known	Piasai et al. 2009 Piasai et al. 2009 Jeamjitt et al. 2007
Talaromyces rotundus (Raper & Fennell) C.R. Benj.	Elephant, horse, mouse, toad	Not known	Jeamjitt et al. 2007
Talaromyces sp	Elephant, camel, horse	Not known	Jeamjit et al. 2007
Talaromyces bacillisporus (Swift) C.R. Benj.	1) Barking deer, elephant 2) Elephant, gaur, rabbit, buffalo, cow, goat, horse, mouse	1) Not known 2) Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces	Jeamjitt et al. 2007 Piasai et al. 2009
Thielavia terricola (J.C. Gilman & E.V. Abbott) C.W. Emmons	1) Wild boar and buffalo 2) Buffalo, cow, goat	1) Ko Samaesarn and Mu Ko Angthong 2) Not known	Piasai et al. 2009 Jeamjitt et al. 2007
Trichoderma hamatum (Bonord.) Bainier	Wild boar	Ko Samaesarn	Piasai et al. 2009
Volutella ciliata (Alb. & Schwein.) Fr.	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai N.P. in Nakhon Ratchasima Province	Somrithpol et al. 2002
Wiesneriomyces laurinus (Tassi) P.M. Kirk	Sambar deer, common barking deer, Asian elephant, cattle	Khao Yai N.P. in Nakhon Ratchasima Province	Somrithpol et al. 2002
Xylaria sp.	Cow	Khao Yai N.P. and Phu Luang W.S. in Nakhon Ratchasima and Loei Provinces	Piasai et al. 2009
Xylaria sp.	Elephant	Not known	Jeamjitt et al. 2007
Zopfiella latipes (N. Lundq.) Malloch & Cain	Deer	Not known	Jeamjitt et al. 2007
Zygospermella sp.	Sambar deer, common barking deer, Asian elephant, cattle	Not known	Somrithpol et al. 2002

References

Abdullah SK, Rattan SS. 1978 – *Zygopleurage*, *Tripterosporella* and *Podospora* in Iraq. Mycotaxon 8, 102–105.

Ahmed SI, Cain RF. 1972 – Revision of the genera *Sporormia* and *Sporormiella*. Canadian Journal Botany 50, 419–477.

Arx von JA, Guarro J, Figueras MJ. 1986 – The Ascomycetes Genus *Chaetomium*. Nova Hedwigia 84, 1–161.

Bell A. 1983 – Dung Fungi an illustrated guide to coprophilous fungi in New Zealand. Victoria University Press.

Bell A. 2005 – An illustrated guide to the coprophilous ascomycetes of Australia. Centraalbureau voor Schimmelcultures. Fungal Biodiversity Series 3.

Brummelen J. van. 1967 – A world-monograph of the genera *Ascobolus* and *Saccobolus* (Ascomycetes, Pezizales). Persoonia Supplement1, 1–260.

Brummelen J. van. 1969 – Studies on Discomycetes III. Persoonia 5, 225–231.

Brummelen J. van. 1977 – A new genus of Pezizales from Thailand. Kew Bulletin 3, 617–620.

Brummelen J. van. 1981 – The genus *Ascodesmis*. Persoonia 11, 333–358.

Cain RF. 1934 – Studies of coprophilous Sphaeriales in Ontario. University of Toronto Study Series in Biology 38, 1–126.

Caretta G, Piontelli E, Savino E, Bulgheroni A. 1998 – Some coprophilous fungi from Kenya. Mycopathologia 142, 125–134.

Chang JH, Kao HW, Wang YZ. 2010 – Molecular Phylogeny of *Cercophora*, *Podospora* and *Schizothecium* (Lasiosphaeriaceae, Pyrenomycetes). Taiwania 55, 110–116.

Chang JH, Wang YZ. 2008 – Two Species of *Kernia* (Plectomycetes) in Taiwan. Taiwania 53, 414–416.

Cinto IE, Dokmetzian DA, Ranalli ME. 2007 – *Iodophanus carneus* and *Iodophanus testaceus* (Ascomycota-Pezizales): Independent taxonomic identity or synonymy, A study of their morphology and isozymes. Biology Society Arrgent Botany 42, 185–186.

Dokmetzian DA, Ramos AM, Cinto IE, Suárez ME, Ranalli ME. 2005 – Six species of the genus *Coprotus* (Pyronemataceae) from Argentina studied in culture. Hickenia 57, 243–252.

Doveri F. 2004 – Fungi Fimicoli Italici. Associazione Micologica Bresadola, Trento, Italy.

Doveri F. 2008a – A bibliography of *Podospora* and *Schizothecium*, a key to the species, and a description of *Podospora dasypogon* newly recorded from Italy. Pagine Di Micologia.

Doveri F. 2008b – An update of the genus *Chaetomium* with descriptions of some coprophilous species new to Italy, Pagine Di Micologia.

Doveri F, Cacialli G, Caroti V. 2000 – Guide pour l'identification des Pezizales fimicoles d'Italie. Nova Scotia Document Mycology 30 (fasc. 117–118), 3–98.

Eberson C, Eicker A. 1992 – Coprophilous fungal species composition and species diversity on various dung substrates of African game animals. Botanical Bulletin of Academia Sinica 33, 85–95.

Eberson C, Eicker A. 1997 – Determination of the coprophilous fungal fruit body successional phases, and the delimitation of species association classes on dung substrates of African game animals. Botanical Bulletin of Academia Sinica 38, 183–190.

Elshafie AE. 2005 – Coprophilous mycobiota of Oman. Mycotaxon 93, 355–357.

Furuya K, Udagawa S. 1972 – Coprophilous pyrenomycetes from Japan II. Journal of General and Applied Microbiology 18, 455–467.

Hanlin RT. 1998a – Illustrated genera of Ascomycetes, Vol II. American Phytopathological Society Press, St. Paul, Minnesota.

Jeamjitt O, Manoch L, Visarathanonth N, Chamswarng C, Watling R, Sharples GP, Kijjoa A. 2007 – Coprophilous ascomycetes in Thailand. Mycotaxon 100, 115–136.

Jeamjitt O, Manoch L, Visarathanonth N, Chamswarng C, Pikulklin S. 2008 – Coprophilous fungi and antagonistic effect of *Sordaria fimicola* against plant pathogenic fungi in vitro. Department of

Plant Pathology, Faculty of Agriculture, Kasetsart University, Bangkok.

Jones EBG, Hyde KD. 2004 – Introduction to Thai Fungal Diversity. In Thai Fungal Diversity (eds. EBG Jones, M Tanti charoen, KD Hyde). BIOTEC, Thailand.

Kaushal SC, Virdi SS. 1986 – Himalayan species of *Saccobolus*. A coprophilous genus of Pezizales. Willdenowia 16, 269–277.

Kimbrough JW, Korf RP. 1967 – A synopsis of the genera and species of the tribe Theleboleae (Pseudoascobolaceae). American Journal of Botany 54, 9–23.

Kimbrough JW, Luck-Allen RE, Cain RF. 1969 – *Iodophanus*, the Pezizeae segregate of *Ascophanus* (Pezizales). American Journal of Botany 54, 1187–1202.

Kimbrough JW. 1970a – Segregates of *Ascophanus*, *Coprotus* vs. *Leporina* (Thelebolaceae, Pezizales). Taxon 19, 779–781.

Kimbrough JW, Luck-Allen ER, Cain RF. 1972 – North American species of *Coprotus* (Thelebolaceae: Pezizales). Canadian Journal of Botany 50, 957–971.

Korf RP. 1972 – Synoptic key to the genera of the Pezizales. Mycologia 64, 937–994.

Kruys A, Wedin M. 2009 – Phylogenetic relationships and an assessment of traditionally used taxonomic characters in the Sporormiaceae (Pleosporales, Dothideomycetes, Ascomycota), utilising multigene phylogenies. Systematics and Biodiversity 7, 465–478.

Lundqvist N. 1969 – *Zygopleurage* and *Zygospermella* (*Sordariaceae* s. lat., Pyrenomycetes). Botaniska Notiser 122: 353–374.

Lundqvist N. 1972 – Nordic *Sordariaceae s*.lat. Symbolae Botanicae Upsalienses 20, 1–374.

Malloch D, Cain RF. 1971 – The genus *Kernia*. Canadian Jounal of Botany 49, 855–867.

Manoch L, Piasai O, Dethoup T, Kokaew J, Eamvijarn A, Piriyaprin S, Paopun Y, Poochinya P, Umrung P. 2009 – Morphological studies of slime molds, Sordariaceous fungi, and an endophytic synnemata fungus. Journal of Microscopy Society of Thailand 23, 25–29.

Mirza JH, Cain RF. 1969 – Revision of the genus *Podospora*. Canadian Journal of Botany 47, 1999–2048.

Piasai O, Manoch L. 2009a – Coprophilous ascomycetes from Phu Luang Wildlife Sanctuary and Khao Yai National Park in Thailand. Kasetsart Journal (National Sciences) 43, 34–40.

Piasai O, Manoch L. 2009b – Diversity of microfungi from animal excrement at Ko Samaesarn and Mu Ko Angthong National Park; 35th Congress on Science and Technology of Thailand. Department of Plant Pathology, Faculty of Agriculture, Kasetsart University, Bangkok.

Richardson MJ, Watling R. 1997 – Keys to Fungi on Dung. 2nd ed. Bulletin of the British Mycological Society 2, 18–46.

Richardson MJ. 2001 – Coprophilous fungi from Brazil. Brazil Archive of Biology and Technology 3, 283–289.

Richardson MJ. 2008 – Records of coprophilous fungi from the Lesser Antilles and Puerto Rico. Caribbean Journal of Science 2, 2–214.

Somrithipol S, Hywel-Jones NL, Valyasevi R. 2002 – Isolation and Identification of Coprophilous Fungi. National Center for Genetic Engineering and Biotechnology, National Science and Technology Development Agency, Ministry of Science, Technology and Environment, Bangkok.

Suarez ME, Ranalli ME, Dokmetzian DA, Ramos AM. 2006 – Characterization of three species of the genus *Coprotus* (Ascomycota) by isozyme analysis. Mycotaxon 97, 257–273.

www.indexfungorum.org – March, 2011.

Zak JC, Willig MR. 2004 – Fungal Biodiversity Patterns. Pp 59–75. In Biodiversity of Fungi, Inventory and Monitoring Methods (eds. GM Muller, FG Bills, MS Foster). Elsevier Academic Press, San Diego, Calif. 777 pp.