Atlas of Invertebrate-Pathogenic Fungi of Thailand

Volume 2

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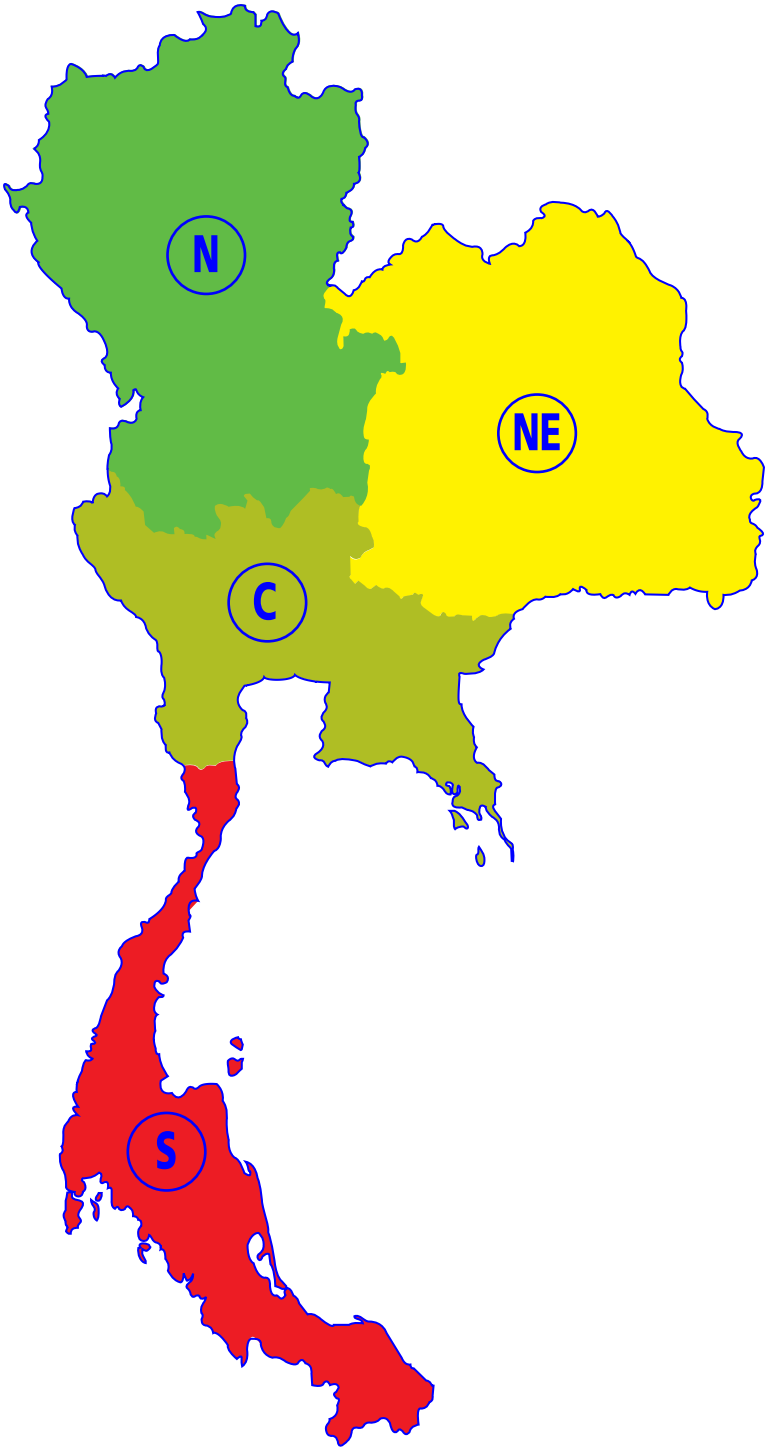
INTRODUCTION

The Kingdom of Thailand lies in Southeast Asia. Its shape and geography divide the country into four natural regions: the mountains and forests of the North; the vast rice fields of the Central Plains; the semi-arid farm lands of the Northeast plateau; and the tropical islands and long coastline of the peninsula South. Thailand is bordered to the west by Myanmar, north and northeast by Laos, in the east by Cambodia and in the south by Malaysia. About 25% of natural habitats still remain and a logging ban has reduced forest destruction although this has not been eliminated completely. A good system of National Parks and Wildlife Sanctuaries provide a degree of protection not enjoyed by many tropical countries.



Forests in Thailand

The rainforest and the monsoon forests are the two basic types of tropical forests associated with Thailand's indigenous vegetation. While rainforests are considered as forests having rainfall for more than nine months in a year, monsoon forests have a distinct dry season. About a fourth of all remaining forest in Thailand is monsoon forest while a half of it is rainforest. These areas are very rich in flora and fauna covering over 27,000 species of flowering plants.

Characteristics of Thai Forests

The tropical forests in Thailand have a wide variety of vegetation. This variety of vegetation can be attributed to several factors: climate, amount of rainfall, humidity, temperature, soil type, and geography. The forests can be divided into two major kinds, namely, evergreen and deciduous forests.

A. Evergreen forest

These forests are green all year round. The trees create new leaves continuously over the year. Unlike the deciduous forests, the evergreen forests look the same during the different seasons of the year. They are found in all areas of Thailand and can be divided into four major parts based on their characteristics:

Tropical Evergreen Forest

Found in all areas in Thailand but are in abundance in the south and east especially in Rayong, Chantaburi and Trat due to heavy rainfall and high moisture levels. In other areas they are concentrated on pockets of high moisture such as valleys and close to water sources (rivers, streams and mountains). It is home to many economically important trees such as rubber and hardwood, bamboos and rakam.

Hill Evergreen Forest

Found at high altitudes over 1,000 meters above sea level especially in the north (Phu Luang and Phu Kradung in Loei, Khao Yai and Khao Luang), this type of forest is less dense than the tropical evergreen forest due to less large trees. Trees are mainly mixed with shrubs and pines.

Coniferous Forest

This forest can be found in altitudes over 700 meters above sea level but can also be found at 200-300 meters. It is in abundance in the north and to a lesser degree in the central plain and northeast. The important vegetation here are the different varieties of pine and is less dense than the other evergreen forests. It might be found together with hill evergreen forests or dry dipterocarp forests.

Mangrove Forest

Forests of this type are found in the seat of the mouth of major rivers where they meet the sea (brackish water). The forest floor is very dense and the roots of the trees are both for breathing and for anchorage. They are found in Chantaburi in the east and on both sides of the peninsula along the coast in the south.

B. Deciduous Forest

The trees shed off their leaves during the dry season in this type of forest. Because of this, forest fires are frequent and often devastating. When rain arrives the forest comes back to life with new leaves and flowers. The forest floor plants grow rapidly giving the forest a lush look. This forest can be divided into three types:

Mixed Deciduous Forest

This type of forest is populated by large and mid-sized trees and is not dense. Bamboos usually grow in the pockets and the soil is porous with sand mixed into it. During the dry season the trees lose all their leaves and forest fires usually sweep the whole forest once a year. Mixed deciduous forests in the north include teak trees. They spread down into Kanchanaburi. Few can be found in the northeast and east and do not have teak trees. They can only be found in specific areas in the south such as Surat Thani, Ranong, Stul and Nakhon Sri Thammarat.

Dry Deciduous Dipterocarp Forest

This forest has big to small trees and the forest floor is covered by grasses or small bamboos. The soil is generally porous mixed with rocks and sand. Absorption of water is not good contributing to the dryness of the forest. Annual forest fires are common. This type of forest is common to the plains and mountain areas. In the north it is common to very dry and shallow areas. The trees are usually small resulting in very open forest environment. In the east and northeast they grow in areas with better soil and are more dense and lush.

Savannas

They can be found in all regions in Thailand. It is the result of man's effort to clear land for agriculture. Trees are destroyed and the soil left to dry. Grass grows over the land. Forest fires are common due to dryness. Savannas are characterized by trees and grass that are fire resistant. Other trees cannot survive the annual forest fires.

National Parks in Thailand

There are more than 100 national parks and wildlife sanctuaries that have been established to preserve and protect Thailand's natural resources. These are generally the north, northeast, central Thailand and southern Thailand and it is convenient to divide Thailand into these four major regions.

Northern Thailand:

There are over fifty national parks in the north of Thailand which encompass over 30,000 km^2. Nine of these are more than 1000 km^2 and sporadic surveys have been carried out in many. Of the national parks in northern Thailand the most important (in terms of surveys made) include: Doi Inthanon National Park, Doi Suthep National Park and Nam Nao National Park. The following details are provided on the most visited of these parks.

Doi Inthanon National Park:

This park is in Chiang Mai province and includes the highest point in Thailand at 2565 metres above sea level (masl). The region to the west of Doi Inthanon consist mainly of mountain ridges and valleys in a north-south orientation. This is a result of the continued movement of the Indian subcontinent into Asia. Doi Inthanon stands out as a granitic basolith intrusion into this landscape of softer and more eroded rocks such as limestone.

A controversial road was carved up to the summit by the Thai military soon after the national park was created to service a radar-listening station. Much of the park (which is *ca.* 500 km^2) is inaccessible or difficult to get at. And most of the 40+ km of road has zero, poor or degraded forest on either side. However, there are small pockets of good forest along this road. By the nature of the terrain it is not easy to get into good forest on either side of the road. This is in contrast to a similar road that cuts through Khao Yai National Park.

The lower slopes of Doi Inthanon are *ca.* 500 masl. and consist of Tectona forest with a pronounced dry season – especially as they face south. As a result, there is a deciduous feel to this area as trees drop their leaves in November/December. This teak-dominated forest gives way to a mixed pine-dipterocarp forest where the dominant pine tree (one of two native to Thailand) is *Pinus merkusii.* Above 1500 masl *Pinus merkusii* gives way to *Pinus kesiya* (the second of two native pines in Thailand) which is mixed with *Castanopsis* and at higher elevations (*eg.* above 1800 masl) it is mixed with *Quercus.* Dense *Quercus*-dominated forest occurs from 1800-2400 masl.

The summit of Doi Inthanon consists of pseudo 'cloud forest' although this is not moist all the year round as true cloud forest would be. Tree trunks are heavily invested with epiphytes such as mosses, ferns and (especially) orchids while the forest floor also is rich in mosses (especially at the summit). Two species of *Rhododenstron* occur at the summit and this is also one of the few places in Thailand where At the summit the December/January night time temperatures regularly drop below zero. Above 1000 metres there is *ca.* 2500 mm of rain a year although much of this falls in a 6-8 month period (April/May to November/December). Temperatures of Doi Inthanon (day and night) are significantly below those of other regions of tropical Thailand.

Northeast Thailand:

There are more than 20 national parks covering *ca.* 10,000 km^2 in the north east of Thailand which is dominated by the arid Isan plateau. This plateau region is bordered to the north and east by the Mekong river, to the west by the hills of Thung Salaeng Luang National Park (especially Khao Kor which was a major hold-out of the Communist Party of Thailand in the seventies) and to the south by the Dongrak Mountain Range which stretches into Cambodia and includes two of Thailand's largest national parks – Khao Yai and Thap Lan. Apart from these two, most of the parks in Isan are very small (*ca.* 100-200 km^2). Because of the small size of the parks and the very dry nature of the region few parks in Isan have been surveyed. However, of these, Khao Yai National Park represents the most surveyed national park in Thailand – due mainly to its proximity to Bangkok.

Khao Yai National Park:

This was the first national park to be established in 1962 and is now a UNESCO World Heritage Park. However, it is cut in two by a road although, unlike Doi Inthanon National Park, there is good forest on either side of much of this road. Where Doi Inthanon is a granite basolith, most of Khao Yai (which means big mountain) consists of a sandstone plateau at 700-1000 masl along with some limestone outcrops to the northwest. The forest consists mostly of seasonal monsoon forest from 300 to *ca.* 900 masl. The highest point in Khao Yai is *ca.* 1350 masl and (like Doi Inthanon) also features a Thai military installation.

Nighttime temperatures can regularly drop below 10°C and daily temperatures rarely rise above 30°C (except in the hot season of March/April). Rainfall over much of the park is above 2000 mm a year although most of this is concentrated in the rainy season (May to October/November). Much of the forest cover is dominated by *Dipterocarpus*, *Hopea* and *Xylia* spp. An elevations above 1000 masl *Lithocarpus* and *Castanopsis* with some *Quercus* can be found. Unlike Doi Inthanon National Park, there are no pines and teak is very restricted in distribution.

Although large areas of Khao Yai National Park are difficult to reach, the road bisecting the park and its proximity to Bangkok mean that Khao Yai suffers from very heavy human pressure – especially weekend visitors. The plus side is that there are over 50 km of well-managed trails that lead into the forest.

Central Thailand:

Much of Central Thailand consists of the rice plains of the Chao Phraya river system and is therefore agricultural. Forest areas are confined to the west with the Burmese border and to the east with the Cambodian border. There are fifteen national parks in this region covering *ca.* 10,000 km^2. Four of these national parks extend over more than 1000 km^2 and include Kaeng Krachan National Park which is the largest single national park in Thailand at 2900 km^2. Because this region includes Bangkok, nine of these national parks have received significant surveys. However, the largest national park is presented as an example of the region.

Kaeng Krachan National Park:

This is in the Thenasserim range of hills that were created by the collision of the Indian sub-continent with Asia. This range effectively forms the border between Myanmar and Thailand from the far north to *ca.* 300 km south of Kaeng Krachan National Park. Unlike northern Thailand, elevations are rarely above 500 metres with the highest point being 1200 masl. Because of its size and border with Burma this park has some of the best preserved forest. Having said that much of it is inaccessible or requires hikes of several days. Most visitors are confined to a few readily accessible sites around waterfalls.

Southern Thailand:

The peninsular part of Thailand hosts 20 national parks covering a total area of *ca.* 7500 km^2. Although these are mostly small national parks with none more than 1000 km^2 this belies the fact that there is a tremendous change in the habitats resulting in areas of forest in the south that more closely match the forests of Peninsular Malaysia and Indonesia. Khao Sok National Park, Khao Luang National Park and Bala Hala wildlife sanctuary have been the most surveyed national parks in the south.

Khao Sok National Park:

Khao Sok is in the Surat Thani province, between Surat Thani on the east and Takuapa on the west coast. The national park covers an area of 739 km^2. The combined sizes of Khao Sok (740 km^2), Sri Phang nga (246 km^2) and Khlong Phanom (410 km^2) National Parks along with Khlong Saeng (1156k km^2) and Khlong Naka (480 km^2) wildlife sanctuaries is just over 3000 km^2. The rainforest in the southern region is some of the oldest in the world, since over the last 160 million years Thailand has remained in a similar equatorial position. The climate in the area has been relatively unaffected by ice ages. The landmass is small and has seas on both sides. Khao Sok and surroundings still received enough rainfall to sustain the forests, even while other places on the planet were suffering droughts. Species diversity is high in Khao Sok, since during the last ice age sea levels fell to such an extent that there was a land bridge between Malaysia, Borneo and some of the Indonesian islands. This opened up new migration routes to land based organisms.

The rainforest in Khao Sok has features of both tropical evergreen forest and tropical rainforest. It is also famous for its limestone or 'karst 'mountains. In most of the region, ground level is about 200 masl, with the average mountain heights around 400 m. The tallest peak in the National Park is 960 m. in height.

The invertebrate-pathogenic fungus flora of Thailand

'Insect fungi' are known from several taxonomic regions of the Kingdom Fungi. However, the majority of species reported from Thailand are members of the families Clavicipitaceae, Cordycipitaceae and Ophiocordycipitaceae (Order Hypocreales). This bias is reflected in this work. Most of the 'insect fungi' we will describe in this series will also be members of these three families.

Before 1989 less than ten 'insect fungi' were reported from Thailand. Most of these were species that could be commonly found around the World as pathogens of insects in agricultural ecosystems. Species such as the ubiquitous *Beauveria bassiana* and *Metarhizium anisopliae* which infect a wide range of invertebrate hosts.

The first reliably recorded species of 'insect fungus' from Thailand was reported by Petch (1932). This was *Cordyceps gentilis* on a hornet which was collected in July 1929 from 'northern Siam'. *Cordyceps gentilis* is a close relative of *Cordyceps sphecocephala* (which was the first species of *Cordyceps* to be recognised and illustrated by Father Torrubia from Cuba in 1754) and was considered a synonym by Hywel-Jones (1995a).

It was a further sixty years before a systematic survey of the insect fungi of Thailand was started. *Cordyceps khaoyaiensis* and *Cordyceps pseudomilitaris* became the first new species of 'insect fungi' described from Thailand (Hywel-Jones 1994). After more than fifteen years of forest survey and collecting there are now about 400 species reported from natural forest in Thailand – more than any other country in the World.

Description of these fungi is a continuing process with many new species having been reported (Hywel-Jones 1993, 1994, 1995a-e; 1996 a,b; 1997 a,b; Hywel-Jones & Evans 1993; Hywel-Jones & Samuels 1998; Hywel-Jones & Sivichai 1995; Hywel-Jones, Evans & Jun 1997; Hywel-Jones & Goos 1998). More recently the powerful tool of molecular phylogenetics has been applied to increasing our understanding of the taxonomy of these fungi as well as their relatedness and evolution. Major papers have involved research from the study of insect fungi in Thailand (Artjariyasripong *et al.* 2001; Luangsa-ard *et al.* 2004, 2005; Stensrud *et al.* 2005; Spatafora *et al.* 2007; Sung *et al.* 2007a; Sung *et al.* 2007b).

The Mycoflora of Thailand

Before reviewing a specialised group such as invertebrate-pathogenic fungi it is opportune to consider what is known of the number of fungi in the world and to compare these with what is known of the number of fungi in Thailand. A starting point is the 1990 Presidential Address to the British Mycological Society by Professor David Hawksworth (Hawksworth 1991). In that address Hawksworth noted that about 69,000 species of fungi are known. He presented several figures to predict what the undescribed pool of species might be. These estimates went from an almost revolutionary 13.5 million fungi (based interestingly on extrapolation from insect species number estimates) to a more conservative 1.5 million. For the purpose of consequent number predictions the conservative 1.5 million fungi is presumed.

A feature of many mycological studies in the tropics is that these were made by colonial scientists stationed in colonies of European powers. Thailand is unique in being the only tropical Asian country never to be controlled from Europe. A consequence of this, however, is that now little is known of the biological diversity of any fungi in Thailand.

With a land area half that of Thailand's, temperate and insular the British Isles has 12,000 species of fungi recorded. When the Norwegian scientist Trond Schumacher surveyed the ascomycetes from northern Thailand he noted 'The mycoflora of Thailand is badly known' (Schumacher 1982). Schumacher reviewed

the published literature for Thailand stating that 'about 250 species have previously been reported'. There are now records for about 3000 species (Hywel-Jones, unpubl. data).

David Hawksworth noted that the British fungal flora has increased 62% in the last 47 years and has a rate of increase of 13% per decade. In the *Index of Fungi* from 1981-90 there were 459 new species described from Britain (2.9% of the World total of 16013 species for this period). In contrast, Thailand had 31 new species described (0.2% of the world total). This demonstrates what little is known of fungi in general from Thailand. Biodiversity is a huge issue!

BIOLOGICAL CLASSIFICATION

Systematics and classification are often viewed by biologists as something permanent. This is probably only true in plants and animals, where almost every species has already been discovered and named. In the fungal kingdom revisions are constantly made due to discovery of new taxa. The classification of fungi has changed even more in the last decade not only because of new discoveries but also due to the advancement of molecular techniques. In the fungal world classification is a very dynamic process.

For classification purposes related genera are grouped into **families,** families are grouped into **orders**, orders into **classes**, classes into **phyla**, and phyla into **Kingdoms**. For fungi it has been arranged into a fixed hierarchy and characterized by these set of endings:

Phylum (Division):	*-mycota*
Subphylum (Subdivision):	*-mycotina*
Class:	*-mycetes*
Subclass:	*-mycetidae*
Order:	*-ales*
Family:	*-aceae*

Species and genus concepts.

The species is the smallest unit of taxonomy and is central to biology. Although this topic has been much debated, and still is, it has targeted mostly plants and animals and less the fungi. Despite the complexity of the fungal life cycle, we believe that species exist in fungi. There are several species concepts and definitions (theoretical and practical) and it will be difficult to stick to one particular species concept. Here are some of the commonly used concepts that provide some recognition criteria:

Morphological species concept. This concept is based on differences and similarities in morphological characters. However, in the fungi, morphological features prove to be highly variable and are strongly affected by environment/culture conditions. A character's degree of importance is often a mycologist's personal choice.

Biological species concept. Mayr (1940) recognized species as "groups of actually or potentially interbreeding populations which are reproductively isolated from other such groups". In fungi, this concept has been used to identify compatibility among individuals. However, mating tests are impossible for those

that lack the production of meiospores. Significantly, many fungi are homothallic and produce meiospores readily without a 'partner'. Also, other heterothallic fungi will just not mate *in vitro.*

Phylogenetic species concept. In the molecular age where DNA sequencing is routine, phylogenetic analysis of variable nucleic acid characters clusters organisms into groups within which patterns of ancestry and descent can be recognized. Changes in the gene sequences of the offspring from the parent/ancestor can be recognized before changes have occurred in morphology or mating behaviour.

THE SERIES

This is the second volume in a continuing series which will illustrate *ca.* 30 taxa a year of invertebrate-pathogenic fungi from Thailand. As with the first volume, this is not an authoritative taxonomic treatment of these fungi. However, we hope that for each taxon enough information is brought together to give the interested reader some insight into the diversity and distribution of these fungi in Thailand. Please enjoy.

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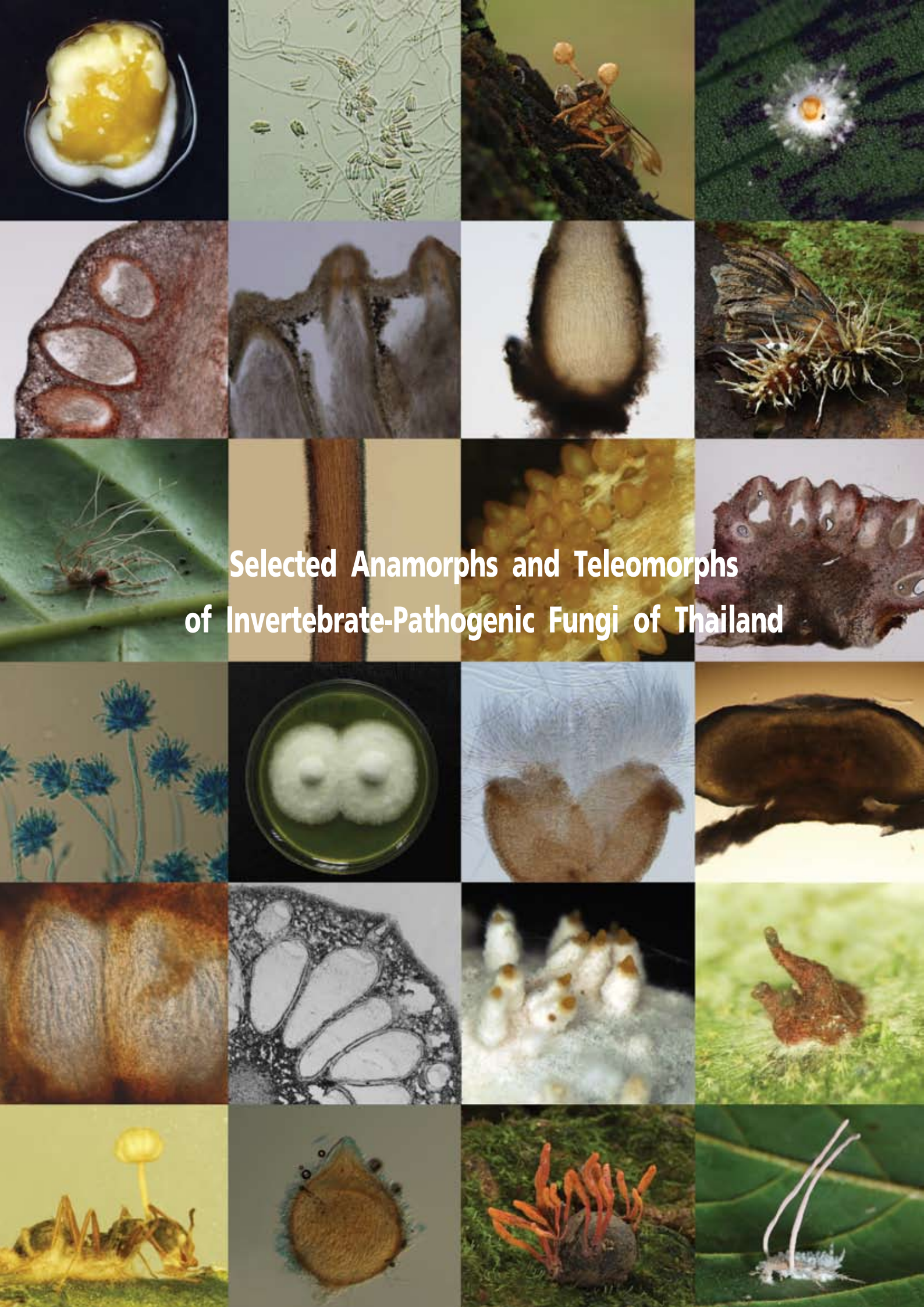
December 2008



Selected Anamorphs and Teleomorphs of Invertebrate-Pathogenic Fungi of Thailand

Akanthomyces aranearum (Petch) Mains

Mycologia **42**: 574 (1950)

Synonyms:

Hymenostilbe aranearum Petch, Trans. Br mycol Soc. **16**: 221 (1931)

Teleomorph state: *Cordyceps thaxteri* Mains

Specimens were found on underside of living leaves of forest plants. Hosts are spiders. Stroma of white mycelium completely covering the host. Synnemata brown at the sterile base, becoming cream to grey-white when conidia present, erect, numerous, simple (occasionally branched), cylindrical, up to 15 mm high, 50-100 μm diam., up to 200 μm diam. because of chains of spores, hyphal strands composed of brownish cells 2.5-10 x 2.5-4 μm. Phialides in a monolayer, crowded, obovoid (when immature) to ellipsoid, minutely verrucose, 5.0-11.5 x 3.5-5.5 μm, with a round apex and a short but distinct neck, 0.5 x 0.5 μm. Conidia catenate, one-celled, smooth-walled, hyaline, narrowly obclavate, 6.0-13.5 x 1.5-2.5 μm.

Conidia germinate after 24 h on PDA. Colonies are slow-growing, attaining a diam. of 1 cm in 1 mo at 25°C and have a white mycelium. A red-brown pigment is produced in the agar.

This species was originally described from North America and is found in association with *Cordyceps thaxteri*. However, in Thailand we have not found a *Cordyceps* state associated with the *Akanthomyces*.

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Mains, E.B. (1950). Entomogenous species of *Akanthomyces*, *Hymenostilbe* and *Insecticola* in North America. *Mycologia* **42**: 566-589.

Hywel-Jones, N.L. (1996). *Akanthomyces* on spiders in Thailand. *Mycological Research* **100**: 1065-1070.

Akanthomyces aranearum (Petch) Mains

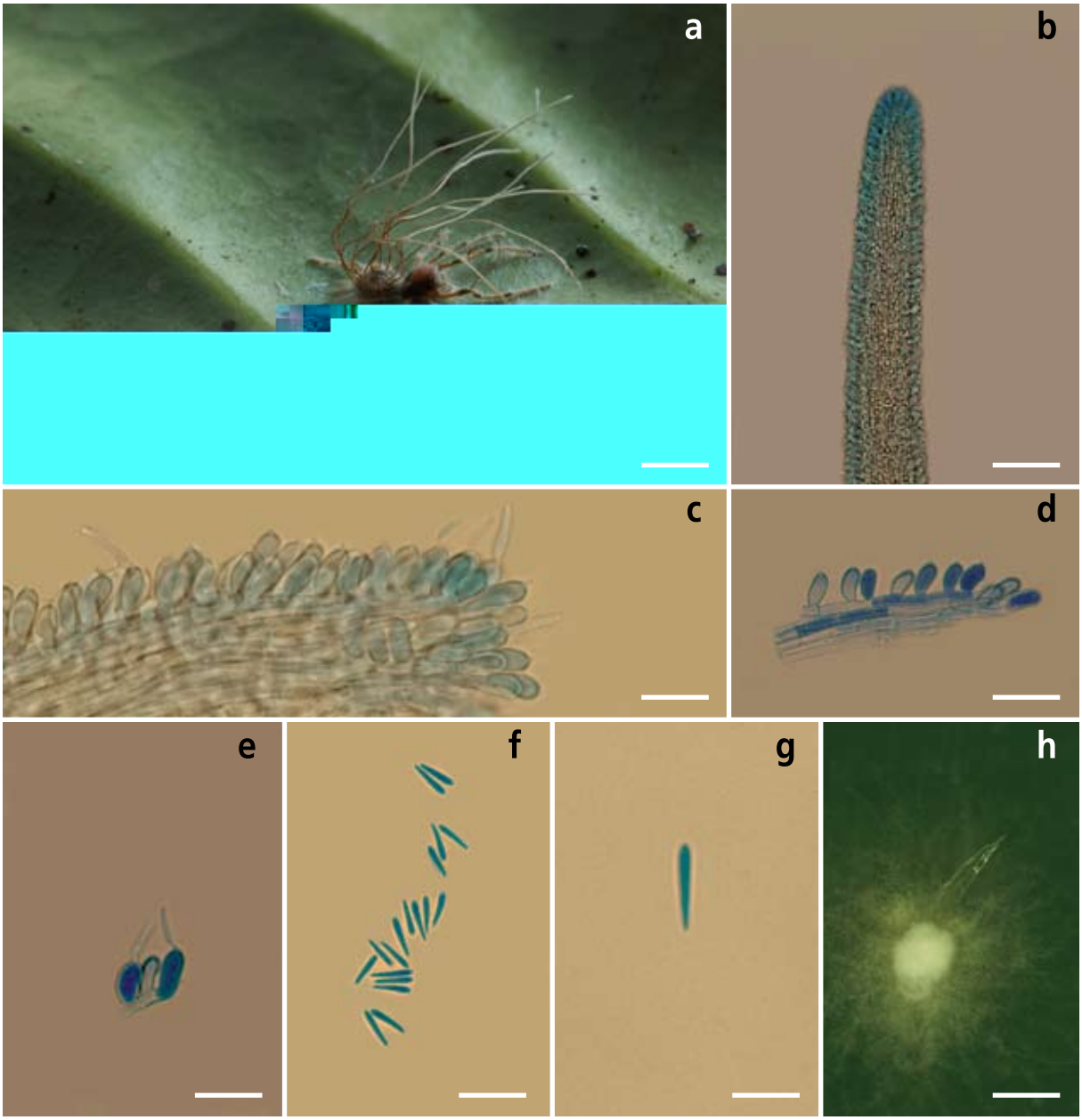

Fig. 1 a synnemata arising from spider host; **b-e** part of synnema showing phialides and conidia; **f-g** conidia; **h** colony on PDA. Bars = 5 mm in Figs a, h, 50 µm in Fig b, 10 µm in Figs c-f, 5 µm in Figs g-h.

Akanthomyces pistillariiformis (Pat.) Samson & H.C. Evans

Acta bot. neerl. **23**: 29 (1974)

Basionym:

Isaria pistillariiformis Pat. [as '*pistillariaeformis*], Bull Soc. Myc. **9**: 163 (1893)

Synonyms:

Insecticola pistillariiformis (Pat.) Mains, [as '*pistillariaeformis*'] Mycologia **42**: 579 (1950)

Teleomorph state: *Cordyceps tuberculata* Lebert

Specimens were found on the underside of mostly dicotyledonous leaves of forest plants. Hosts are adult moths (*Lepidoptera*). The fungus fastens the host on the leaves of the plants with thin hyphae surrounding the legs and edges of the wings; producing scattered white to cream synnemata arising from thin whitish mycelium over the insect, up to 4 cm long. Some specimens producing a mixture of synnematal forms–long, thin, cylindrical, emerging from the body of the moth and tiny, clavate synnemata up to 3 mm scattered over the wings, body and head. The hyphae of the synnema loosely interwoven and longitudinal, on the surface the phialides form a layer of compact hymenium. Phialides subcylindric to fusoid with long necks, 6.5-12.5 x 1.7-2.5 µm, conidia elongate cylindrical with rounded ends, catenulate, 2.5-4.5 x 1 µm.

In culture the colonies on PDA are moderately fast-growing, attaining a diam. of 3-4 cm in 14 d at 25°C. Colonies white, floccose with cream reverse.

Akanthomyces pistillariiformis is a common species infecting adult moths in Thailand. The teleomorph *Cordyceps tuberculata* sometimes accompanies the anamorph state but is rarely found.

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Akanthomyces pistillariiformis (Pat.) Samson & H.C. Evans

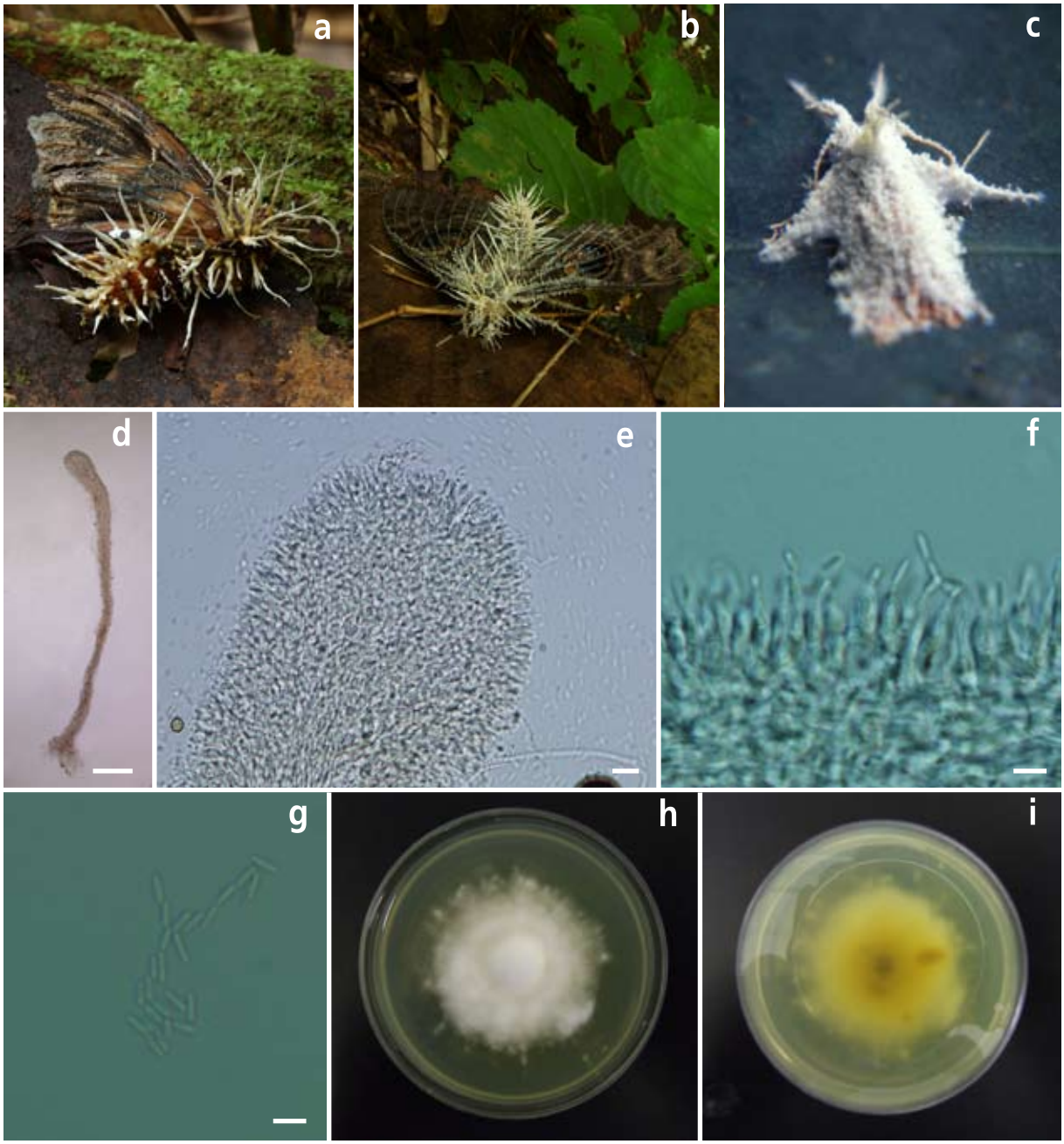

Fig. 2 a-c fungus on host; **d** synnema; **e** phialides on tip of synnema; **f** phialides and conidia; **h** conidia; **i** colony obverse on PDA; **j** colony reverse on PDA. Bars = 200 µm in Fig d, 10 µm in Fig e, 5 µm in Figs f, g.

Aschersonia hypocreoidea (Cooke & Massee) Petch

Annals of the Royal Botanic Gardens Peradeniya **7**: 255 (1921)

Synonyms:

Fusarium hypocreoideum Cook & Massee, Grevillea, **16**: 76 (1888)
? Aschersonia zenkeri P. Henn., Engler's Bot. Jahrb., **23**: 541 (1897)

Teleomorph state: expected in *Moelleriella*

Specimens were found on the underside of dicotyledonous or monocotyledonous leaves of forest plants. Hosts were scale insect nymphs (*Homoptera*; *Aleyrodidae*). Stromata almost plane, circular or oval, surrounded by a thin white hypothallus; pycnidia central, arranged irregularly or in a circle, concave, widely open, spore mass pale yellow or orange yellow, paraphyses present, linear, up to 140 μm long; phialides cylindrical, up to 40 μm; conidia narrow-oval, tapering slightly towards the ends, 20-22.5 x 2.5-3.5 μm. The conidia of Thai specimens were longer and wider than those described by Petch (1921) (8-13 x 2-2.5 μm).

Conidia will germinate within 24 h on PDA. Colonies are slow-growing attaining a diam. of 5-7 mm and producing conidia after *ca.* 4 wk on PDA at 20°C. Colonies compact, white, spore mass orange spreading over the stroma.

This species is similar to *Aschersonia placenta* in producing cream-orange spore masses on a white mycelium. However, whereas *Aschersonia placenta* is very common (even appearing in orchards) *Aschersonia hypocreoidea* is rare. Collections in Thailand have been from the northeast (Khao Yai National Park) and south (Khao Sok National Park, Khlong Nakha Wildlife Sanctuary and Hala Bala Wildlife Sanctuary). The *Moelleriella* state is very rarely found in Thailand and when it is it is not with the *Aschersonia.*

References:

Chaverri, P., Lui, M., & Hodge, K.T. (2008). Neotropical *Hypocrella* (anamorph *Aschersonia*), *Moelleriella*, and *Samuelsia. Studies in Mycology* **60**: 1-66.

Petch, T. (1921). Studies in entomogenous fungi: II. The genera *Hypocrella* and *Aschersonia. Annals of the Royal Botanic Gardens Peradeniya* **7**: 167-278.

Aschersonia hypocreoidea (Cooke & Massee) Petch

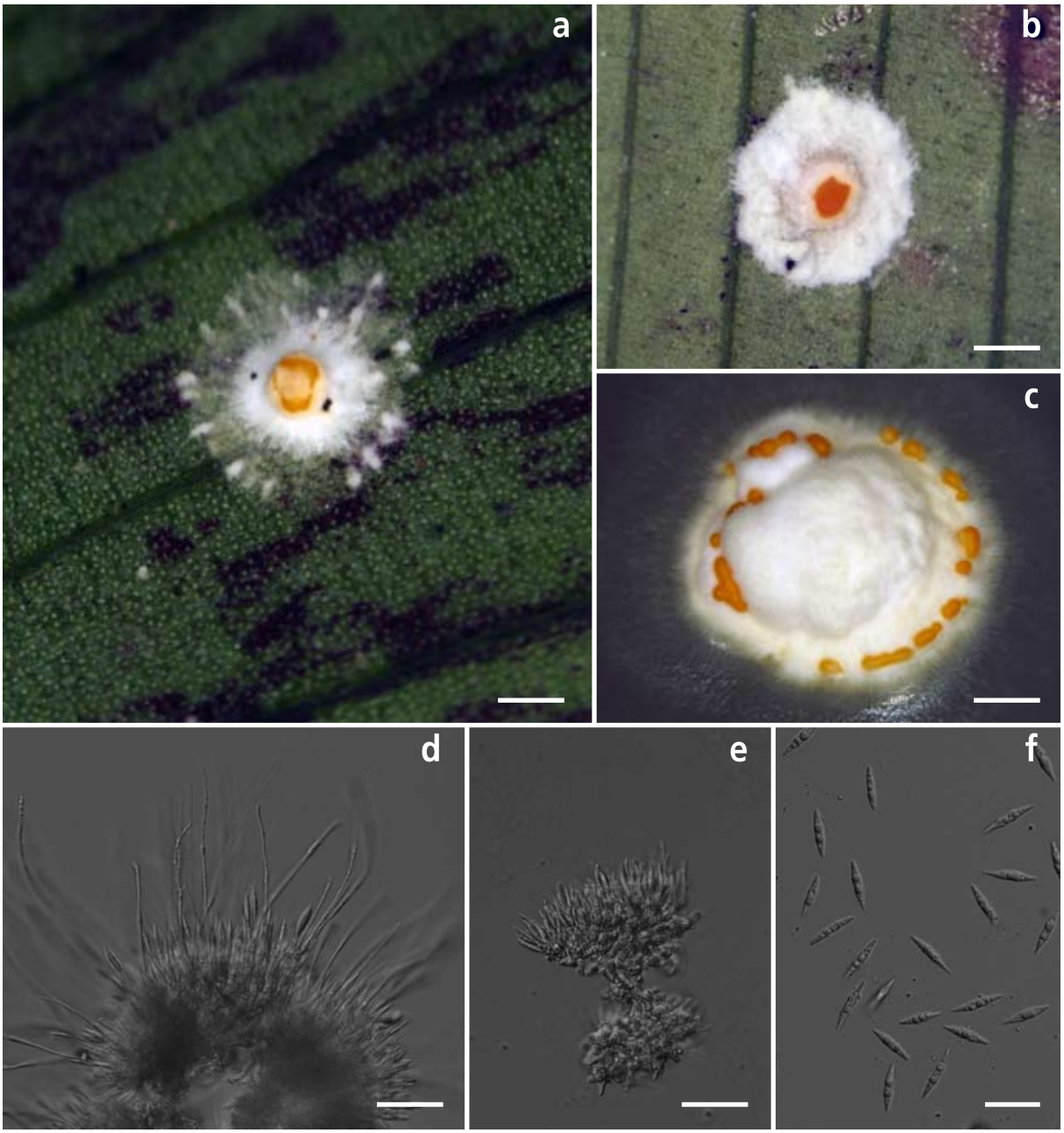

Fig. 3 a-b stroma on scale insect; **c** culture at 20°C on PDA after 4 wk (sporulation present); **d** conidiogenous cells and paraphyses; **e** conidiogenous cells; **f** conidia. Bars = 1 mm in Figs a-c, 20 µm in Figs d, f, 50 µm in Fig e.

Aschersonia sp.

Teleomorph state: not known but probably a *Moelleriella*

Specimens were found on the underside of bamboo leaves. Hosts were scale insect nymphs (*Homoptera*). Stromata usually discoid, distinctly stud-shaped, up to 4 mm diam., up to 2 mm high, pale yellow, base surrounded by a membranous hypothallus; conidiomata pycnidial, scattered around a narrow neck, extruded as an orange-yellow mass of conidia; paraphyses present, linear up to 110 µm long; phialides cylindrical; conidia fusoid, 9-12.5 x 1.7-2.5 µm. *Hirsutella*-like anamorph scattered on the upper surface of the stroma; conidia citriform, 2.3-2.8 x 1.3-1.5 µm.

Conidia will germinate within 24 h on PDA. Colonies are slow-growing producing conidia after *ca.* 2 wk on PDA. Colonies compact, pale yellow at first, then cream to pale yellow with mucoid spore mass covering the stroma, surrounded by pale orange hypothallus.

This specimen of *Aschersonia* was initially compared with *A. placenta*. This was discussed by Petch (1921) and Mains (1959). In a molecular study, the resulting phylogeny based on sequences of the 5.8S rDNA and flanking internal transcribed spacers regions clearly showed the Thai material separated from the clade of *A. placenta*. The overall form of the stroma can also be compared with *Aschersonia basicystis* from South America. However, a significant difference is in the shape of the South American conidia which are more similar to the Old World *Aschersonia oxystoma.*

This species is not commonly found in Thailand. So far, these samples are only known from two sites, in Pong Dueat Pa Pae Geyser in Huai Nam Dang National Park (north Thailand) and Sip Et Chan Waterfall, Khao Sok National Park (south Thailand).

References:

Chaverri, P., Liu, M. & Hodge K.T. (2008). Neotropical *Hypocrella* (anamorph *Aschersonia)*, *Moelleriella*, and *Samuelsia*. *Studies in Mycology* **60**: 1-66.

Petch, T. (1921). Studies in entomogenous fungi: II. The genera *Hypocrella* and *Aschersonia*. *Annals of the Royal Botanic Gardens Peradeniya* **7**: 167-278.

Aschersonia sp.

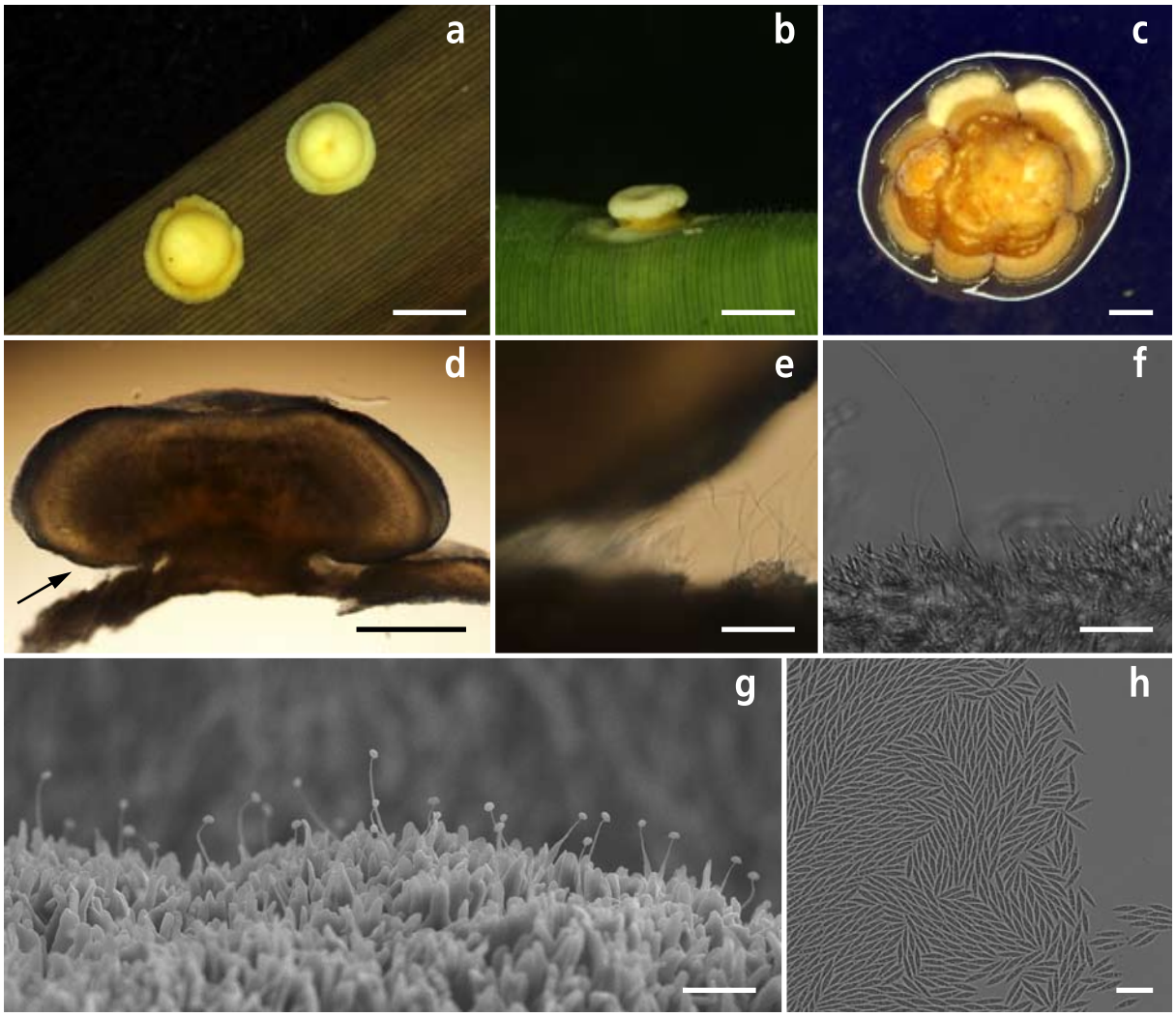

Fig. 4 a-b stroma on host; **c** culture at 20°C on PDA after 4 wk (sporulation present); **d** cross-section through stroma showing pycnidium (arrow); **e** paraphyses; **f** conidiogenous cells and paraphyses; **g** SEM of *Hirsutella*-like conidiophores on stroma; **h** conidia. Bars = 1 mm in Figs a-d, 50 µm in Fig e, 20 µm in Fig f, 10 µm in Figs g, e.

Conoideocrella luteorostrata (Zimm.) D. Johnson, G.-H. Sung, Hywel-Jones & Spatafora

Mycol. Res.: doi:10.1016/j.mycres.2008.09.008.

Synonyms:

Torrubiella luteorostrata Zimm., Zentralbl. Bakt. ParasitKde. Zweite Abt. **7**(no. 24): 872 (1901)

Anamorph state: *Paecilomyces cinnamomeus* (Petch) Samson & W. Gams, *Stud. Mycol.* **6**: 62 (1974)

Specimens were found on the underside of mostly dicotyledonous leaves of forest plants. Hosts are whitefly nymphs (*Aleyrodidae*). The fungus produces dark red or mustard-yellow stromata on the insect *ca.* 1-3 mm in diam. Perithecia developing either on the stroma or on the edges of the stroma, elongated flask-shaped to conical, bottom dark red to reddish-brown turning yellowish at the tip with ostioles hyaline or whitish, up to 1.2 mm long. Asci cylindrical, 450-600 x 4 m; ascospores filiform, 440-460 x 1 m, whole.

In culture the colonies on PDA are moderately fast-growing, attaining a diam. of 20-30 mm in 14 d at 25°C. Colonies white, floccose with cinnamon brown reverse, producing the *Paecilomyces* anamorph in culture.

Conoideocrella luteorostrata is a common species infecting scale insects in Thailand. There are two color morphs producing red and yellow stromata. The anamorph is more common than the teleomorph and can be collected all year round. The sexual state usually develops later in the rainy season until the cold season in November to January. The asci in the perithecia when mature seem to be discharged within a short period all together. The perithecia of herbarium specimens are usually void of asci/ascospores.

References:

Hywel-Jones, N.L. (1993). *Torrubiella luteorostrata,* a pathogen of scale insects and its association with *Paecilomyces cinnamomeus* with a note on *Torrubiella tenuis. Mycological Research* **97**: 1126-1130.

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Conoideocrella luteorostrata (Zimm.) D. Johnson, G.-H.Sung, Hywel-Jones & Spatafora

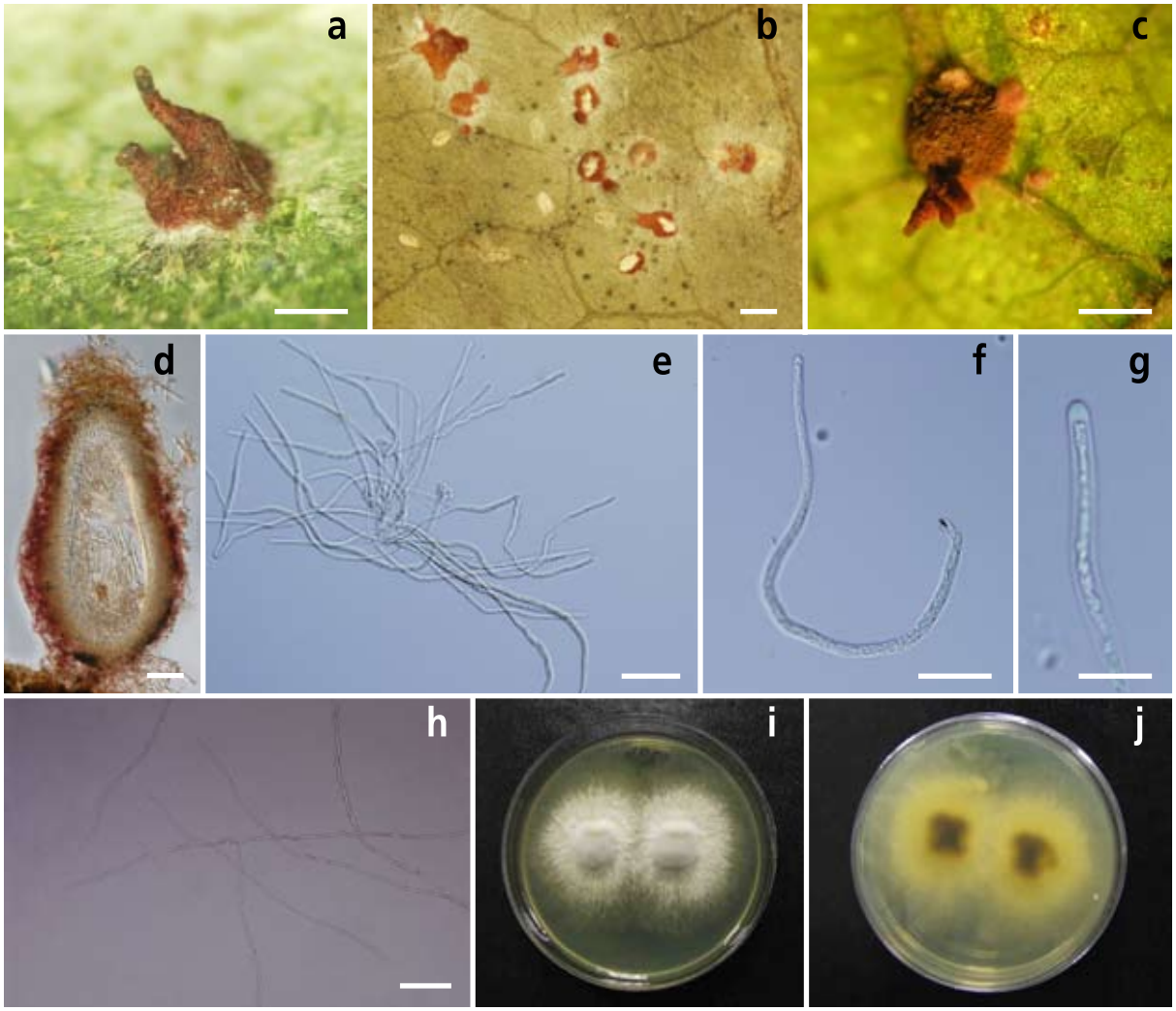


Fig. 5 a-c perithecia arising from the stromata covering the scale insect or in close proximity to the stroma; **d** cross-section of a perithecium; **e** asci; **f** whole ascus; **g** ascus tip; **h** whole ascospores discharged on PDA plate; **i** obverse of colony on PDA; **j** colony reverse on PDA. Bars = 1.5 mm in Figs a-c, 100 µm in Fig d, e, h, 50 µm in Fig e, 10 µm in Fig g.

Conoideocrella tenuis (Petch) D. Johnson, G.-H. Sung, Hywel-Jones & Spatafora

Mycol. Res.: doi:10.1016/j.mycres.2008.09.008

Synonyms:

Torrubiella tenuis Petch, Ann. R. Bot. Gard. Peradeniya **7**: 323 (1922)

Anamorph state: unknown

Specimens were found on the underside of mostly dicotyledonous leaves of forest plants. Hosts are whitefly nymphs (*Aleyrodidae*). The fungus produces a white mycelium over the insect, completely covering the host, *ca.* 900-1200 μm in diam. Perithecia developing either on the stroma or on the edges of the stroma, elongated flask-shaped to conical, white turning cream with age, up to 750 μm long. Asci cylindrical, up to 700 μm long x 3.5 μm wide; ascospores filiform, 350- 600 x 1 μm, whole.

In culture the colonies on PDA are moderately fast-growing, attaining a diam. of 3-4 cm in 14 d at 25° C. Colonies white, floccose with cream reverse.

Conoideocrella tenuis is a common species infecting scale insects in Thailand. The anamorph was not seen and did not develop in culture. Immature specimens with only the sterile stroma covering the host can be collected all year round. The sexual state usually develops later in the rainy season until the cold season in November to January in central and northern Thailand but throughout the year in places that are constantly high in humidity. Like *Conoideocrella luteorostrata*, the other member of the genus, the ascospores in the perithecia, when mature, seem to be discharged all at once. As a result, these cannot be seen easily in herbarium specimens.

References:

Hywel-Jones, N.L. (1993). *Torrubiella luteorostrata* a pathogen of scale insects and its association with *Paecilomyces cinnamomeus* with a note on *Torrubiella tenuis*. *Mycological Research* **97**: 1126-1130.

Johnson, D., Sung, G.-H, Hywel-Jones, N.L., Luangsa-ard, J.J., Bischoff, J.F., Kepler, R.M. &. Spatafora, J.W. (200-). Systematics and evolution of the genus *Torrubiella* (Hypocreales. Ascomycota). *Mycological Research*: doi:10.1016/j.mycres.2008.09.008.

Petch, T. (1922). Interim notes on entomogenous fungi. *Annals of the Royal Botanic Gardens Peradeniya* **7**: 323-327.

Petch, T. (1923). Studies in entomogenous fungi. *Transactions of the British Mycological Society* **9**: 108-128.

Sung, G.-H., Hywel-Jones, N.L., Sung, J.-M., Luangsa-ard, J.J., Shrestha, B. & Spatafora, J.W. (2007). Phylogenetic classification of *Cordyceps* and the clavicipitaceous fungi. *Studies in Mycology* **57**: 5-59.

Conoideocrella tenuis (Petch) D. Johnson, G.-H.Sung, Hywel-Jones & Spatafora

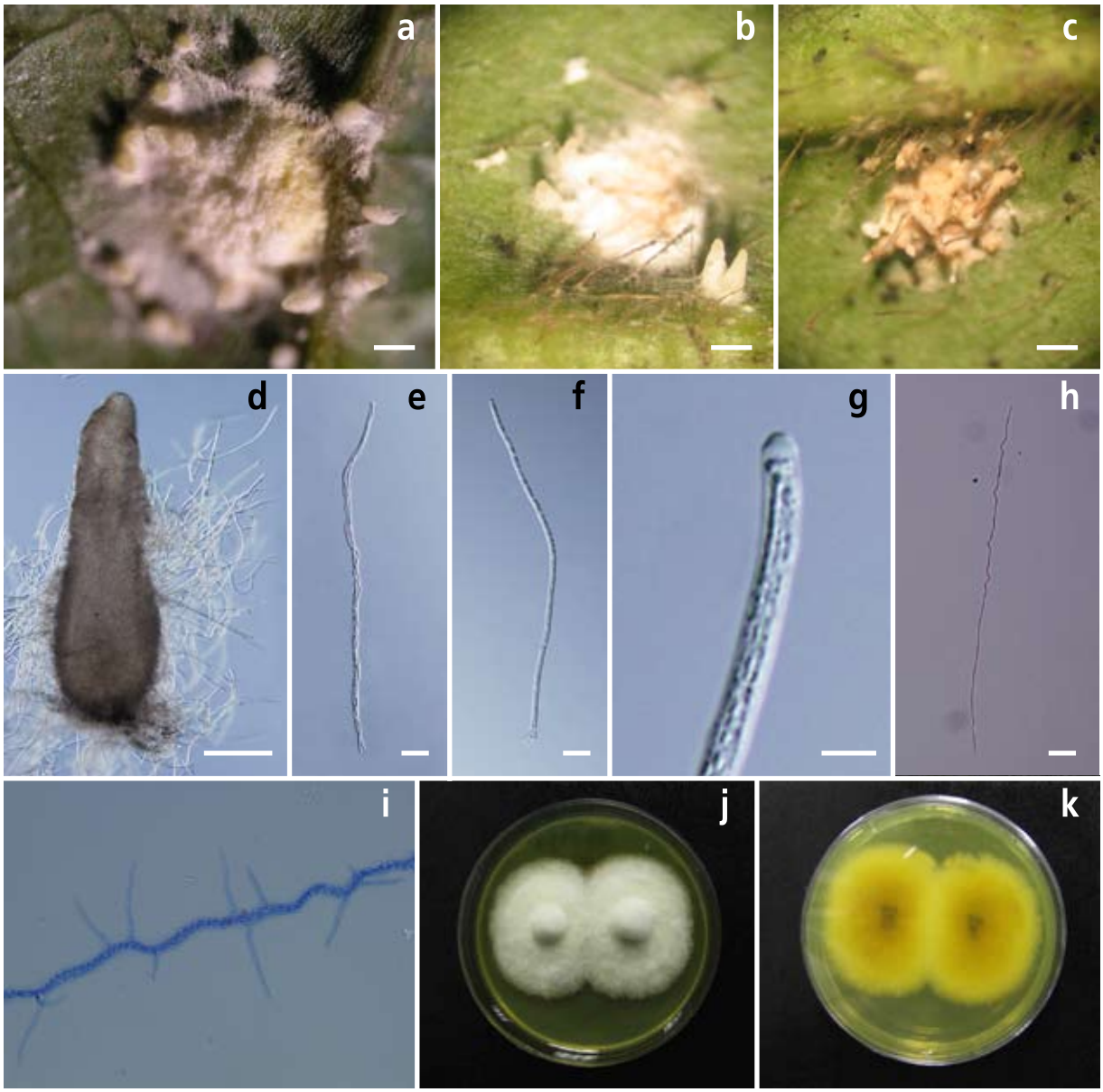


Fig. 6 a-c stromata on host with superficial perithecia; **d** perithecium; **e-f** ascus; **g** ascus tip; **h** ascospore; **i** germinating ascospores; **j** colony obverse on PDA; **k** colony reverse on PDA. Bars = 500 µm in Figs a-c, 200 µm in Fig d, 50 µm in Figs e, f, h, 5 µm in Fig g.

Cordyceps ninchukispora (C.H. Su & H.H. Wang) G.-H. Sung, J.-M. Sung, Hywel-Jones & Spatafora

Stud. Mycol. **57**: 49 (2007)

Synonym:

Phytocordyceps ninchukispora C.H. Su & H.H. Wang, Mycotaxon **26**: 338 (1986).

Anamorph state: *Isaria*-like, *Lecanicillium*-like, shows a lot of morphological plasticity

Specimens were in the ground or in the leaf litter. Hosts are lepidopteran pupae - *Limacodidae*. The fungus produces multiple bright orange stromata on the insect pupa, mostly erect up to 3 cm high. Fertile part is at the upper half of the stroma. Perithecia narrowly ovoid, orange, superficial and tightly packed perpendicular to the stroma, *ca.* 300-450 µm long, 85-190 µm in diam. Asci cylindrical, 8-spored, 200-240 x 2-2.5 µm. Ascopores whole, skipping-rope shaped, up to 200 µm long.

In culture the colonies on PDA are relatively fast-growing, attaining a diam. of 4-6 cm in 14 d at 25°C. Colonies floccose with areas looking powdery containing sporulating conidiophores. Colonies white changing to orange when the synnemata starts to develop.

Cordyceps ninchukispora can be found throughout Thailand from as far north in the mountains of Doi Inthanon until the rainforest of the south. The limacodid pupa resembles a seed and this can lead to assumptions that the host is a plant seed and not an insect. The genus *Mariannaea* has been linked with *Cordyceps ninchukispora* but the type species, *Mariannaea elegans*, is in the *Nectriaceae*. For now we consider the anamorph to be better compared with *Isaria/Lecanicillium.*

References:

Su, C.H. & H.H. Wang. (1986). *Phytocordyceps*, a new genus of the Clavicipitaceae. *Mycotaxon* **26**: 338.

Sung, G.-H., Hywel-Jones, N.L., Sung, J.-M., Luangsa-ard, J.J., Shrestha, B. & Spatafora, J.W. (2007). Phylogenetic classification of *Cordyceps* and the clavicipitaceous fungi. *Studies in Mycology* **57**: 5-59.

Cordyceps ninchukispora **(C.H. Su & H.H. Wang) G.-H. Sung, J.-M. Sung, Hywel-Jones & Spatafora**

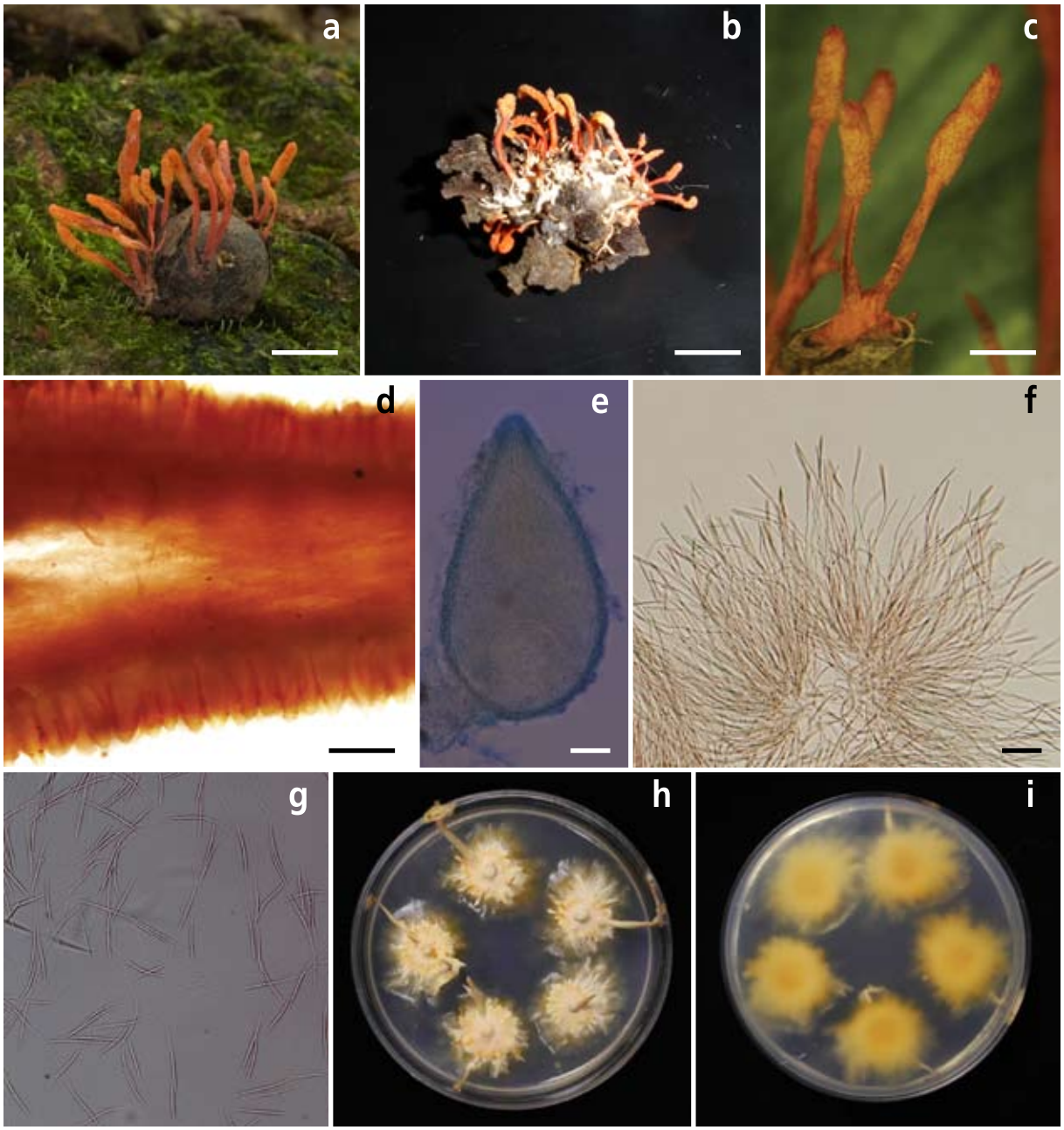


Fig. 7 a-c stromata arising from the host; **d** cross-section of the fertile part of the stroma; **e** perithecium; **f** asci; **g** ascospores; **h** colonies on PDA with synnemata; **i** reverse of colonies on PDA. Bars = 4 mm in Figs a, c, 5 mm in Fig b, 350 µm in Fig d, 50 µm in Figs e, f.

Cordyceps nipponica Kobayasi

Bull. Biogeogr. Soc. Japan **9**: 151 (1939)

Anamorph state: *Polycephalomyces* sp.

Specimens were found mostly buried in the soil, seldom in the leaf litter. Hosts are *Homoptera* or *Neuroptera* nymphs, up to 25 mm long. The fungus produces reddish brown stromata when fresh, erect, mostly branched, up to 40 mm long and 300-500 μm in diam. with orange brown perithecial plates, some terminal, with many subterminal plates. Perithecia, narrowly ovoid to conoid, within a loose hyphal network making a cushion surrounding the perithecial plates, perpendicular to the stroma, 580-720 x 200-250 μm. Asci cylindrical, almost as long as the perithecia, ascus tip 3-3.5 μm. Ascospores filiform, multiseptate but looks like whole ascospores when discharged, readily breaks into 128 fragments, 2.5-5 x 0.8-1 μm.

Colonies on PDA slow-growing, attaining a diam. of 3-4 cm in 14 d at 25°C. Colonies at first floccose with white mycelium, with age producing patches of slimy cream-yellow conidia.

Cordyceps nipponica is commonly found in the eastern part of Thailand especially near the Cambodian border but collections have also been made throughout Thailand. Kobayasi (1939) identified the anamorph as *Isaria nipponica*. No anamorph was seen in nature. However, in culture this is clearly allied to *Polycephalomyces*.

References:

Kobayasi, Y. (1939). On the genus *Cordyceps* and its allies on cicadae from Japan. *Bull. Biogeogr. Soc. Japan* **9** (8) : 145-176.

Sung, G.-H., Hywel-Jones, N.L., Sung, J.-M., Luangsa-ard, J.J., Shrestha, B. & Spatafora, J.W. (2007). Phylogenetic classification of *Cordyceps* and the clavicipitaceous fungi. *Studies in Mycology* **57**: 5-59.

Cordyceps nipponica Kobayasi

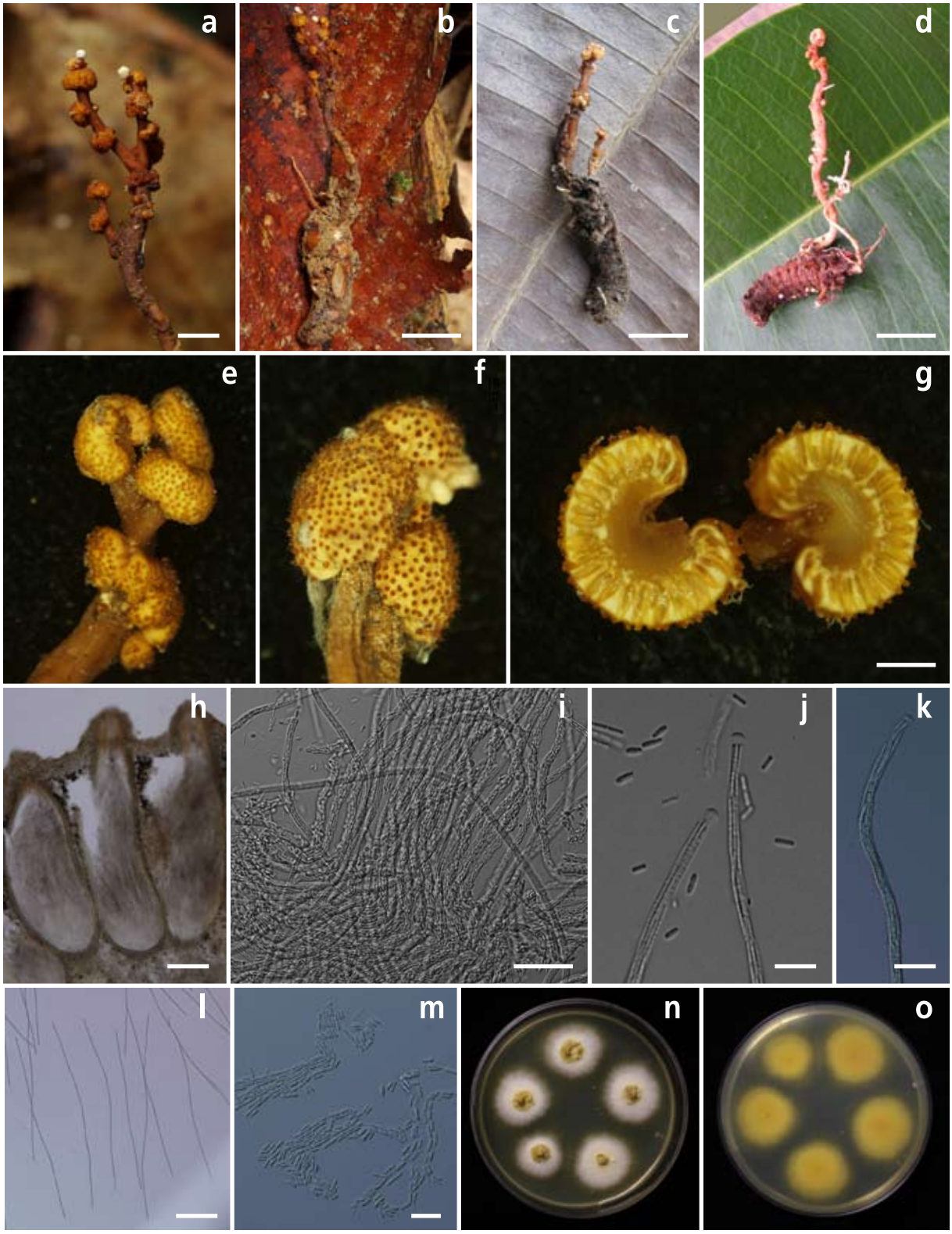


Fig. 8 a stroma showing several perithecial plates; **b-d** fungus on host; **e-f** perithecial plates; **g** section of **a** perithecial plate; **h** perithecium; **i-j** asci showing ascospores; **k** ascus tip; **l** discharged ascospores on plate; **m** part-spores; **n** colony obverse on PDA; **o** colony reverse on PDA. Bars = 1 cm in Figs a-d, 1 mm in Fig g, 100 µm in Figs h, l, 20 µm in Fig i, 10 µm in Figs j, k, m.

Gibellula sp.

Teleomorph state: suspected *Torrubiella* sp.

Specimens were found on spiders attached to the underside of leaves. Spider host completely covered by white mycelial mat. Synnemata one to several, arising directly from the dorsal side of the host, cylindric, attenuated, 1.5-2 mm long, 100 μm wide. Conidiophores arising from synnemata, hyaline, septate, scattered or densely compacted, 6.5-7.5 μm long, 2.5-4 μm wide, distinctly roughened along the length, narrowing abruptly to a slender apex. Conidial head 8-11 μm diam. Vesicle ellipsoidal, subglobose to globose, smooth, occasionally slightly verrucose, hyaline, 4.5 x 4.5-6.5 μm. Metulae broadly ellipsoidal, hyaline, smooth, occasionally 4-6.5 x 3-5 μm, borne on a vesicle. Conidiogenous cells cylindrical to flask-shaped, 6-7.5 x 2.5-4 μm. Conidia filiform to bacilliform, in chains, 3-6.5 x 1.5-2.5 μm, hyaline, smooth.

When conidia are spread on to PDA these are extremely slow-growing, attaining a diam. of 5-10 mm in 1 mo at 25°C.

This species is commonly found throughout Thailand but does not match with any described species. Its overall form is superficially similar to *Gibellula pulchra*. However, the gray-white mycelium, synnemata and conidia contrast with the sulfur-yellow mycelium and purple spore heads of *Gibellula pulchra*. The *Torrubiella* state has not been seen.

References:

Samson, R. A. & Evans, H. C. (1992). New species of *Gibellula* on spiders (Araneida) from South America. *Mycologia* **84**: 300-314.

Hirsutella formicarum Petch

Trans. Br. Mycol. Soc. **19**: 183 (1935)

Teleomorph state: *Ophiocordyceps unilateralis* (Tul. & C. Tul.) Petch

Specimens were found attached to the underside of leaves of forest plants. Hosts are ants (*Hymenoptera*: *Formicinae*). Synnemata arising from between the head and the thorax. They are slender, light-brown to brown, 3-8 mm long, 50-80 μm wide, composed of compact longitudinal brown hyphae. Hyphae septate, smooth. Conidiogenous cells arising from the hyphae of synnemata. Conidiogenous cells produce a single long, slender phialide with one or two conidia. Conidia hyaline, smooth, ovoid, 4-7 x 2-3 μm.

When conidia are spread on to PDA these are very slow to germinate – if at all. In Thailand only one culture was made from conidia growing directly on PDA. Many more isolates have been secured by first spreading conidia onto PDA and then transferring to Grace's insect tissue culture medium (Wongsa *et al.* 2005). The original culture from PDA readily produced the *Hirsutella* in culture. However, most of the cultures made from insect tissue culture medium remain sterile when eventually transferred to PDA. To date, only one isolate has been able to make the *Hirsutella* when transferred to PDA (Fig. l).

Hirsutella formicarum has been found throughout Thailand from Doi Inthanon National Park in the North to Hala Bala National Park on the Malay border. Usually the hosts bite into the underside of leaves. However, occasionally hosts appear to wander to the drip tip of forest leaves and die by biting into the tip and then clinging to the leaf-tip.

References:

Evans, H.C. & Samson, R.A. (1984). *Cordyceps* species and their anamorphs pathogenic on ants (Formicidae) in tropical forest ecosystems ll. The *Camponotus* (Formicinae) complex. *Transactions of the British Mycological Society* **82**: 127-150.

Petch, T. (1935). Notes on entomogenous fungi. *Transactions of the British Mycological Society* **19**: 161-194.

Wongsa, P., Tasanatai, K., Watts, P. & Hywel-Jones, N.L. (2005). Isolation and *in vitro* cultivation of the insect pathogenic fungus *Cordyceps unilateralis*. *Mycological Research* **109**: 936-940.

Hirsutella formicarum Petch

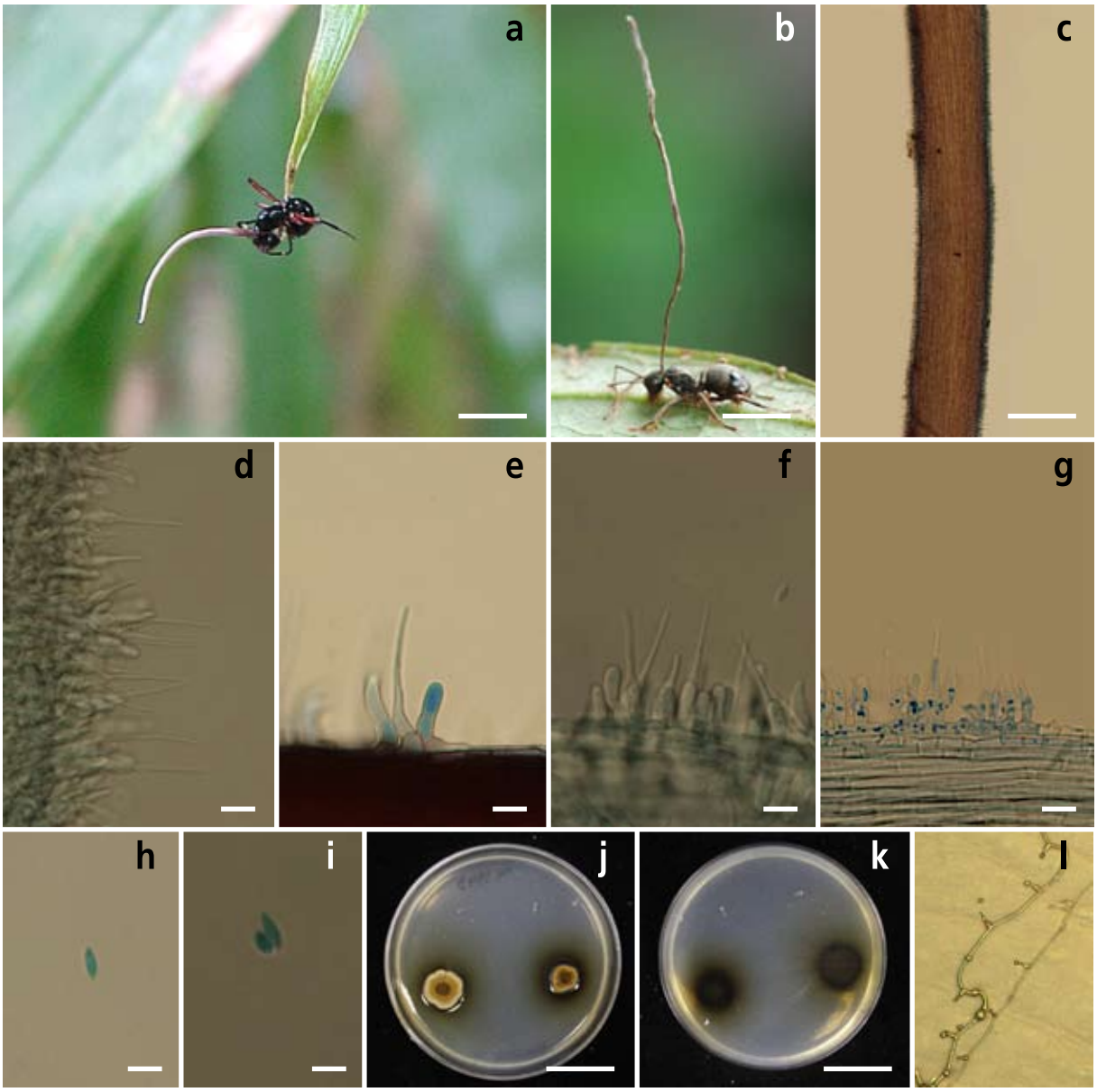


Fig. 10 a-b synnema arising from between the head and the thorax of ants; **c-g** part of synnema showing conidiogenous cells; **h-i** conidia; **j-k** colonies on PDA; **l** conidiogenous cells structures on PDA. Bars = 1mm in Figs a-b, 50 µm in Fig c, 5 µm in Figs d-i, 1 cm in Figs j-k

Hirsutella saussurei (Cooke) Speare

Mycologia **12**: 69 (1920)

Synonyms:

Isaria saussurei Cooke (1892)

Teleomorph state: *Ophiocordyceps humberti* (C.P. Robin) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora (2007)

Specimens were found attached to the margins of leaves of forest plants. Hosts are *Hymenoptera* (*Polistes* and vespid wasps). Synnemata arising from various parts of the head, thorax and abdomen including legs, slender, terete, attenuated upward, very variable in length, 1-15 mm long, 50-80 μm wide, light brown to dark brown, composed of compact, parallel, longitudinal hyphae. Synnemata sometimes develop several short side branches. Conidiogeneous cells monophialidic, scattered to moderately crowded, arising laterally from the hyphae, cylindric to ellipsoid, 15-25 μm long, forming a thin long neck, 25-40 μm long, 1.5-2.5 μm wide. Conidia hyaline, smooth, one-celled, citriform, 5-10 x 4-7 μm.

Conidia germinate readily on PDA. Colonies are gray to gray brown with a hyaline margin immersed in the agar, slow-growing reaching 5-6 cm in 3 mo. On reaching the edge of a 6 cm petri plate cultures produce erect synnemata similar to those found on the host and *Hirsutella* phialides and conidia become clearly visible.

Specimens have been found from northern Thailand (Loei Province) to the far south on the Malay border (Hala Bala Wildlife Sanctuary). Usually this is very rare with only solitary specimens being found. However, at Nam Nao National Park (Petchabun Province) an epizootic was observed where 30-40 dead wasps could be found attached to the margin of leaves.

References:

Speare, A.T. (1920). On certain entomogenous fungi. *Mycologia* **12**: 62-76.

Hirsutella saussurei (Cooke) Speare

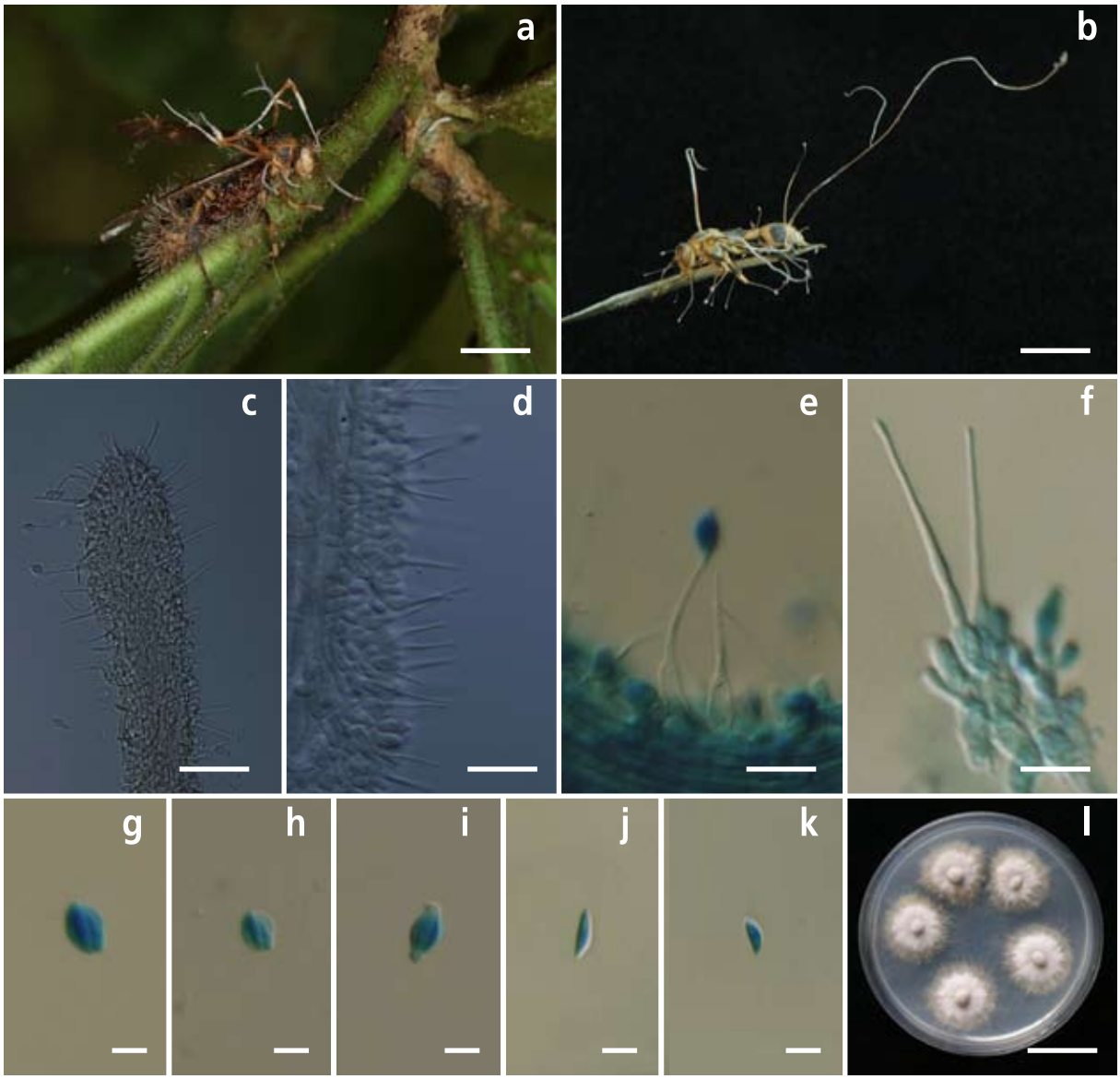


Fig. 11 a-b synnemata arising from hosts; **c-d** part of synnema showing conidiogenous cells; **e-f** conidiogenous cells with attached conidia; **g-i** conidia with mucous coat; **j-k** conidia without mucous coat showing citriform shape; **l** colonies on PDA. Bars = 10 mm in Figs a-b, 40 µm in Figs c-d, 10 µm in Figs e-f, 5 µm Figs g-k, 10 mm in Fig l.

Hymenostilbe dipterigena Petch

Trans. Br. Mycol. Soc. **16**: 212 (1932)

Teleomorph state: *Ophiocordyceps dipterigena* (Berk. & Broome) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora

Specimens were found on the underside of leaves of forest plants. Hosts are dipteran flies (especially *Asilidae* and *Calliphoridae*). Synnemata solitary, arising from posterior abdomen of host, 50-100 mm long, 0.5-1 mm wide, brown to dark brown at the base, light brown to cream white toward the apex, composed of longitudinal, more or less parallel, closely compacted hyphae. Hyphae hyaline, slightly thick-walled, smooth. Conidiophores arising from hyphae of synnemata, forming a hymenial layer, consisting of clavate, cylindrical basal parts, and solitary, 10-20 x 2-3 μm. Conidia hyaline, smooth, ellipsoid to obovoid, occasionally broadly fusoid, one-celled, 3.5-7 x 2-3 μm.

Conidia germinate within 24-36 h on PDA to produce slow-growing gray-white colonies becoming irregularly gray-brown with age. Colonies take *ca.* 2 mo to grow 2-3 cm at 25°C. Colonies remain sterile.

This species is rather common in Thailand. The specimens invariably have two perithecial clavae and one conidial synnema. The flies usually appear cemented to the underside of leaves by a pad of mycelium emerging from the abdomen. Mycelium also emerges from the mouthparts and feet to further fix the fly to the leaf.

References:

Petch, T. (1932) Notes on entomogenous fungi. *Transactions of the British Mycological Society* **16**: 209-245.

Hymenostilbe dipterigena Petch

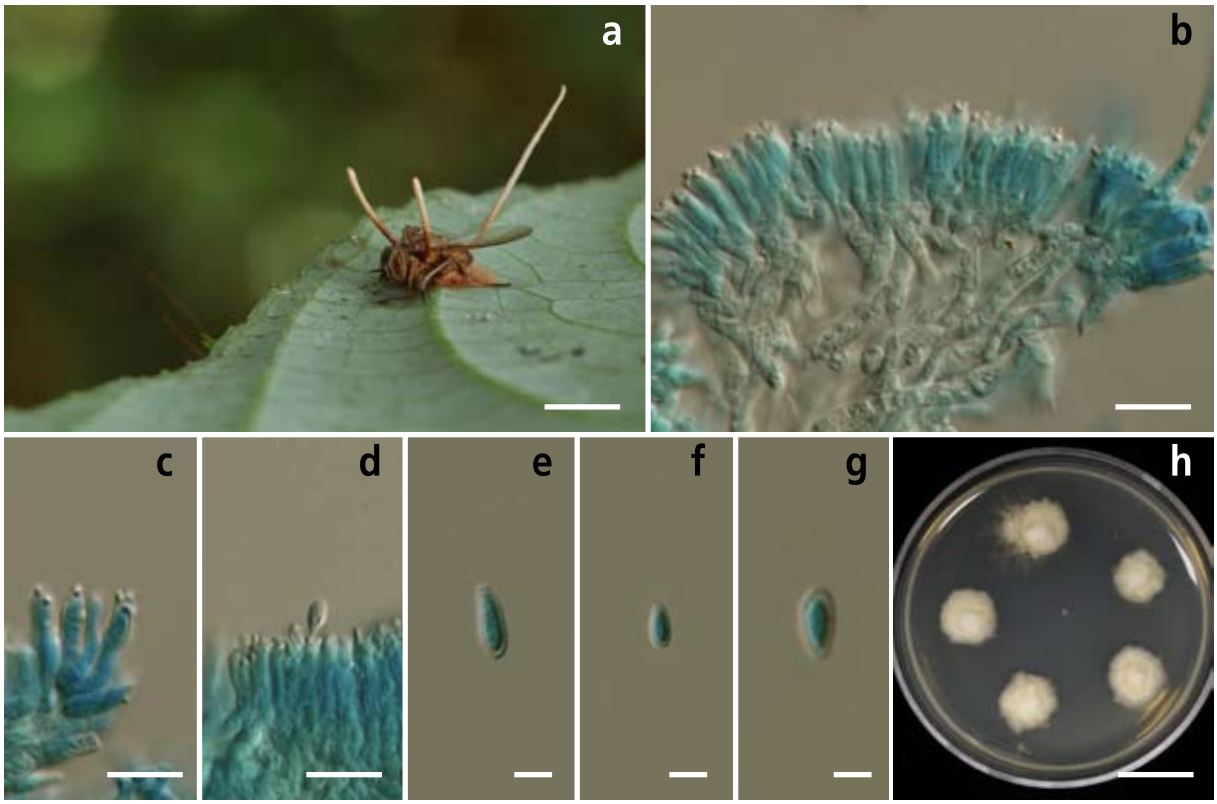


Fig. 12 a synnemata arising from fly; **b-d** part of synnema showing hymenial conidiogenous cells; **e-g** conidia; **f** young colony on PDA. Bars = 5 mm in Fig a, 10 µm in Figs b-e, 5 µm in Figs f-g, 10 µm Fig h.

Hymenostilbe ventricosa Hywel-Jones

Mycol. Res. **99**: 1201-1204 (1995)

Synonyms:

Hymenostilbe furcata Aung, J.C. Kang, Z.Q. Liang, Soytong & K.D. Hyde, Mycotaxon **97**: 243 (2006)

Teleomorph state: Not known

Hosts are cockroach nymphs (*Blattaria*). Synnemata up to 20 (rarely one), up to 30 mm long, x 200-350 μm wide, cylindrical, very pale pink. Central core of parallel hyphae, cells 9.5-40 μm long x 3-4 μm wide. Hymenium of basal cells 4-18 μm long x 2.5-4 μm wide, each with one or two conidiogenous cells. Conidiogenous cells polyblastic, cylindrical to clavate, 11-20 μm long x 4.5-6 μm wide. Denticles crowded at the apex, cuneiform, 2-5 μm long, 1-1.5 μm wide at the base x 1.5-2.5 μm at the apex. Conidia solitary, ventricose, smooth-walled, hyaline, 10-14 μm x 3.5-5.5 μm, base truncate 2-3 μm wide.

Conidia on PDA germinated to produce microconidia but developed no further. Recently a method for isolating *Ophiocordyceps unilateralis* has proved successful with slow-growing isolates of blastospores in Grace's insect tissue culture medium giving rise to slow-growing cultures on PDA (Wongsa *et al.* 2005).

Hymenostilbe ventricosa is known only from central and northern Thailand: from Nam Nao National Park, Petchabun; Khao Yai National Park, Nakorn Ratchassima; Khlong Lan National Park, Kamphangpet; Phu Luang Wildlife Sanctuary, Loei and Huai Nam Daeng National Park, Chiang Mai. It is especially common at the end of the rainy season.

Aung *et al.* (2006) described *Hymenostilbe furcata* from a nymph in the insect order *Hemiptera*. However, the photograph of the nymph is clearly a cockroach in the order *Blattaria* and the description of the furcate nature of the conidiogenous cells is a misinterpretation of the cuneiform denticles. Given the host, the unique shape of the conidia and other details *Hymenostilbe furcata* is really *Hymenostilbe ventricosa*.

References:

Aung, O.M., Kang, J.C., Liang, Z.Q., Soytong, K. & Hyde, K.D. (2006). A new entomopathogenic species, *Hymenostilbe furcata*, parasitic on a hemipteran nymph in northern Thailand. *Mycotaxon* **97**: 241-245.

Hywel-Jones, N.L. (1995). *Hymenostilbe ventricosa* sp. nov. a pathogen of cockroaches in Thailand. *Mycological Research* **99**: 1201-1204.

Wongsa, P., Tasanatai, K., Watts, P. & Hywel-Jones, N.L. (2005). Isolation and cultivation of the insect pathogenic fungus *Cordyceps unilateralis*. *Mycological Research* **109**, 936-940.

Hymenostilbe ventricosa Hywel-Jones

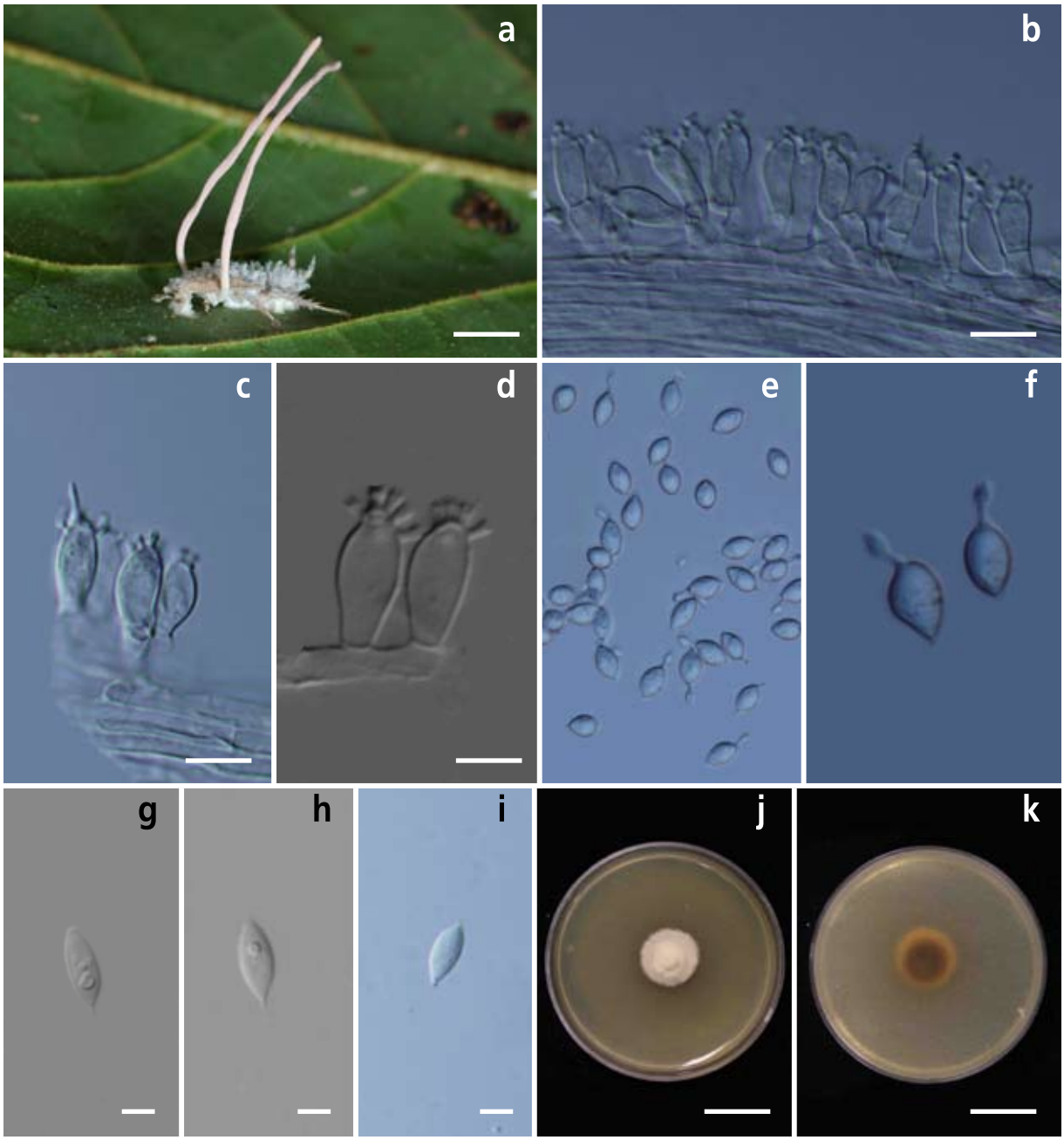


Fig. 13 a pale pink synnemata arising from a small cockroach; **b-d** conidiogenous cells forming a hymenium-like layer; **e-f** germination of conidia; **g-i** conidia; **j-k** colony on PDA. Bars = 5 mm in Fig a, 10 µm in Figs b-i, 10 mm in Figs j-k.

Metarhizium cylindrosporae Q.T. Chen & H.L. Guo

Acta. Mycol. Sin. **5**: 177-184 (1986)

Synonyms:

Nomuraea cylindrosporae (Q.T. Chen & H.L. Guo) Tzean, S.S., Hsieh, J.L. Chen & W.J. Wu Mycologia **85:** 514-519 (1993).

Teleomorph: expected in *Metacordyceps*

Specimens were found clinging on to twigs and branches of dicotyledonous plants. Hosts are adult cicadas. The fungus starts to come out of the joints especially between the head and the thorax and spreads along the body of the host. Mycelia at first white, turning green when sporulation has taken place. Conidiophores are of variable length, simple to two-staged branched, penicillate forming a green sporulation layer at the apex. Phialides short cylindrical, reminiscent of *Nomuraea,* 6-7 x 2.5-3 µm. Conidia cylindrical with rounded ends, green, 8-16 x 1.6-4.2 µm. The philalides are mixed with small globose to fusiform conidia, which are believed to be the young stages and elongates until *ca.* 16 µm long.

In culture the colonies on PDA are relatively fast-growing, attaining a diam. of 3-4 cm in 14 d at 25°C. Colonies floccose with areas looking powdery containing sporulating conidiophores. Colonies white changing to green when the conidia start to mature.

Metarhizium cylindrosporae is not a common species but when it infects the cicadas there can be an epizootic and several specimens can be collected at once. This infects a wide range of cicada species but is especially notable on a large *Tosena* sp.

References:

Guo, H.L., Ye, Yue, Chen, Q.T., & Fu, (1986). Three new species of *Metarhizium. Acta Mycol. Sin.* **5**: 177-184.

Tzean, S.S., Hsieh, L.S., Chen J.L., & Wu, W.J. (1993). *Nomuraea cylindrospora* comb. nov. *Mycologia* **85**: 514-519.

Metarhizium cylindrosporae Q.T. Chen & H.L. Guo

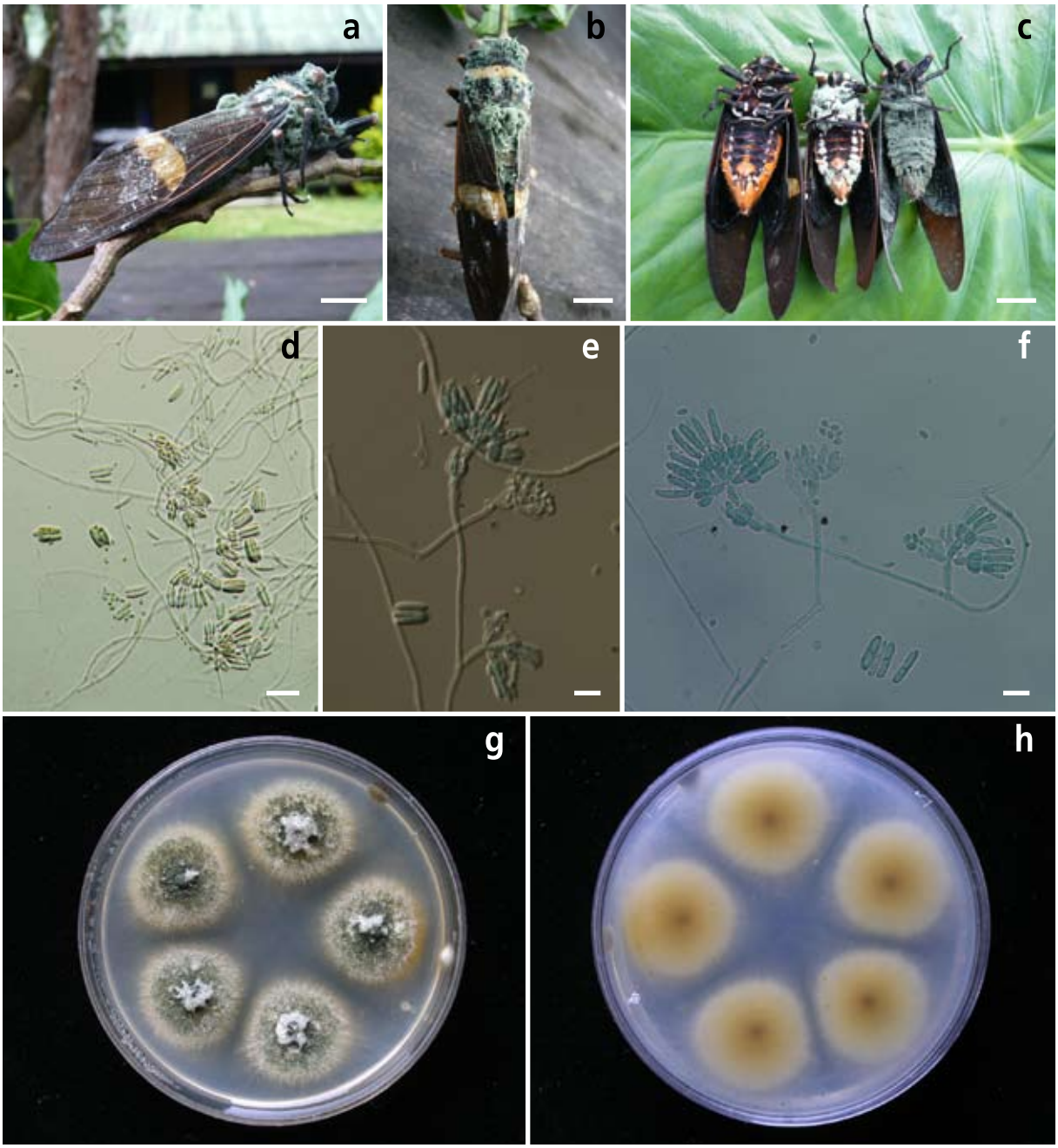


Fig. 14 a-c fungus on *Tosena* sp.; **d-f** conidiophores bearing two kinds of conidial shapes and sizes; **g** colony obverse on PDA; **h** colony reverse on PDA. Bars = 1 cm in Figs a-c, 50 µm in Fig d, 10 µm in Figs e, f.

Moelleriella aff. *mollii* Koorders

Bot. Untersuch., p. 179 (1907)

Anamorph state: *Aschersonia* sp.

Specimens were found on the underside of dicotyledonous leaves of forest plants. Hosts were scale insect nymphs (*Homoptera*). Stromata flattened pulvinate, up to 4 mm diam., about 1.5 mm high, white yellowish, mycelium cottony; perithecia scattered to crowded, slightly projecting, red-brown, broadly flask-shaped with short neck, *ca.* 400 µm long, *ca.* 220 µm diam., with a hyaline cap 6 µm long and 5 µm diam.; asci cylindric up to 225 µm long and 6-6.5 µm diam.; ascospores divide into part-spores, cylindrical, hyaline, 12.5-16.5 x 2-2.5 µm.

Part-spores will germinate within 24 h on PDA. Some part-spores produced secondary conidia on hard surfaces (*eg.* cover slip). Colonies are slow-growing, attaining a diam. of 5 mm and producing conidia after *ca.* 2 wk on PDA at 20°C. Colonies compact, pale yellow, spore mass pale yellow spreading over the stroma.

This species is morphologically similar to *Moelleriella mollii.* However, recent molecular work indicated that this species is basal to *Moelleriella mollii.* An important difference is that the ostioles of *M. mollii* are cream brown whereas those of the current species are red-brown. So far, the teleomorph is only known from one site in Khao Yai National Park (central Thailand) while the *Aschersonia* anamorph was found in Loei Province (north eastern Thailand).

References:

Chaverri, P., Liu, M. & Hodge K.T. (2008). Neotropical *Hypocrella* (anamorph *Aschersonia*), *Moelleriella,* and *Samuelsia. Studies in Mycology* **60**: 1-66.

Mains, E.B. (1959). North American species of *Aschersonia* parasitic on *Aleyrodidae. Journal of Insect Pathology* **1**: 43-47.

Petch, T. (1921). Studies in entomogenous fungi: II. The genera *Hypocrella* and *Aschersonia. Annals of the Royal Botanic Gardens Peradeniya* **7**: 167-278.

Moelleriella aff. *mollii*

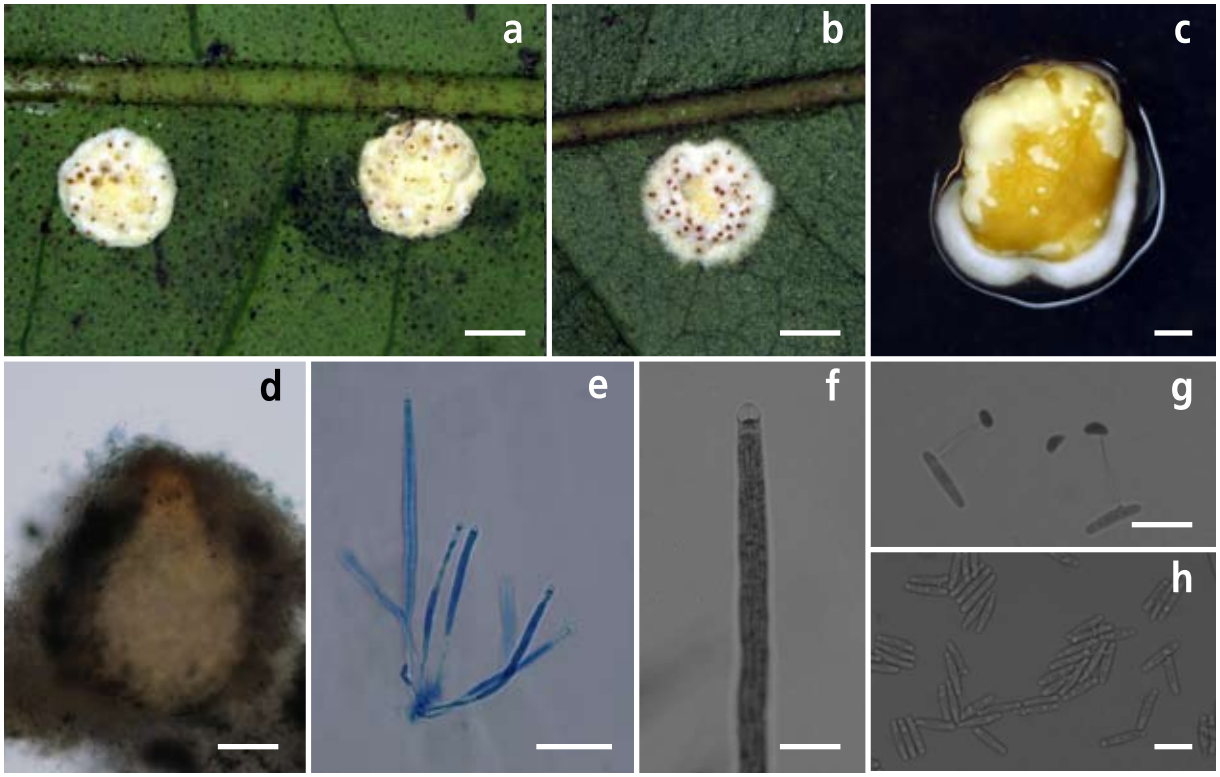


Fig. 15 a-b stroma on scale insect; **c** culture at 20°C on PDA after 4 wk (sporulation present as cream yellow masses); **d** perithecia; **e** one mature ascus with four developing asci of different lengths; **f** tip of ascus; **g** secondary conidia produced from part-spores; **h** part-spores. Bars = 1 mm in Figs a-c, 100 µm in Fig d, 50 µm in Fig e, 10 µm in Figs f-h.

Moelleriella reineckiana Henn.

Engler's Bot. Jahrbuch, **23**: 286 (1896)

Synonyms:

Hypocrella pernettyæ Pat., Ann. Bot. Jardin Buitenzorg, 1st Supplement, p. 125 (1897);
non *Fleischeria scleroliuides* v. Höhnel, Fragmente zur Mykologie, 8. Mitt., p. 26 (1909)
Hypocrella melæna Syd., Philippine Jour. of Sci., 8.C, p. 494

Anamorph state: *Aschersonia marginata* E. & E.

Specimens were found on the under and upper side of leaves of forest plants and often along the mid-vein and petioles. Hosts are scale insect nymphs (*Homoptera*, *Coccoidea*). Stroma, hemispherical (conico-pulvinate to pulvinate in immature specimens), moderately hard, consisting of densely interwoven hyphae, up to 4 mm diam., *ca.* 1.5-2 mm high, orange to brownish orange; perithecia scattered, slightly projecting, ostioles red brown, flask-shaped, *ca.* 400 µm deep, 125-150 µm diam. (300 x 150 µm); asci cylindrical 160-250 x 7.5-8.5 µm (170-180 x 8 µm); ascospores divide into part-spores, cylindrical, ends tapering 10-12.5 -1.5-2 µm (6-8 x 1-1.5 µm).

Conidia will germinate within 24 h on PDA. Colonies are slow-growing attaining a diam. of 5 mm and producing conidia after *ca.* 4 wk on PDA at 20°C. Colonies compact, pale yellow, spore mass pale orange spreading over the culture.

Collections in Thailand have been from Doi Inthanon National Park in the far north and as far as Khao Pu – Khao Ya National Park in the south. Collections have been made throughout the year. To date there have been no records from monocotyledonous plants (*eg.* Bamboo).

References:

Chaverri, P., Liu, M. & Hodge K.T. (2008). Neotropical *Hypocrella* (anamorph *Aschersonia*), *Moelleriella,* and *Samuelsia. Studies in Mycology* **60**: 1-66.

Mains, E.B. (1959). North American species of *Aschersonia* parasitic on *Aleyrodidae. Journal of Insect pathology* **1**: 43-47.

Petch, T. (1921). Studies in entomogenous fungi: II. The genera *Hypocrella* and *Aschersonia. Annals of the Royal Botanic Gardens Peradeniya* **7**: 167-278.

Moelleriella reineckiana Henn.

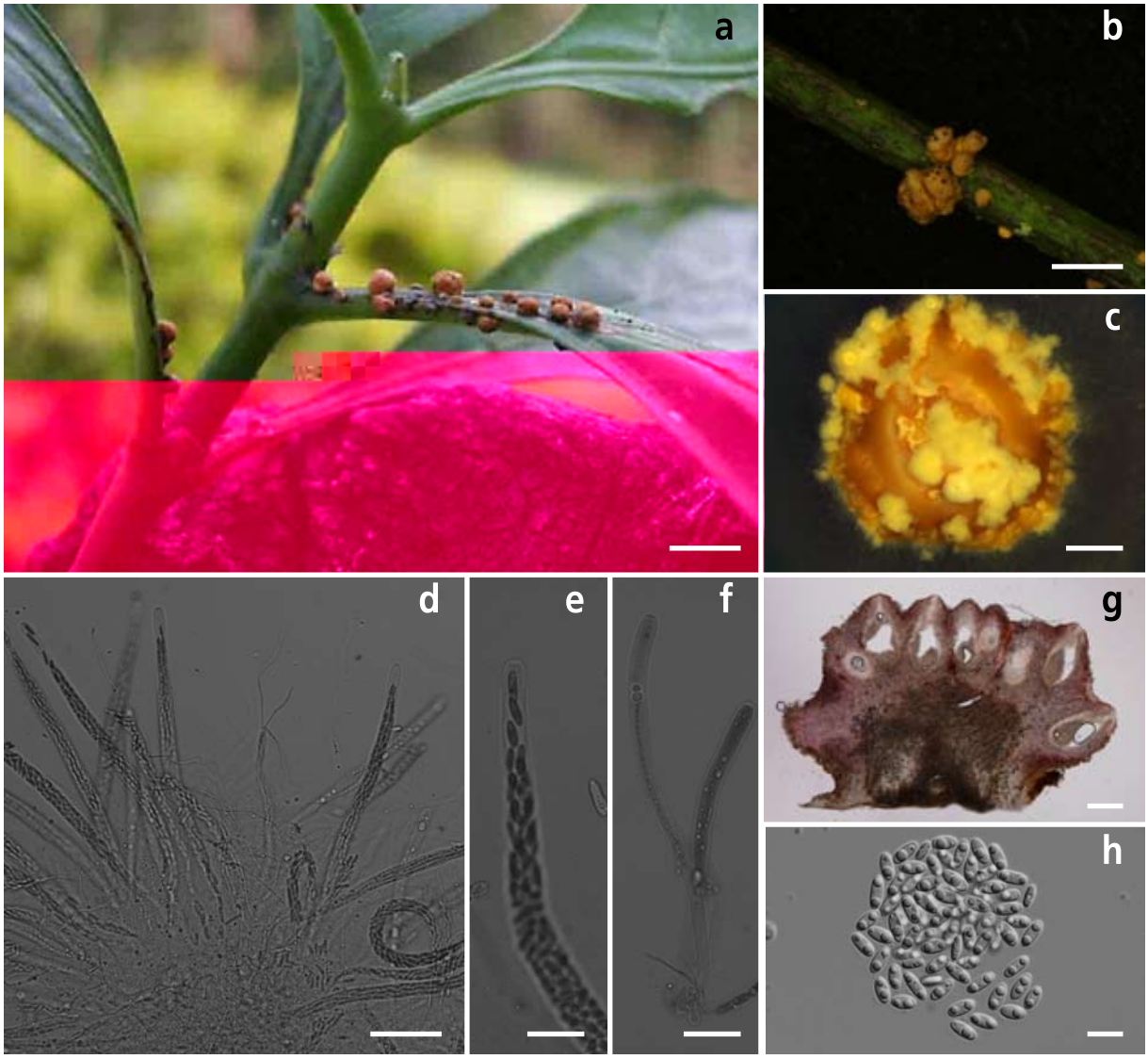


Fig. 16 a-b stroma on scale insect; **c** culture at 20°C on PDA after 4 wk (sporulation present as pale orange masses); **d** mature asci; **e** part of ascus with thickened tip showing ascospores separating into part-spores within the ascus; **f** immature asci; **g** section through stroma showing perithecia; **h** conidia. Bars = 10 mm in Fig a, 5 mm in Fig b, 1 mm in Fig c, 50 µm in Fig d, 10 µm in Figs e, h, 20 µm in Fig f, 200 µm in Fig g.

Moelleriella sp.

Anamorph state: *Aschersonia* sp.

Specimens were found on the underside and stems of dicotyledonous leaves of forest plants. Hosts were scale insect nymphs (*Homoptera*, *Coccoidea*). Stromata hemispherical, moderately hard, somewhat surrounded by a broad hypothallus, up to 5 mm in diam., *ca.* 3.5 mm high, when fresh, orange to brownish orange, when old dark orange to orange red, perithecia scattered to crowded, slightly projecting, red brown, broadly flask-shaped, *ca.* 300-400 µm long, 150-165 µm diam., with a hyaline cap 2.5 µm long and 3.8 µm diam.; asci cylindric up to 200 µm long and 6-7 µm diam.; ascospores divide into part-spores, cylindrical, hyaline, 7.5-10 x 1-2 µm.

Conidia will germinate within 24 h on PDA. Colonies are slow-growing attaining a diam. of 8 mm and producing conidia after *ca.* 4 wk on PDA at 20°C. Colonies compact, pale yellow, spore mass pale yellow spreading over the stroma.

This species is rare with only two collections from Chatchanat Farm, Loei province and Doi Inthanon National Park (Chiang Mai province) in September 2006.

References:

Chaverri, P., Lui, M., & Hodge, K.T. (2008). Neotropical *Hypocrella* (anamorph *Aschersonia*), *Moelleriella*, and *Samuelsia*. *Studies in Mycology* **60**: 1-66.

Mains, E.B. (1959). North American species of *Aschersonia* parasitic on *Aleyrodidae*. *Journal of Insect Pathology* **1**: 43-47.

Petch, T. (1921). Studies in entomogenous fungi: II. The genera *Hypocrella* and *Aschersonia*. *Annals of the Royal Botanic Gardens Peradeniya* **7**: 167-278.

Moelleriella sp.

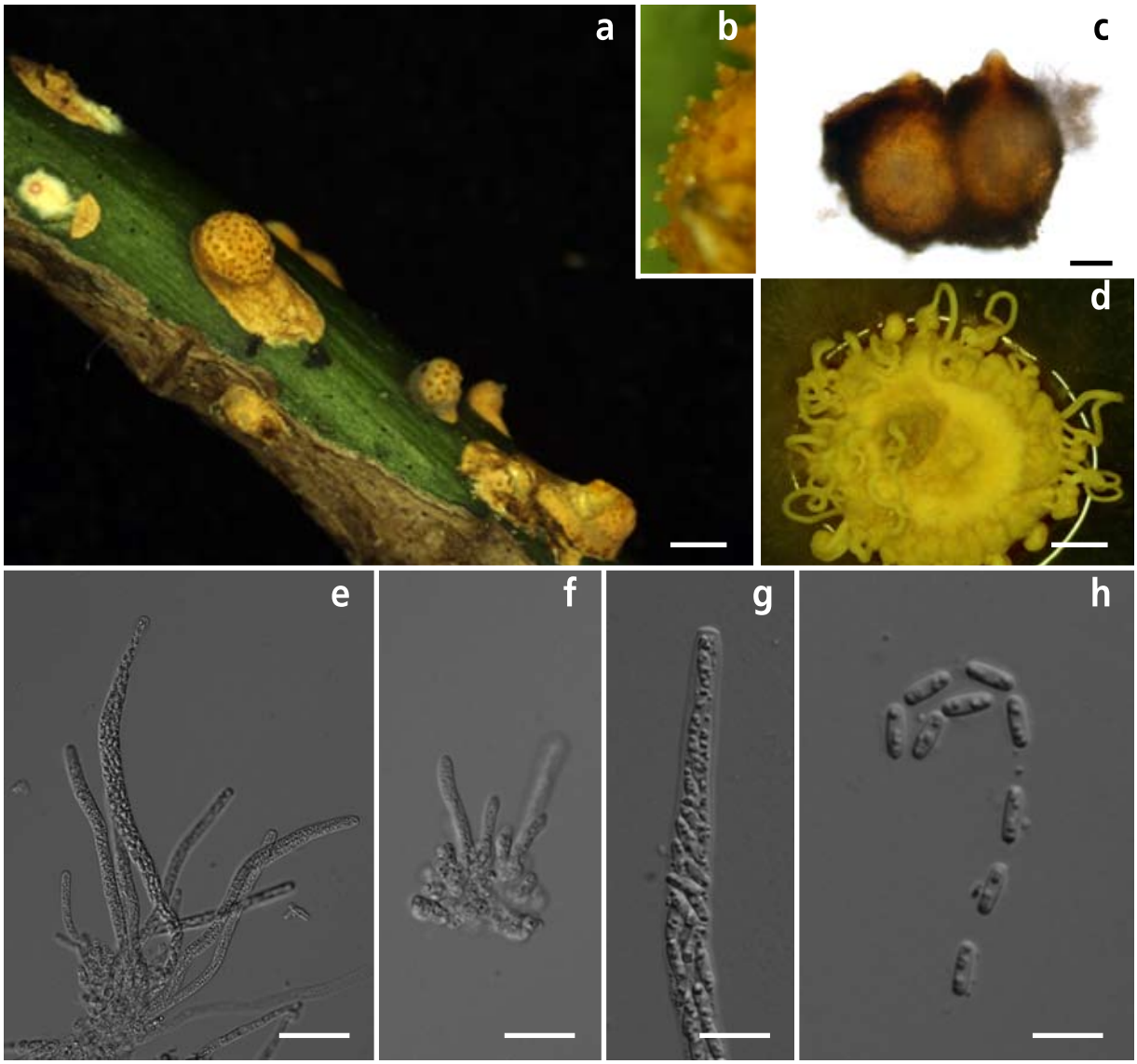


Fig. 17 a-b stroma on scale insect; **c** perithecia; **d** culture at 20°C on PDA after 4 wk (sporulation present as cream yellow masses); **e** showing one mature ascus with separated part-spores plus developing asci of different lengths; **f** immature asci; **g** tip of ascus; **h** part-spores. Bars = 1 mm in Figs a, d, 100 µm in Fig c, 50 µm in Fig f, 20 µm in Fig e, 10 µm in Figs g, h.

Ophiocordyceps aff. *acicularis* (Ravenel) Petch

Trans. Brit. mycol. Soc., **18**: 60 (1933)

Anamorph state: *Hirsutella* sp.

Specimens were found in the leaf litter or on fallen, rotting logs. Hosts are lepidopteran larvae. The fungus produces one to several stromata on the insect larva, mostly erect, seldom branched, slender cylindric, 5-14 cm long. The formation of the anamorph state precedes the formation of the teleomorph. Fertile part starts midway along the stroma with anamorph state usually at the tip of the stroma. Perithecia superficial, distributed irregularly, partly gregarious, others isolated, subglobose to ovoid with flattened base, light to dark brown, 350-400 x 335-400 µm. Asci cylindrical, 170-250 µm x 5.5-6.5 µm. Ascospores filiform, 160-250 µm x 1.5 µm, not breaking into part-spores.

In culture the colonies on PDA are slow-growing, attaining a diam. of 1-2 cm in 14 d at 25°C. Colonies cream to cinnamon brown. Reverse dark brown. Colonies produce brown synnemata after 1-2 mo with a pruinose area bearing conidiogenous cells and conidia of a *Hirsutella* anamorph.

Ophiocordyceps aff. *acicularis* can be collected all throughout Thailand at different times of the year and is a relatively common *Ophiocordyceps* species on large larvae with urticating hairs. This is one of several species found in Thailand on *Lepidoptera* larvae which produce superficial perithecia and discharge whole ascospores. All members of this group produce a *Hirsutella* at the apex of the slender, wiry stroma. This was initially compared with the North American *Ophiocordyceps acicularis*. The Thai species differs significantly in having a *Lepidoptera* host rather than *Coleoptera*. The group producing superficial perithecia and whole ascospores is the subject of a major study in Thailand.

References:

Ravenel, (1856). Act. Linn. Soc: 159.

Petch, T. (1933). *Transactions of the British Mycological Society* **18**: 60.

Sung, G.-H., Hywel-Jones, N.L., Sung, J.-M., Luangsa-ard, J.J., Shrestha, B. & Spatafora, J.W. (2007). Phylogenetic classification of *Cordyceps* and the clavicipitaceous fungi. *Studies in Mycology* **57**: 5-59.

Ophiocordyceps aff. *acicularis*

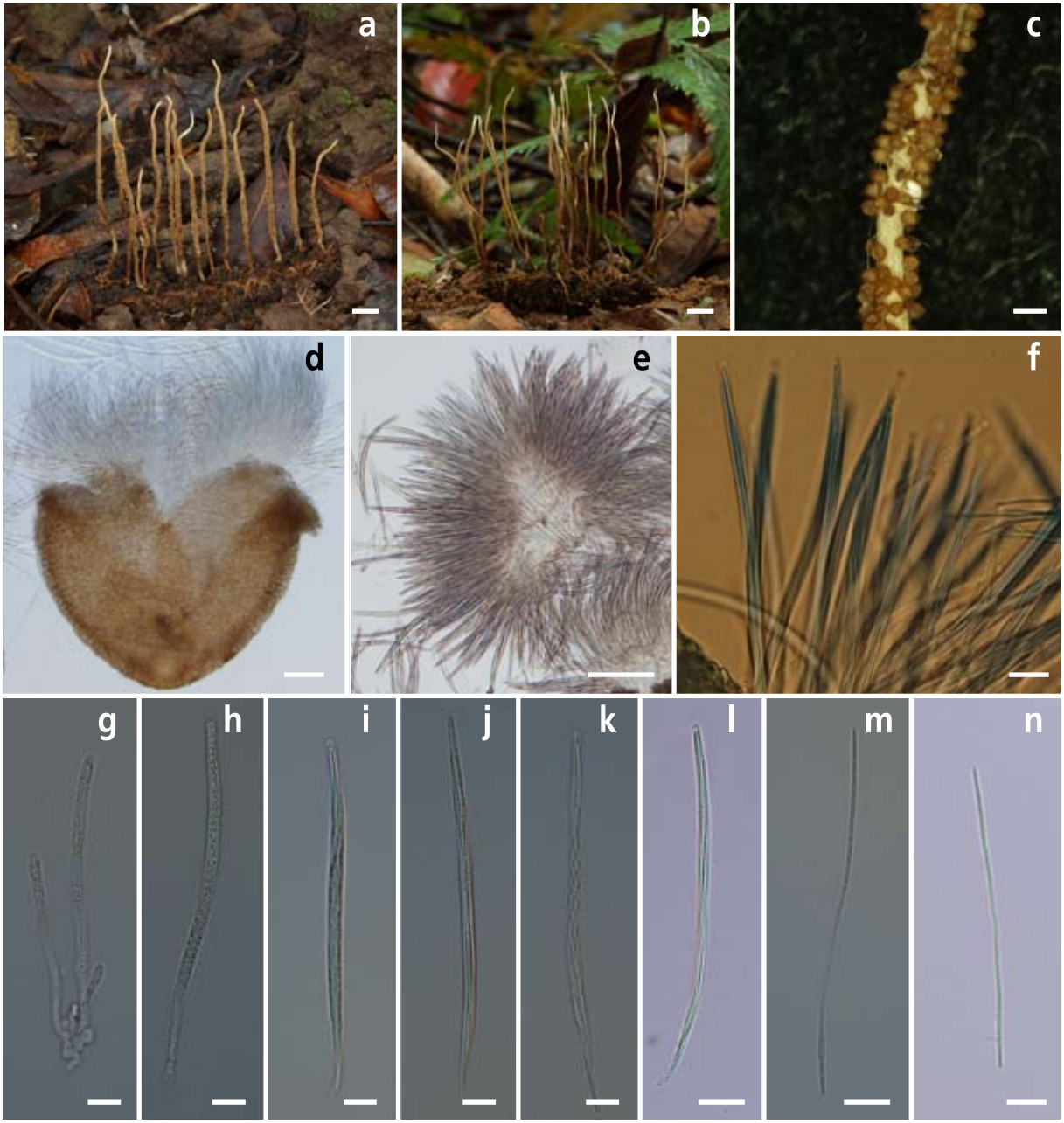
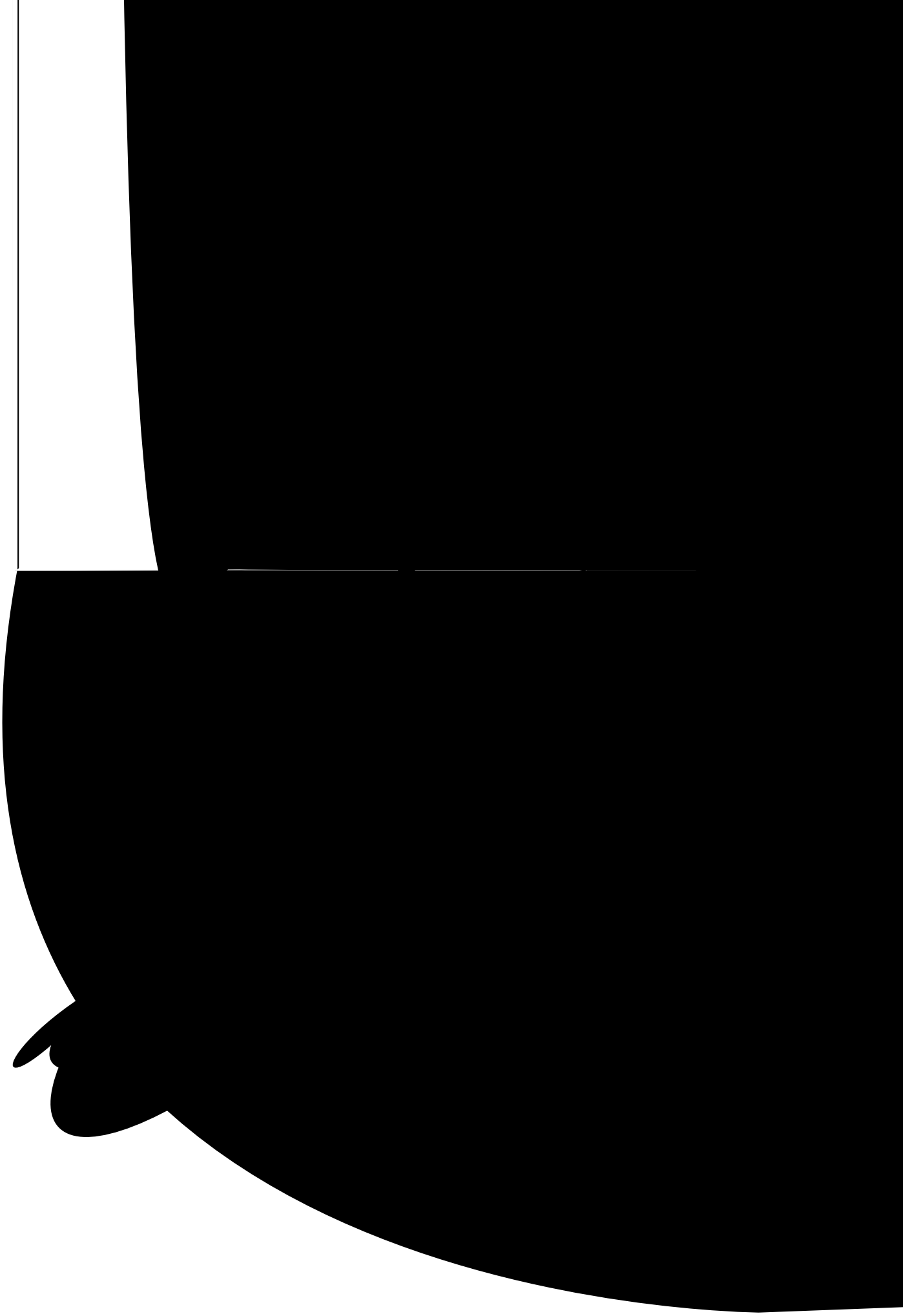


Fig. 18 a-b stromata arising from infected lepidopteran larva; **c** superficial perithecia; **d** perithecium broken showing the asci; **e** asci; **f** asci with ascospores; **g** immature asci; **h-l** ascus; **m-n** ascospores. Bars = 1 cm in Figs a-c, 100 µm in Figs d, e, 20 µm in Figs f-n.



Ophiocordyceps barnesii (Thwaites) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora

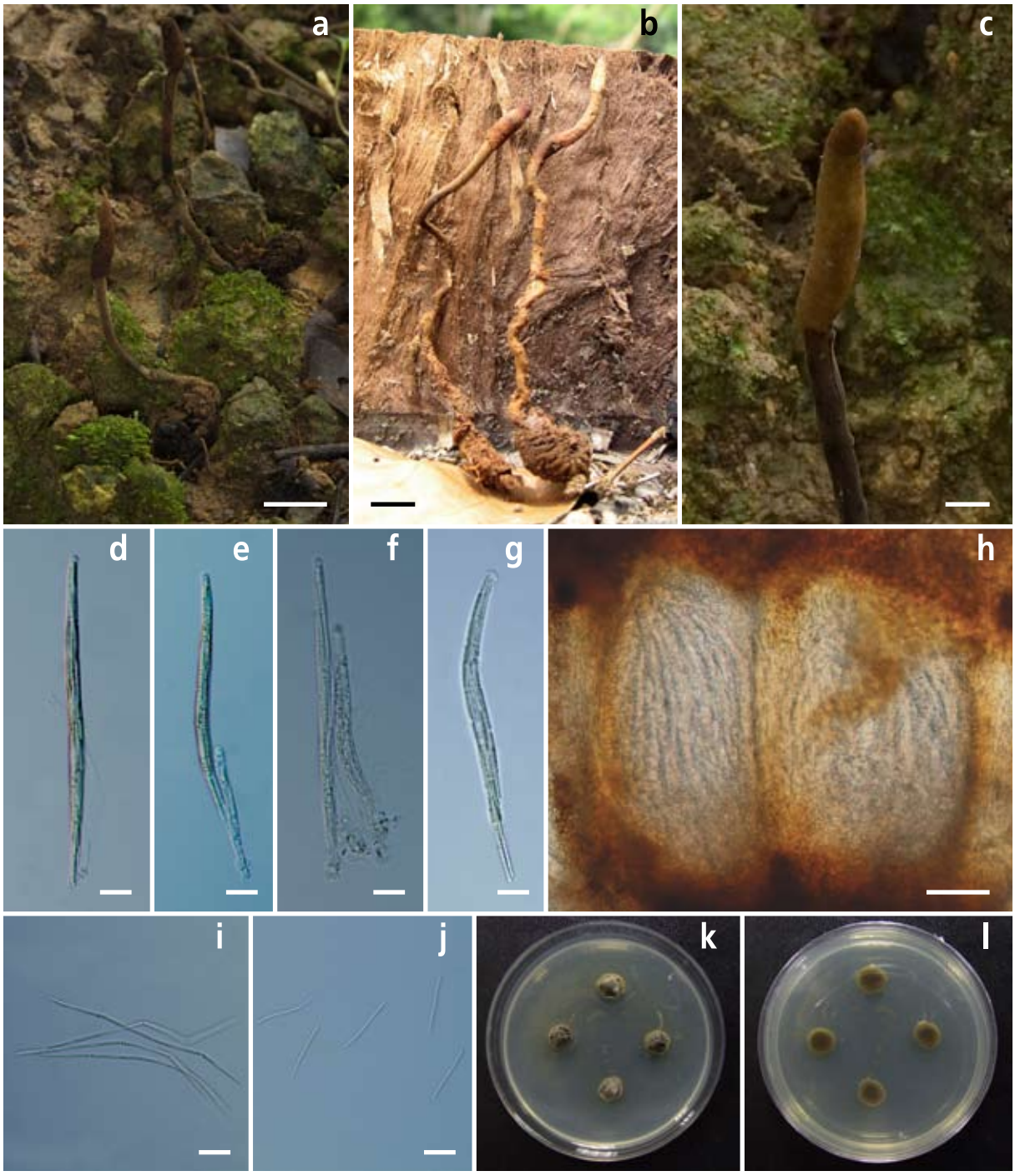


Fig. 19 a-b fungi on host; **c** fertile head; **d-g** asci; **h** section of stroma showing tightly packed perithecia; **i-j** ascospores; **k** colony obverse on PDA; **l** colony reverse on PDA. Bars = 1 cm in Figs a-c, 50 µm in Fig h, 20 µm in Figs d-g, i, j.

Ophiocordyceps brunneipunctata G.-H. Sung, J.-M. Sung, Hywel-Jones & Spatafora

Stud. Mycol. **57**: 40 (2007)

Synonyms:

Cordyceps brunneipunctata Hywel-Jones [as *'brunneapunctata'*], Mycol. Res. **99** (10): 1195 (1995).

Anamorph state: *Hirsutella*

Specimens were found buried in forest soils or fallen trunks and rotting logs. Hosts were elaterid beetle larvae (*Coleoptera*, *Elateridae*). The fungus produced reddish-purple or cinnamon to brown stromas on one end of the insect larva, mostly erect. Stroma usually solitary, rarely up to 3, simple, 25-90 mm high. The stipe was simple, cylindric, 5-15 mm x 1-1.8 mm, depending on the size of the beetle larva. The fertile head was distinctly sub-terminal with anamorph state at apex. The ascomata were immersed, perithecioid, brown, ovate to pyriform, brown-walled, 270-335 μm high, 110-160 μm across. Asci hyaline, cylindric, capitate, 8-spored, 280-295 μm x 6-7 μm. Ascospores hyaline, filiform, multiseptate breaking into 64 part-spores, cylindric and truncated at the ends, 4-6 μm x 1-1.5 μm.

In culture the colonies on PDA are slow-growing, attaining a diam. of 1-2 cm in 14 d at 25°C. Colonies at first white changing to cinnamon brown with age. Colonies readily produced a mononematous *Hirsutella* anamorph on hyaline hyphae after 3-4 wks. Cinnamon brown synnemata arise with a pruinose white to cream area bearing conidiogenous cells and conidia after 10-12 wks.

The fungus is regularly found in Khao Yai National Park but collections have also been made throughout the country.

References:

Hywel-Jones, N.L. (1995). *Cordyceps brunneapunctata* sp. nov. infecting beetle larvae in Thailand. *Mycological Research* **99**: 1195-1198.

Sung, G.-H., Hywel-Jones, N.L., Sung, J.-M., Luangsa-ard, J.J., Shrestha, B. & Spatafora, J.W. (2007). Phylogenetic classification of *Cordyceps* and the clavicipitaceous fungi. *Studies in Mycology* **57**: 5-59.

Ophiocordyceps brunneipunctata G.-H. Sung, J.-M. Sung, Hywel-Jones & Spatafora

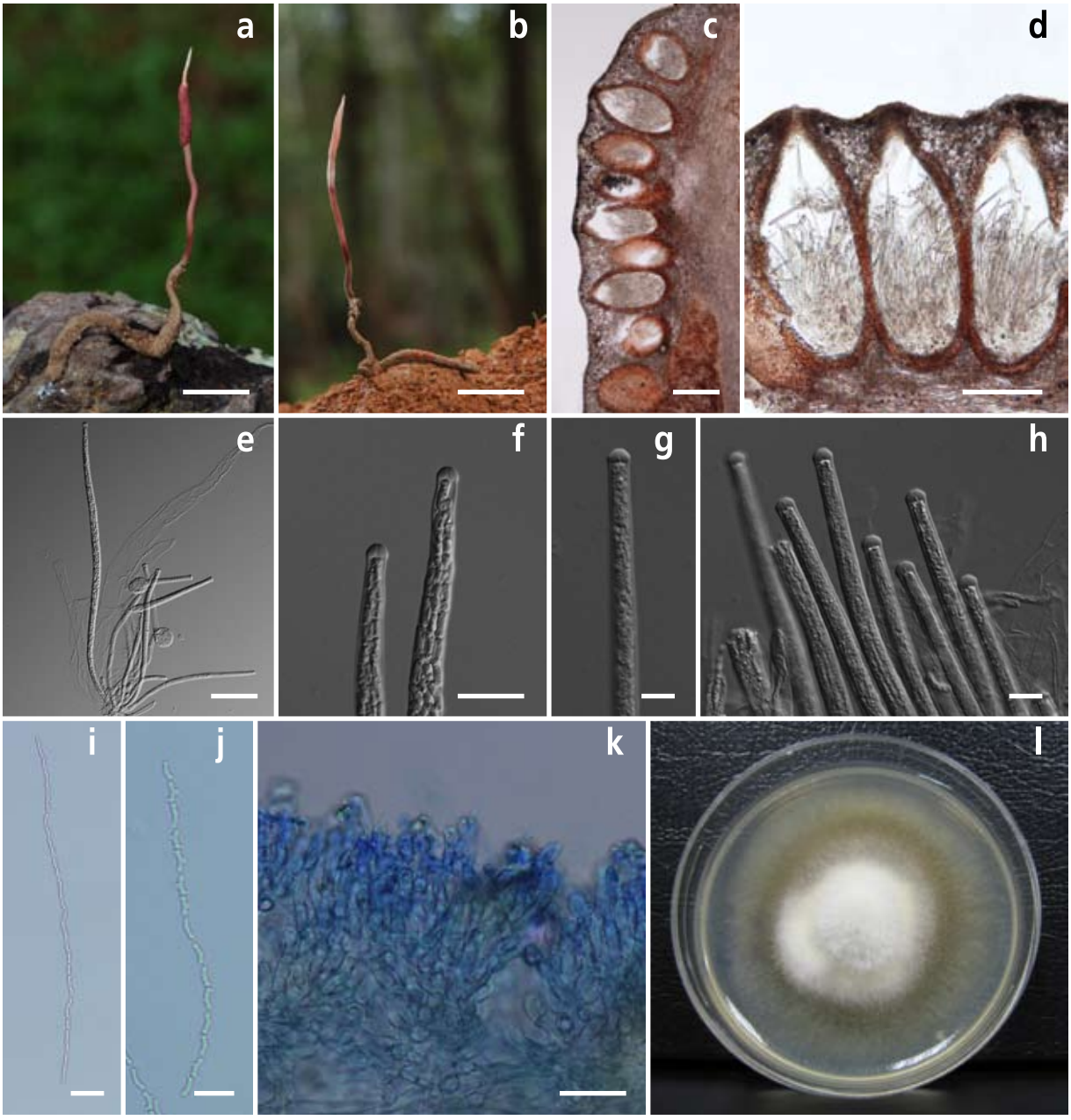


Fig. 20 a stroma with sub-terminal fertile head; **b** immature stroma only with the anamorph on elaterid larva; **c** section of the fertile part of the stroma; **d** perithecia; **e** mature and developing asci; **f** ascus tip showing part-spores of mature asci; **g** ascus tip of immature asci; **h** asci; **i** ascospore; **j** germinating ascospore; **k** anamorph; **l** colony obverse on PDA. Bars = 1 cm in Figs a-b, 200 µm in Fig c, 100 µm in Fig d, 50 µm in Fig e, 10 µm in Figs f, g, h, j, 20 µm Figs i, k.

Ophiocordyceps cochlidiicola (Kobayasi & Shimizu) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora

Stud. Mycol. **57**: 41 (2007)

Synonyms:

Cordyceps cochlidiicola Kobayasi & Shimizu (1980) *Bull. natn. Sci. Mus.,* Tokyo, B **6**(4): 125-145.

Anamorph state: *Hirsutella* sp.

Specimens were found in the leaf litter or on fallen, rotting logs. Hosts are lepidopteran larvae - cochlidiid. The fungus produces one to multiple stromata on the insect larva, mostly erect, seldom branched, slender cylindric, up to 10 cm long. The formation of the anamorphic state precedes the formation of the teleomorph. Fertile part starts midway along the stroma with anamorphic state usually at tip of the stroma. Perithecia superficial, distributed irregularly, partly gregarious, others isolated, subglobose with flattened base, light to dark brown, 350-400 x 335-400 µm. Asci cylindrical, 170-250 µm x 5.5-6.5 µm. Ascospores filiform, 160-250 µm x 1.5 µm, not breaking into part-spores.

In culture the colonies on PDA are slow-growing, attaining a diam. of 1-2 cm in 14 d at 25°C. Colonies cream to cinnamon brown. Reverse dark brown. Colonies produce brown synnemata after 1-2 mo with a pruinose area bearing conidiogenous cells and conidia of a *Hirsutella* anamorph.

Ophiocordyceps cochlidiicola is not a common species in Thailand. Collections were made mostly during the rainy season.

References:

Kobayasi, Y. & Shimizu, D. (1980). *Cordyceps* species from Japan 3. *Bull. natn. Sci. Mus.,* Tokyo, B **6**(4): 125-145.

Sung, G.-H., Hywel-Jones, N.L., Sung, J.-M., Luangsa-ard, J.J., Shrestha, B. & Spatafora, J.W. (2007). Phylogenetic classification of *Cordyceps* and the clavicipitaceous fungi. *Studies in Mycology* **57**: 5-59.

***Ophiocordyceps cochlidiicola* (Kobayasi & Shimizu) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora**

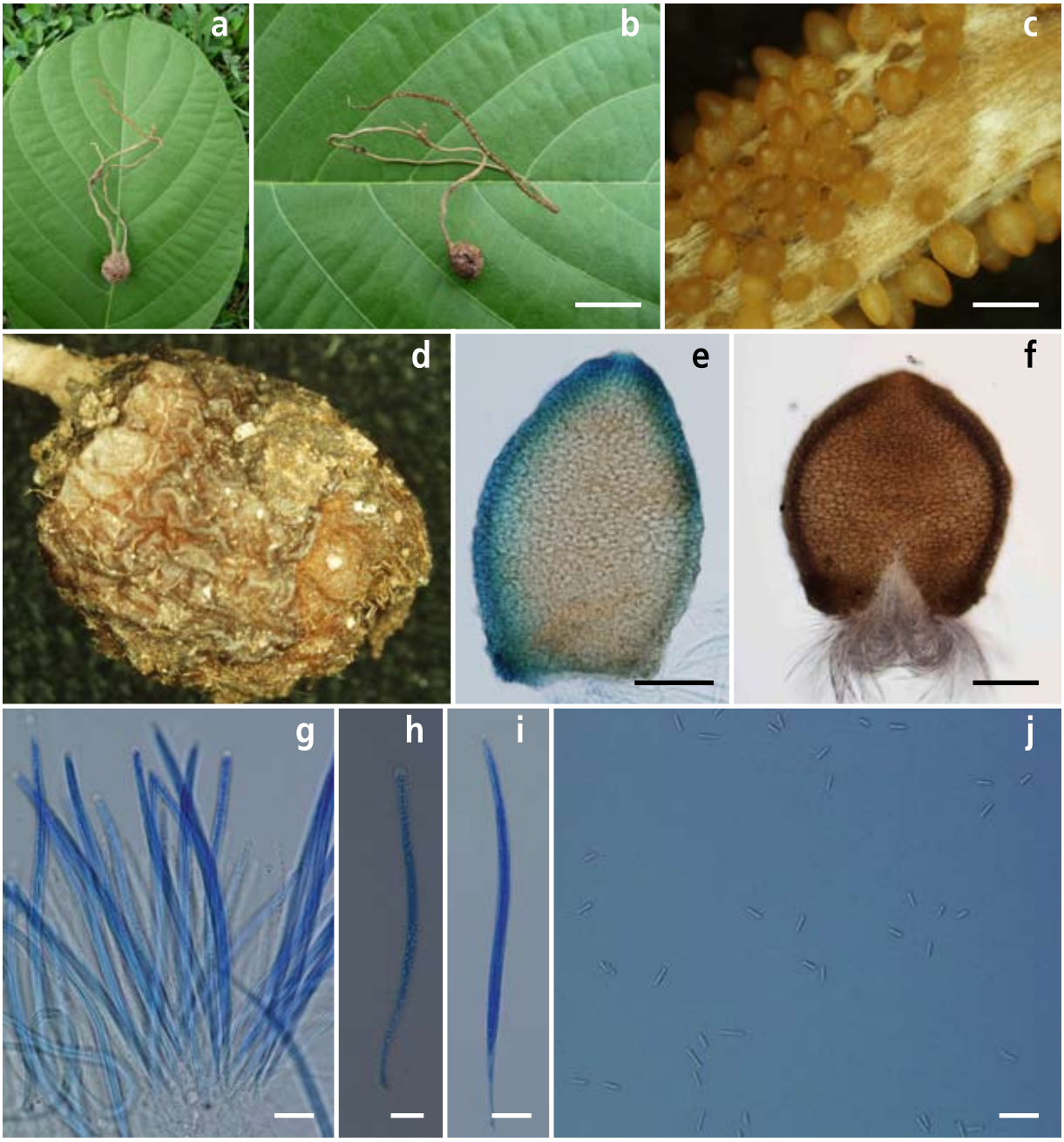


Fig. 21 a-b fungus on host; **c** superficial perithecia; **d** host; **e-f** perithecium; **g** asci; **h** immature ascus; **i** mature ascus; **j** ascospores. Bars = 1 cm in Fig b, 500 µm in Fig c, 100 µm in Figs e-f, 20 µm in Figs g, i, j, 10 µm in Fig h.

Ophiocordyceps dipterigena (Berk. & Br.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora

Stud. Mycol. **57**: 42 (2007)

Synonyms:

Cordyceps dipterigena Berk. & Broome, J. Linn. Soc., Bot. **14**: 111 (1875)

Anamorph state: *Hymenostilbe dipterigena* Petch

Species were found on the underside of leaves of forest plants and on twigs of living plants. Hosts are *Diptera* (true flies). Usually two stromata arise from the pleural membrane of the thorax, beneath the wings, 4-10 mm long, pale cream-yellow to orange-brown. Fertile head terminal, disk-like to subglobose, 1-1.5 mm high and 1.5-2.5 mm diam. with ridges, flattened apically. Perithecia arranged vertically with ostiole openings on the upper surface of the head, narrowly ovoid to obclavate 800-1000 x 200-300 µm. Asci cylindrical with a 2-3.5 µm thick perforated refractive cap, 450-600 x 4-6 µm. Ascospores parallel within the ascus, hyaline, filiform, breaking up into 64 one-celled part-spores. Part-spores cylindrical to fusiform, 6-12 x 1-1.5 µm.

This species is rather common in Thailand. The specimens invariably have two perithecial clavae emerging from the thorax and one conidial synnema emerging from the abdomen. When the thoracic clavae first appear, these produce the *Hymenostilbe* state and later develop the terminal *Ophiocordyceps* fertile head.

References:

Sung, G.-H., Hywel-Jones, N.L., Sung, J.-M., Luangsa-ard, J.J., Shrestha, B. & Spatafora, J.W. (2007). Phylogenetic classification of *Cordyceps* and the clavicipitaceous fungi. *Studies in Mycology* **57**: 5-59.

Ophiocordyceps dipterigena (Berk. & Br.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora

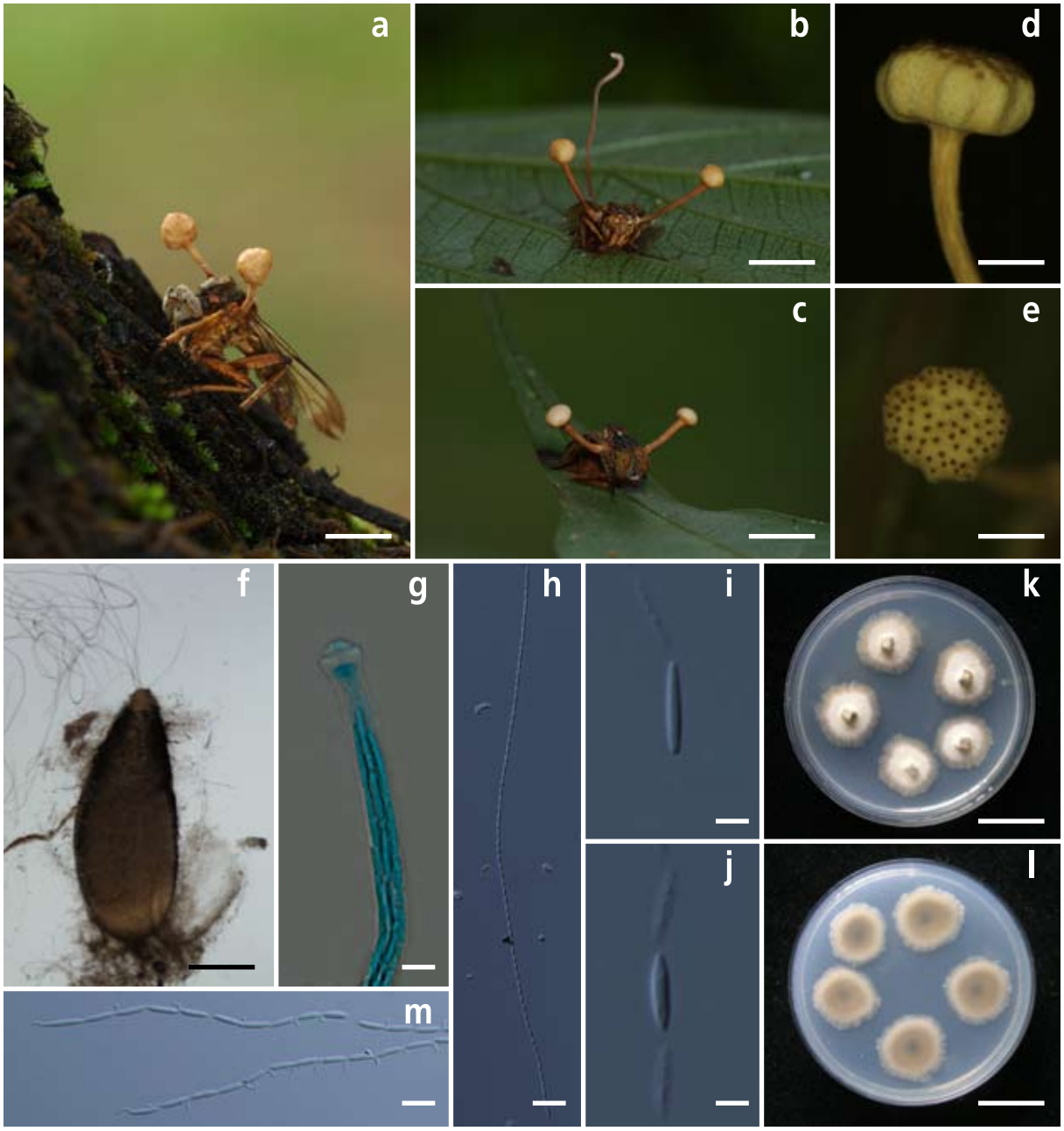


Fig. 22 a-c two perithecial stromas arising from fly; **d** fertile head in side view; **e** fertile head from top; **f** perithecium; **g** tip of mature ascus; **h** single ascospore; **i-j** part-spores; **k-l** colony on PDA; **m** germination of part-spores. Bars = 10 mm in Figs a-c, 1 mm in Figs d-e, 200 µm in Figs f, 5 µm in Fig g, 50 µm in Fig h, 5 µm in Figs i-j, 7.5 µm in Fig m, 10 mm in Figs k-l.

Ophiocordyceps nutans (Pat.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora (2007)

Bull. Soc. mycol. Fr. **3**: 127 (1887)

Synonyms:

Cordyceps nutans Pat. (1887) Bull. Soc. mycol. Fr. **3**: 127 (1887)
Cordyceps bicephala subsp. *nutans* (Pat.) Moureau, Mem. Inst. Col. Belge Sci. nat., **7**,: 47 (1949)

Anamorph state: *Hymenostilbe nutans* Samson & H.C. Evans

Specimens were found in the leaf litter or buried in soil. Hosts are hemipteran stink bugs. Stroma solitary on small hosts, multiple on larger specimens (body size 20-30 mm), 50-90 mm long, 400-800 μm across, marasmioid black or blackish brown, becoming red 8-12 mm below the fertile head which was red, salmon pink or orange-yellow, 6-17 x 3-5 mm. Perithecia immersed, hyaline-walled, oblique with a curved neck, 550-800 x 130-200 μm. Ostioles visible on the surface. Asci cylindric, up to 780 μm x 7-8 μm diam., 8-spored. Ascospores break easily into 64 part-spores. Part-spores cylindric or slightly barrel-shaped, ends blunt, 9.5-15 x 1.5-2 μm.

In culture the colonies on PDA are slow-growing attaining a diam. of 5-10 mm in 2 mo at 25°C.

Ophiocordyceps nutans has been found throughout Thailand from Doi Inthanon National Park in the North to Hala Bala National Park on the Malay border.

References:

Hywel-Jones, N.L. (1995). *Cordyceps nutans* and its anamorph, a pathogen of Hemipteran bugs in Thailand. *Mycological Research* **99**: 724-726.

Sung, G.-H., Hywel-Jones, N.L., Sung, J.-M., Luangsa-ard, J.J., Shrestha, B. & Spatafora, J.W. (2007). Phylogenetic classification of *Cordyceps* and the clavicipitaceous fungi. *Studies in Mycology* **57**: 5-59.

Ophiocordyceps nutans (Pat.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora

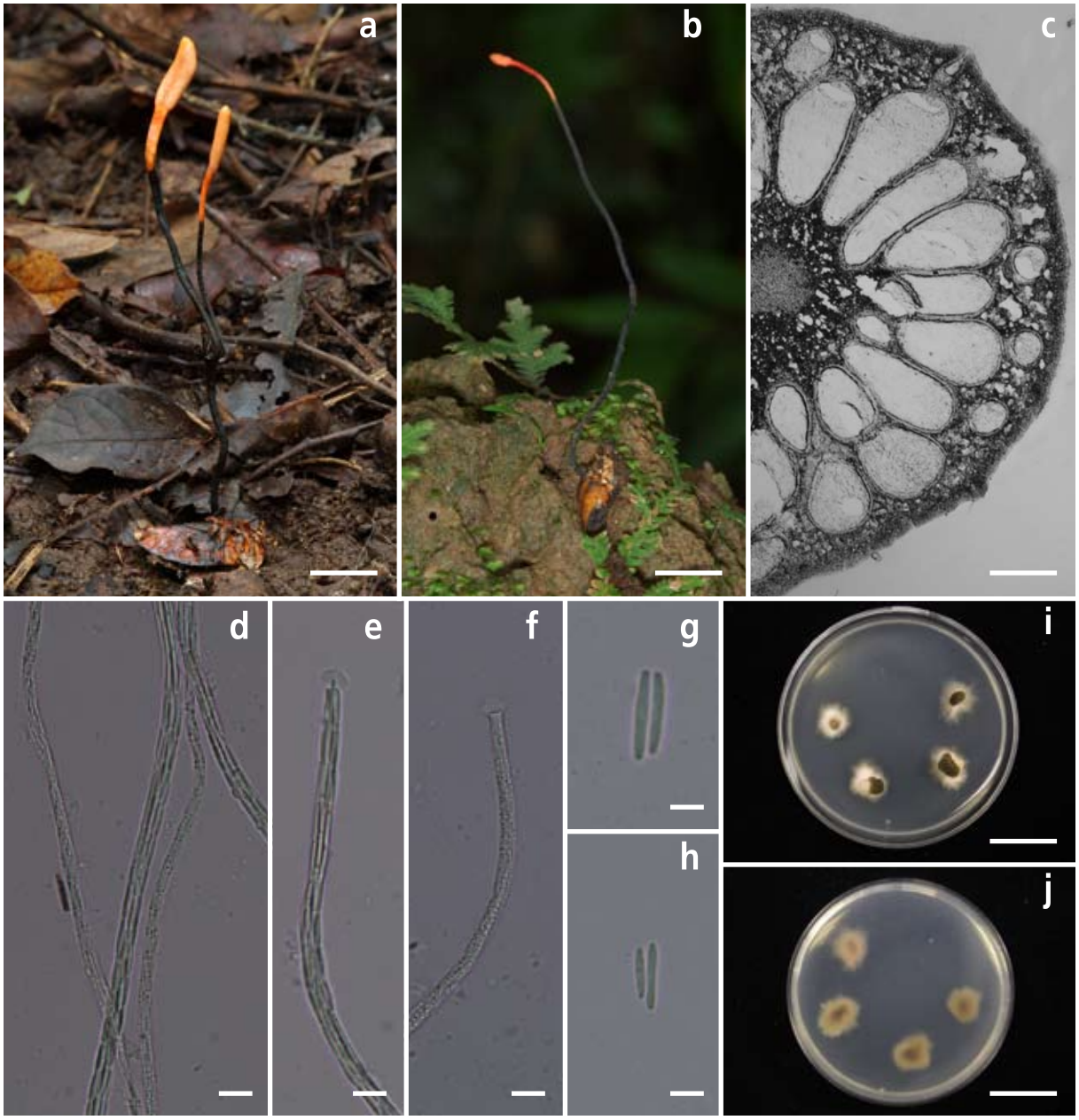


Fig. 23 a-b stroma arising from host; **c** cross section of fertile head showing perithecia; **d** asci; **e** mature ascus **f** immature ascus; **g-h** part-spores; **i-j** colonies on PDA. Bars = 1 cm in Figs a-c, i-j, 5 µm in Figs d-h.

Ophiocordyceps pseudolloydii (Evans & Samson) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora

Trans. Br. Mycol. Soc. **82**: 127-150 (1984)

Basionym:

Cordyceps pseudolloydii Evans & Samson, Trans. Brit. Mycol. Soc. **82**: 133 (1984)

Anamorph state: *Hymenostilbe* sp.

Specimens were found on the underside of leaves of forest plants. Stroma arising from between the head and thorax of adult worker ants (*Hymenoptera*: *Dolichoderinae*), pale cream-yellow to cream-yellow, 0.3-1 x 0.5-1 mm, single (rarely double). Fertile head terminal, concolorous with clava, hemispherical, slightly flattened, 1.5-2.5 mm diam., ridged and furrowed. Perithecia semi-erumpent, flask-shaped, 350-550 x 130-200 µm. Asci cylindrical, 250-400 x 5-8 µm, apex thickened. Ascospores filiform, breaking into 64 part-spores, 230-370 x 1.5-2.5 µm. Part-spores ellipsoidal with truncate, frilled ends, 4-10 x 1.5-2.5. µm, hyaline, smooth walled.

In culture the colonies on PDA are slow-growing, attaining a diam. of 5-10 mm in 1 mo at 25°C.

Ophiocordyceps pseudolloydii has been found throughout Thailand from Doi Inthanon National Park in the North to Hala Bala National Park on the Malay border.

References:

Evans, H.C. & Samson, R.A. (1984). *Cordyceps* species and their anamorphs pathogenic on ants (Formicidae) in tropical forest ecosystems II. The *Camponotus* (Formicinae) Complex. *Transactions of the British Mycological Society* **82**: 127-150.

Sung, G.-H., Hywel-Jones, N.L., Sung, J.-M., Luangsa-ard, J.J., Shrestha, B. & Spatafora, J.W. (2007). Phylogenetic classification of *Cordyceps* and the clavicipitaceous fungi. *Studies in Mycology* **57**: 5-59.

***Ophiocordyceps pseudolloydii* (Evans & Samson) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora**

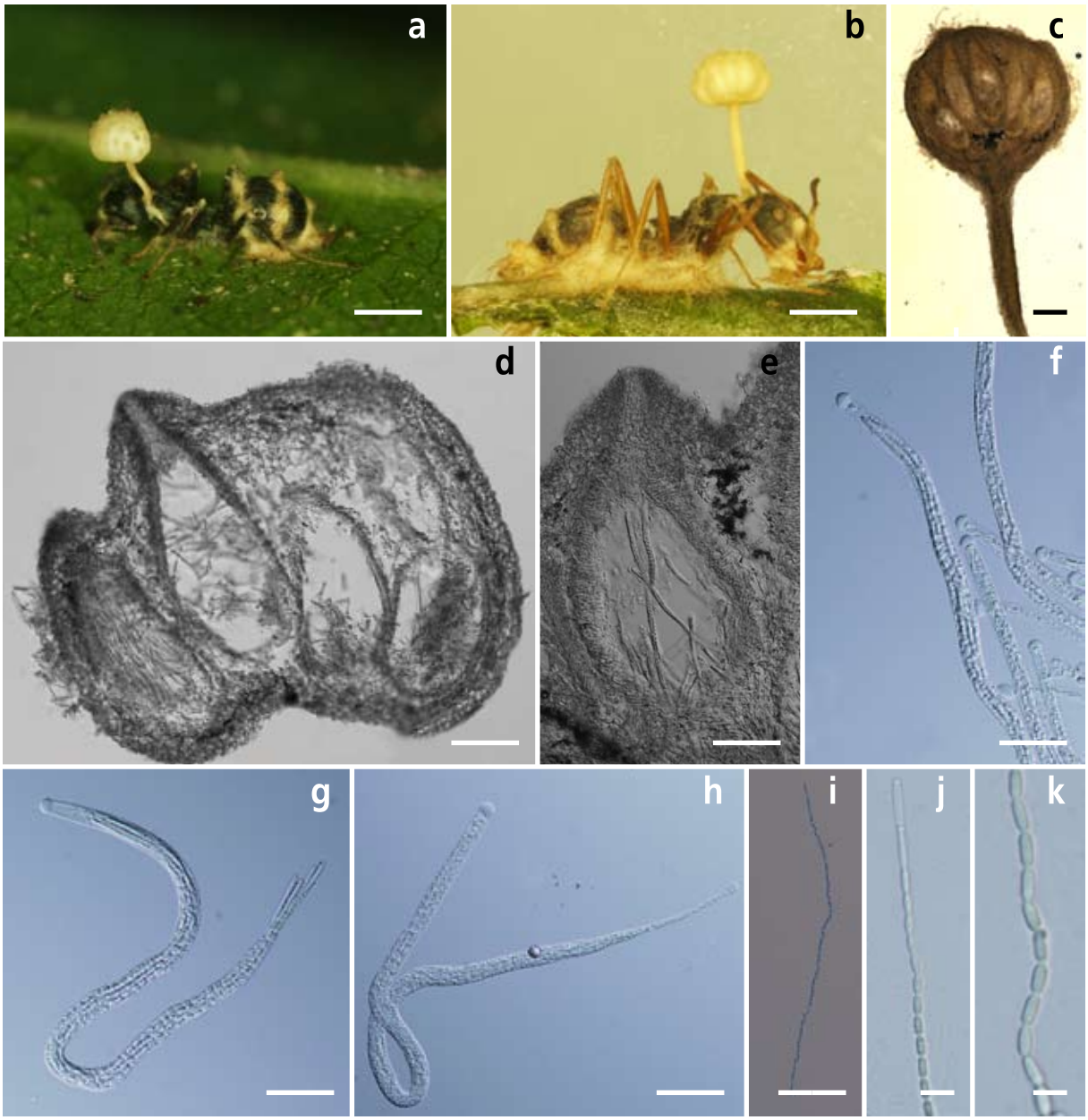


Fig. 24 a-b Fertile head arising from infected *Dolichoderinae* ant; **c-e** cross section of stroma showing perithecia with asci; **f** asci; **g** mature ascus; **h** immature ascus; **i-k** part-spores. Bars = 1 mm in Figs a-b, d-e, f-h, 50 µm in Fig c, 5 µm in Figs i-k

Orbiocrella petchii (Hywel-Jones) D. Johnson, G.-H. Sung, Hywel-Jones & Spatafora

Mycol. Res., doi: 10.1016/j.mycres.2008.09.008

Synonyms:

Torrubiella petchii Hywel-Jones, Mycol. Res. **101:** 143 (1997)

Anamorph state: *Hirsutella-like*

Specimens were found on the underside of forest bamboo leaves. Hosts were scale insect nymphs (*Homoptera*). Stroma covering the host body, ascomata crowded, superficial, ring-like, up to 5 mm diam., yellow mycelium; perithecia flask-shaped, *ca.* 550-600 μm long (630-680 μm), *ca.* 350 μm diam. (200-300 μm); asci cylindric up to *ca.* 400 μm long (580-600 μm) and 5-7.5 μm diam. (5-6 μm) with a distinct, thickened hyaline cap, *ca.* 5 μm long, *ca.* 7.5 μm diam.; ascopores whole, filiform, *ca.* 350 μm long, 1.5-2 μm (450-500 x 1-1.2 μm).

Spores will germinate within 24 h on PDA and produce the Hirsutella-like anamorph. The hyaline conidiogenous cells were *ca.* 25 μm long (14.9-23.8 μm) and *ca.* 2.5 diam. (2.2-2.7 μm). Conidia form singly, reniform with a truncate attachment point and *ca.* 5.5 μm long, *ca.* 2.5 μm diam. Colonies are moderately fast-growing, attaining a diam. of 1 cm after 1 wk at 20°C on PDA. Colonies white-yellowish when young, turning cream-yellow with age.

Collections in Thailand have been made from Doi Inthanon National park in the far north and as far as Kaeng Krachan National Park in the south. Collections have been made throughout the year. To date there have been no records from dicotyledonous leaves.

References:

Hywel-Jones, N.L (1997). *Torrubiella petchii,* a new species of scale insect pathogen from Thailand. *Mycological Research* **101:** 330-332.

Johnson, D., Sung, G.-H., Hywel-Jones, N.L., Luangsa-ard, J.J., Bischoff, J.F., Kepler, R.M., & Spatafora, J.W. (2009). Systematics and evolution of the genus *Torrubiella* (Hypocreales, Ascomycota), *Mycological Research* doi: 10.1016/j.mycres.2008.09.008.

Stilbella burmensis (Mains) Samson & H.C. Evans

Proc. K. Ned. Akad. Wet., Ser. C. **84**: 289-301 (1981)

Synonyms:

*Stilbum burmens*e Mains. Mycologia **40**: 410 (1948)

Teleomorph state: Not known

Specimens were found in the leaf litter. Hosts are ants. Synnemata multiple, flexuous, arising from behind the head, thorax and abdomen of host, 5-10 mm long, 0.5-1 mm wide, dark brown to marasmioid black, becoming cream-white at the swollen apex. Apex 1-1.5 x 1-1.5 mm forming a hymenial layer of conidiogenous cells. Conidiogenous cells phialidic, elongate cylindrical, 10-20 x 2-3 µm, hyaline, smooth-walled. Conidia appearing powdery, fusiform to obclavate, one end truncate, smooth-walled, 5-7.5 x 2.5-3 µm.

Conidia germinate within 24-36 h on PDA. Colonies on PDA growing slowly reaching 10 mm in 3 mo at 25°C. Conidiogenous structures as in nature. In culture synnemata develop at the margin of the colonies after 8 wk. These synnemata were marasmioid black for much of their length becoming pinkish red at the apex. All other characteristics compared with *Stilbella burmensis* on the host. However, the pinkish-red of the anamorph in culture bears comparison with *Stilbella buquetii.* Both species are very rarely observed and more work needs to be done on field-collected material and cultures to determine their relationship.

This is a very rare species in Thailand with records from Thung Yai Naresuan Wildlife Sanctuary in Kanchanaburi.

References:

Mains, E.B. (1948). Entomogenous Fungi. *Mycologia* **40**: 402-416

Samson, R. A., Evans, H.C., and Klashorst, G. van de. (1981). Notes on entomogenous fungi from Ghana V. The genera *Stilbella* and *Polycephalomyces. Proc. K. Ned. Akad. Wet., Ser. C*, **84**: 289-301.

Stilbella burmensis (Mains) Samson & H.C. Evans

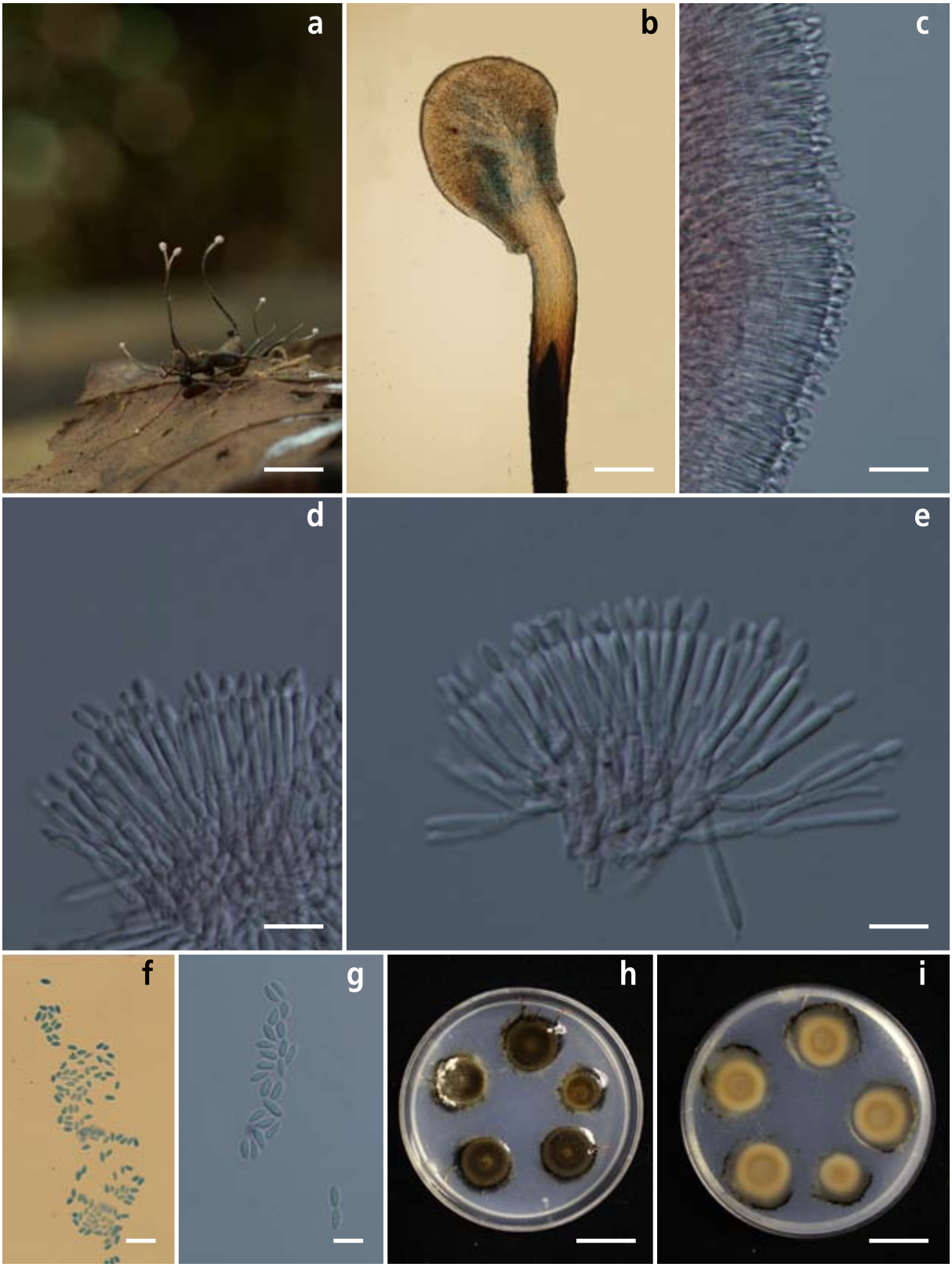


Fig. 26 a synnemata arising from ant; **b-c** part of synnema showing conidiogenous cells; **d-e** conidiogenous cells and conidia; **f-g** conidia; **h-i** colonies on PDA. Bars = 5 mm in Fig a, 0.5 mm in Fig b, 10 µm in Figs c,g, 5 µm in Figs d-e, 25 µm in Fig f, 10 mm in Figs h-i.

Torrubiella hemipterigena Petch

Trans. Br. Mycol. Soc. **16**: 236 (1932)

Anamorph state: *Verticillium hemipterigenum* Petch, loc. cit.: 237

Specimens were found on leafhoppers attached to the underside of living leaves of forest plants. Stroma consisting of dense hyphae, completely covering the host, white to grayish or pale yellow weft, up to 5 mm; perithecia superficial, scattered on host, grayish or pale yellow, elongate ovoid, *ca.* 850 µm deep, *ca.* 350 µm diam., surrounded by white mycelium; asci cylindrical, up to 650 µm long, *ca.* 3.8 µm diam., with distinct, thickened hyaline cap *ca.* 3.8 µm long, *ca.* 3.5 µm diam.; ascospores, as long as the ascus, hyaline, breaking to part-spores, 125-210 µm long, *ca.* 1 µm diam., mature part-spores up to 600 µm, *ca.* 1 µm diam. Conidiophores scattered, surrounding the perithecia sometimes on leaf surface. Conidiophores consisting of several whorls of phialides. Phialides in whorls of 6, with a swollen elongate flask-shaped base, *ca.* 10.5 µm long, *ca.* 1.2 µm diam.; conidia hyaline, 3.2-4.5 x 1.2-2 µm, smooth-walled, fusoid.

Discharged ascospores will germinate within 12 h on PDA. Some ascospores produced secondary conidia on hard surfaces (*eg.* cover slip). Colonies are fast-growing attaining a diam. of 1 cm after *ca.* 2 wk on PDA at 20°C. Colonies white.

So far, these samples are only known from two sites, in Thung Yai Naresuan Wildlife Sanctuary (west Thailand) and Khao Yai National Park (central Thailand).

References:

Petch, T. (1932). Notes on entomogenous fungi. *Transactions of the British Mycological Society* **16**: 209-245.

Hywel-Jones, N. L., Evans, H. C. & Jun, Y. (1997). A re-evaluation of the leafhopper pathogen *Torrubiella hemipterigena*, its anamorph *Verticillium hemipterigenum* and *V. pseudohemipterigenum* sp. nov. *Mycological Research* **101**: 1242-1246.

Torrubiella hemipterigena Petch

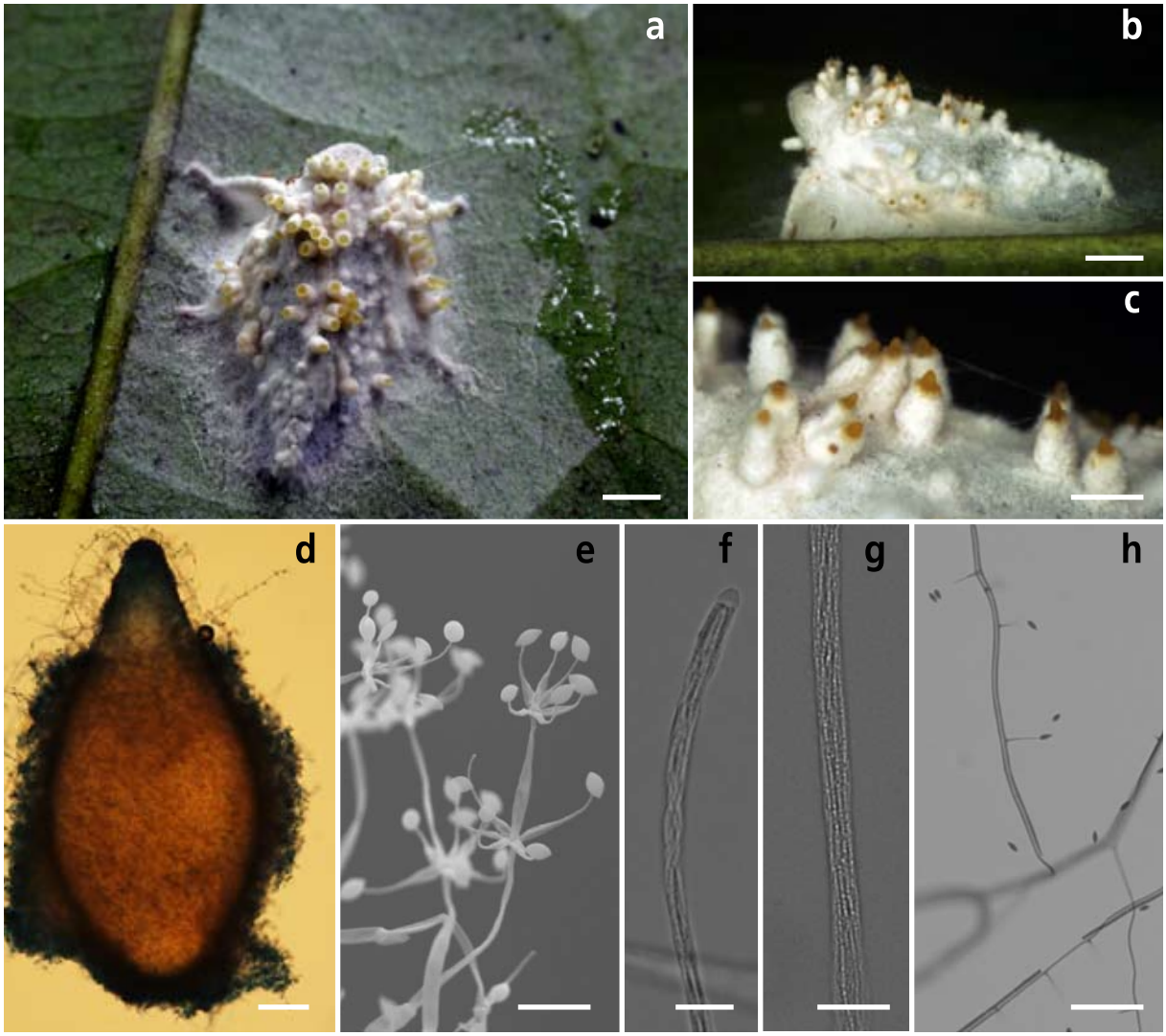


Fig. 27 a-c ascomata arising from the infected leafhopper; **d** perithecium surrounded by mycelium and showing its anamorph (arrow); **e** SEM of anamorph *Verticillium hemipterigenum*; **f** thickened tip of ascus; **g** part of ascus showing mature whole ascospores; **h** secondary conidia producing from whole ascospores. Bars = 1 mm in Figs a-b, 500 μm in Fig c, 100 μm in Fig d, 20 μm in Fig e, 10 μm in Figs f-h.

Torrubiella arachnophila var. *pulchra* Mains

Mycologia **42**(2): 316 (1950)

Synonyms:

Torrubiella pulchra Koval, Klavitsipital'nye Griby SSSR (Kiev): 71 (1984)

Anamorph state:

Gibellula pulchra (Sacc.) F. Cavara

Specimens were found on spiders attached to the underside of leaves of forest plants. Stroma consisting of dense interlaced mycelial mat, sometimes surrounded by membranous hypothallus, up to 5 mm diam., pale yellow to orange-yellow; perithecia surrounded by yellow to yellow-orange mycelium, erect, aggregated, arising from the stroma; perithecia ovoid, 600-800 µm deep, 250-350 µm diam.; asci cylindrical, up to 600 µm long, *ca.* 4-7.5 µm diam., with a distinct, thickened hyaline cap 3.5-5 µm long 3.5-7 µm diam.; ascospores, as long as the ascus, hyaline, breaking into 64 part-spores; part-spores cylindrical, smooth, hyaline, 5.8-10 µm long diam., 1-1.3 µm diam.

Spores will germinate within 12 h on PDA. Colonies are slow-growing, attaining a diam. of 1 cm after 4 wk at 20°C. Colonies whitish.

Although the *Gibellula* anamorph is commonly found throughout Thailand the *Torrubiella teleomorph* is rare. Importantly, where other *Gibellula* species have been found in association with the *Torrubiella* this species is always found either as the anamorph (commonly) or the teleomorph (rarely) but never together.

References:

Mains, E. B. (1950). The genus *Gibellula* on spiders in North America. *Mycologia* **42**: 306-321.

Samson, R. A. & H. C. Evans (1992). New species of *Gibellula* on spiders (Araneida) from South America. *Mycologia* **84**: 300-214.

Torrubiella arachnophila var. *pulchra* Mains

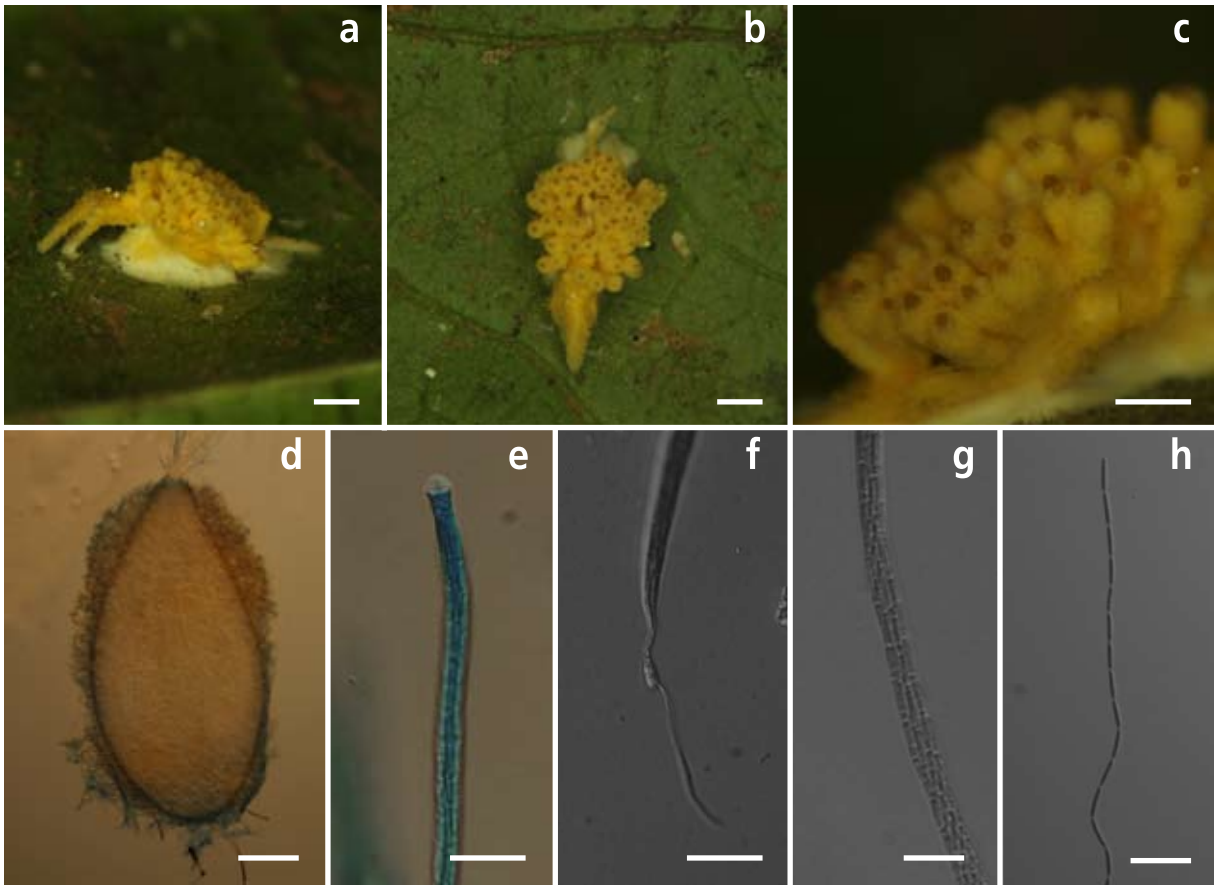


Fig. 28 a-c ascomata arising from the infected spider host; **d** perithecium surrounded by mycelium; **e** thickened tip of ascus; **f** foot of ascus; **g** part of ascus showing mature ascospores; **h** part ascospores. Bars = 500 μm in Figs a-c, 100 μm in Fig d, 10 μm in Figs e-h.

Torrubiella pruinosa (Petch) Minter & B. L. Brady

Trans. Br. Mycol. Soc. **74**: 278 (1980)

Synonyms:

Calonectria pruinosa Petch, Trans. Br. Mycol. Soc. **16**: 227 (1932)

Anamorph state: *Hirsutella versicolor* Petch, Trans. Br. Mycol. Soc. **16**: 227 (1932)

Specimens were found on leafhoppers attached to the underside of leaves of forest plants. Infected leafhopper surrounded with dense mycelial mat, white to greyish, up to 5 mm diam.; perithecia surrounding the stroma with pale brown mycelium, partly embedded in stroma; ostioles red-brown, perithecia ovoid, 300-450 μm deep, 250-320 μm diam.; asci eight-spored, long-clavate, 125-150 μm long, 10-12 μm diam., with thinned perforated cap; ascospores cylindrical, multi-septate, ends somewhat round to obtuse, hyaline, 17.5 -28.5 μm long, 2-5 μm diam., sometimes curved.

Spores will germinate within 24 h on PDA. Colonies are slow-growing, attaining a diam. of 1 cm after 3 wk at 20°C. Colonies whitish.

Torrubiella pruinosa has been found mostly in the central parts of Thailand (Wang Cham Pi (1991), road marker km 44.8 (1992), Heo Sawat (1993), Gong Giao nature trail (1994) (Hywel-Jones, 1997), Princess trail (Km 33) (2007) at Khao Yai National Park.

References:

Hywel-Jones, N. L. (1997). *Hirsutella* species associated with hoppers (Homoptera) in Thailand. *Mycological Research* **101**: 1202-1206.

Minter, D.W. & Brady, B.L. (1980). Mononematous species of *Hirsutella. Transactions of the British Mycological Society* **74**: 271-282.

Petch, T. (1932). Notes on entomogenous fungi. *Transactions of the British Mycological Society* **16**: 209-245.

Torrubiella pruinosa (Petch) Minter & B. L. Brady

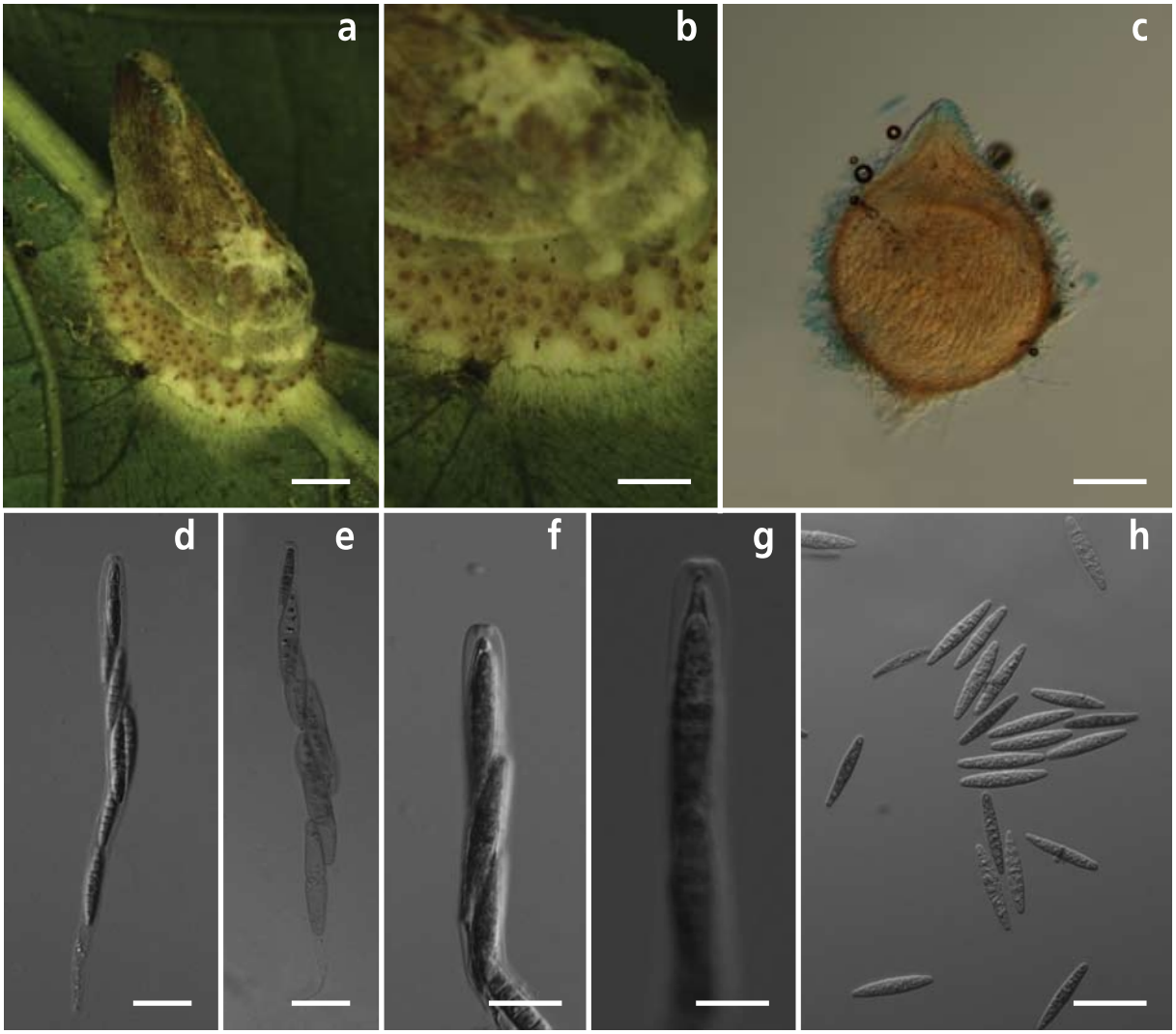


Fig. 29 a-b ascomata arising from the infected leafhopper; **c** perithecium surrounded by mycelium; **d** mature ascus showing ascospores separating into part-spores; **e** immature ascus; **f-g** part of ascus with thickened tip; **h** ascospores. Bars = 1 mm in Figs a, b, 100 µm in Fig c, 20 µm in Figs d-h.

Torrubiella siamensis Hywel-Jones

Mycol. Res. **99**: 330-332 (1995)

Anamorph state: *Hirsutella*-like

Specimens were found on the underside of bamboo or dicotyledonous leaves of forest plants. Hosts were scale insect nymphs (*Homoptera*). Stroma usually very flattened discoid, up to 4 mm diam. white; perithecia clustered, superficial, elongate-ovoid, 500-650 μm long (580-660 μm), 300-400 μm diam. (300-330 μm), hyaline yellow, no paraphyses within the perithecia; asci cylindric up to 550 μm long (570 μm) and 5-7.5 μm diam. (5 μm) with a distinct, thickened hyaline cap 3-5 μm long, 5-6.5 μm diam.; ascospores divide into 32 part-spores, filiform, 12.5-17.5 x 2-3 μm (11.5-15.5 x 1.3-1.5 μm).

The part-spores of *Torrubiella siamesis* germinated on PDA but with no subsequent growth after 2 wk of observation.

This is a very rarely reported species in Thailand. The first collection was from Gong Giao trail at Khao Yai National Park in 2 September 1990 (Hywel-Jones, 1995) with a second collection from Klong Lan National Park in October 2007.

References:

Hywel-Jones, N.L (1995). *Torrubiella iriomoteana* from scale insects in Thailand and a new related species *Torrubiella siamensis* with notes on their respective anamorphs. *Mycological Research* **99**: 330-332.

Torrubiella siamensis Hywel-Jones

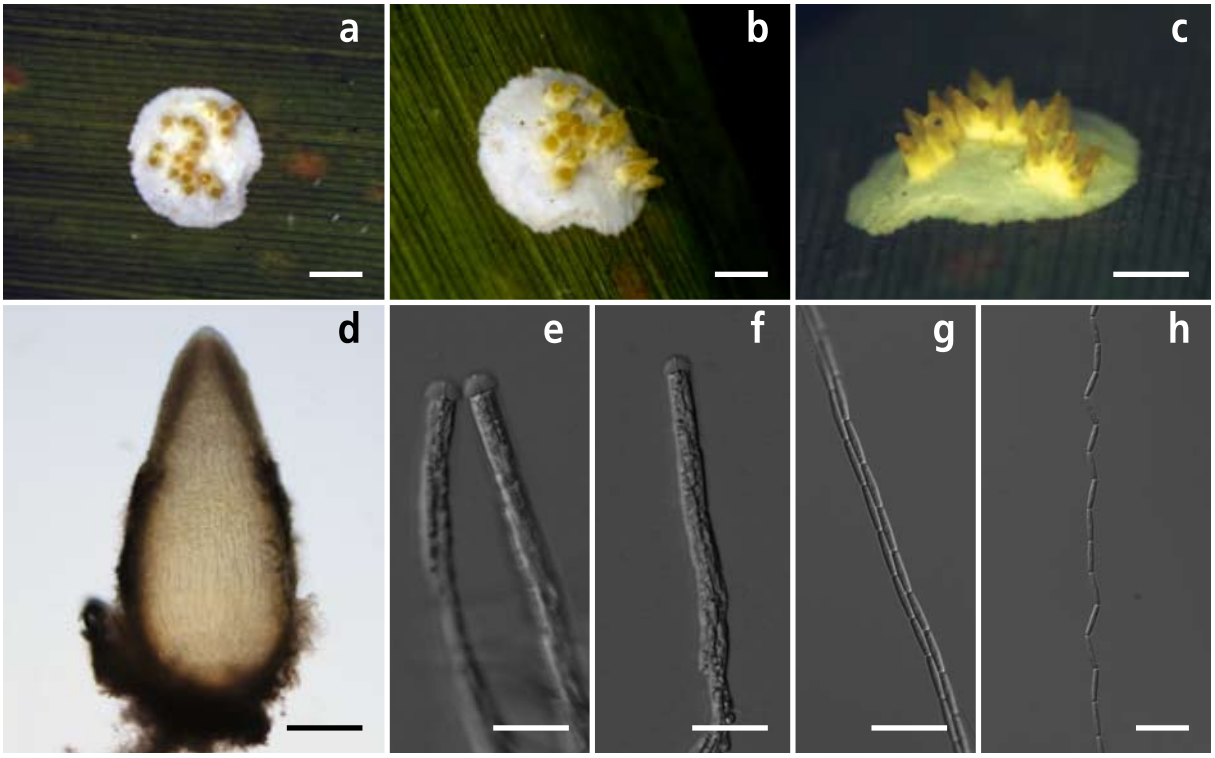


Fig. 30 a-c stroma on host; superficial perithecia arising from the infected host; **d** perithecium; **e** thickened tip of asci; **f** part of mature ascus showing ascospores; **g-h** ascospores. Bars = 1 mm in Figs a-c, 100 µm in Fig d, 10 µm in Figs e, f, 20 µm in Figs g, h.

Glossary:

Many specialist terms have been used in this work which might not be familiar to a general reader. The following glossary of these terms has been adapted from the following sources.

1. Kirk, P. M., Cannon, P.F., David, J. C. and Stalpers, J.A. (2001). Ainsworth and Bisby's Dictionary of the Fungi, 9th Edition CABI, London 624 pp.

2. Ulloa, M. and Hanlin R. 2000. Illustrated Dictionary of Mycology. APS Press, The American Phytopathological Society, St. Paul, Minnesota. 448 pp.

anamorph (Gr. *anamorpho,* to transform): the asexual, conidial or so-called imperfect state of a fungus, which produces its spores by mitosis, in contrast to the **teleomorph,** which is the sexual or so-called perfect state (ascogenous or basidiogenous state) and whose spores are produced by meiosis. The fungus in all its forms is called the **holomorph.**

apical (L. *apicalis*, at the apex, tip <apex, *apicis*, apex> apic- + suf. -*alis*> E. -*al,* relating to or belonging to): located at the top or apex. cf. **basal.**

apiculate (NL. *apiculatus*, small or abruptly pointed <*apiculus*, dim. of L. *apic*-, apex, genit. *apicus*, apex, tip + suf. -*atus*>E. -ate, provided with or likeness): ending abruptly in a small distinct point.

ascospore a spore produced by the ascus by 'free cell formation'; the ascospore wall is multilayered, it consists of an outer **perispore**, an intermediary layer, the proper wall (epispore) and sometimes an internal **endospore;** major differences in which layers are thickened, folded or pigmented can give rise to considerable variation even in a single family.

ascostroma a stroma in or on which asci are produced, usually restricted to groups with ascolocular ontogeny.

ascus (pl. **asci**) term introduced by Nees (Syst. Plize: 164, 1817) for the typically sac-like cell (first figured in Pertusia by Micheli in 1729) characteristic of Ascomycota in which (after karyogamy and meiosis) ascospores (generally 8) are produced by 'free cell formation'. Asci vary considerably in structure and work in the last decades has shown separation into only 2-3 categories (e.g. **bitunicate, prototunicate, unitunicate**) to be an oversimplification. They are homologous to the basidia in the basidiomycetes, but they differ in that the latter form their spores exogenously, whereas the former form them endogenously.

basal (L. *basalis*, basal < basis + suf. –*alis*>E. –*al*, relating to or belonging to): near the base or relative to it; that which is found at the extreme bottom or near the point of attachment or adhesion. cf **apical.**

basionym (basinym, basonym) (in nomenclature, q.) the name-, or epithet- bringing synonym in which a new transfer or combination is based.
(L. *basis*, base + *petere*, to go forward, to grow toward + L. suf. -*alis*> E. -*al*,

basipetal relating to or belonging to): Conidiogenesis. Developing or maturing from the apex toward the base; i.e., the degree of growth is greater with increased distance from the base. e.g., in a basipetal chain of conidia, the conidium at the base is the youngest and the most recent formation.

byssoid cotton-like, made-up of delicate threads; floccose.

capitate having a well-formed head.

citriform (L. *citrus*, citron, lemon + *formis* < forma, shape>: shaped like a lemon.

clavate (NL. *clavatus*, club-shaped ,L. *clava*, club + suf. -*atus* > E. -*ate*, provided with or likeness; L. *claviformis*, *clava* + suf. -*formis*, *forma*, shape): shaped like a club; narrowing in the direction of the base e.g., the synnemata of Hirsutella saussurei.

conidioma (pl. **-ata**), a specialized multi-hyphal, conidia bearing structure (Kendrick & Nag Raj in Kendrick (Ed.), the whole fungus **1**; 51, 1979). See acervulus pycnidium, sporodochium, synnema (all obsol. nouns, but used adjectivally, e.g. acervular conidioma). cf. **conidiophore.**

conidiophore a simple or branched hypha (a fertile hypha) bearing or consisting of conidiogenous cells from which conidia are produced; sometimes used when describing reduced structures for the conidiogenous cell.

dicotyledonous Botany (adj.): referring to a flowering plant with an embryo that bears two cotyledons (seed leaves). Dicotyledons constitute the larger of the two great divisions of flowering plants, and typically have broad, stalked leaves with netlike veins (e.g., hibiscus, jasmine, mango). Compare with **monocotyledonous.**

discoid flat and circular, resembling a disk.

ellipsoid, ellipsoidal, elliptic (L. *ellipsis*, ellipse < Gr. *ellepsis*, a closed curve + L. suf. -*oide* <Gr. -*oeides*, similar to; or + L. suf. *alis*> E. -*al,* relating to or belonging to ; or + Gr. -*ikos* > L. -*icus*> E. -*ic*, belonging to, relating to): refers to a solid body that forms an ellipse in the longitudinal plane and a circle in cross section. (of spores, etc.) elliptical in optical section.

entomopathogenic (Gr. *entomos*, cut, divided into segments, insect,+ Gr. *pathos*, disease + *genos*, origin < *gennao*, to engender + L. -*osus*> E. -*ic*, belonging to, relating to): growing on or obtaining nourishment, as pathogens, from insects.

epidemic widespread occurrence of an infectious disease in a community at a particular time

epizootic (Gr. *epi,* upon + *zoon,* animal + *-tikos*> L. *-ticus*> E. *-tic*, relation, fitness, inclination or ability): a disease that suddenly and extensively affects many animals. cf. **epidemic** and **epiphytotic.**

fibrillose having thin fibrils, with the appearance of very fine silk threads.

filiform (L. *filiformis* < *filum,* linen thread + suf. *-formis* < *forma,* shape): with the shape of a thread, thin and slender, like a linen fiber.

floccose (L. floccosus, full of flocks of wool < *floccus*, flock or tuft of wool + *-osus*, full of, augmented, prone to> ME. *-ose*): tomentose, loosely cottony or woolly, or more densely agglomerated into small bundles like flannel. The colonies of many fungi, which form in natural conditions as well as on agar culture media, have a floccose appearance.

furcate (L. *furcatus,* forked <*furca,* fork + suf. *-atus*> E. *-ate*, provided with or likeness): forked or bifurcate.

fusiform (L. *fusiformis*, spindle-shaped <*fusus*, spindle + *-formis* <*forma,* shape): like a spindle, tapered at the ends, like the conidia of Aschersonia placenta.

fusoid (L. *fusus,* spindle + *-oide* <Gr. *-oeides*, similar to): see **fusiform.**

globose (L. *globosus*, round as a ball): having the shape of a globe or globule; spherical or almost spherical. Applied to structures (spores, sporocarps, etc.) whose length:width ratio is between 1:1.0 and 1:1.05.

hamathecium (pl. **hamathecia**) (Eriksson, Opera Bot. **60:** 15, 1981), a neutral term for all kinds of hyphae or other tissues between asci, or projecting into the locule or ostiole of ascomata; usually of carpocentral origin; interascal tissues. The different types of hamathecium, which occur in distinct taxonomic groups of fungi are: 1) **interascal pseudoparenchyma,** 2) **paraphyses,** 3) **paraphysoids,** 4) **pseudoparaphyses,** 5) **periphysoids,** and 6) **periphyses;** or the hamathecium can be absent.

hyaline having a glassy, translucent appearance.

hypha (pl. **hyphae**) (NL. *hypha* <Gr. *hyphe*, tissue, spider web; hypha): a tubular filament that represents the structural entity (thallus) of the majority of the fungi. Hyphae can be somatic or fertile and from their differentiation are derived a great diversity of structures related to the assimilative and reproductive functions, e.g., rhizoids, stolons, haustoria, appresoria and all of a broad gamut of asexual and sexual sporophores, such as sporangiophores, conidiophores, ascocarps and basidiocarps, all of them

manifesting diverse forms depending upon the species. The two general forms of hyphae are the **coenocytic** (in many of the so-called lower fungi) and the **septate** (in the Zygomycetes and Trichomycetes of the Zygomycota, and in the asexual fungi, Ascomycota and Basidiomycota).

hypothallus 1) (of lichens), the first hyphae of the thallus to grow, usually used of a crustaceous lichen which has no photobiont cells or cortex; = prothallus (protothallus), fide Maas Geesteranus (Blumea 6: 47, 1947) who restricts hypothallus to the spongy tissue on the underside of the thallus in Anzia, Pannaria and Pannoparmelia, but see spongiostratum; 2 (of myxomycetes), the thin layer on the surface of the substratum not used up in sporangial development; Ross (Mycol. 65: 477, 1973) distinguished epi- and subhypothallic development.

in vitro L. *in vitro,* in glass: (of processes or reactions) taking place in a test tube, culture dish, or elsewhere outside a living organism : [as adj.] *in vitro* fertilization. The opposite of in vivo.

In vivo L. *in vivo,* in a living thing: (of processes) taking place in a living organism.

monocotyledonous Botany (adj.): referring to a flowering plant with an embryo that bears a single cotyledon (seed leaf). Monocotyledons constitute the smaller of the two great divisions of flowering plants, and typically have elongated stalkless leaves with parallel veins (e.g., grasses, lilies, palms). Compare with **dicotyledonous.**

mononematous (Gr. *monos,* one + L. *nema,* genit.. *nematos,* thread, filament + L. *-ous, -eus*> E. *-ous,* having, abounding n, possessing the qualities of): a conidiophore composed of a single hypha or filament, as in the majority of the genera of hyphomycetous asexual fungi. cf. **synnematous.**

monophialidic (of a conidiogenous cell), having one locus through which conidia are produced. cf. **polyphialidic.**

mucilaginous referring to a viscous secretion or fluid, sticky when wet, slimy.

mycelium (pl. **mycelia**) the entire mass of hyphae that constitutes the vegetative body or thallus of a fungus.

obclavate inversely clavate (widest at the base).

oblique neither parallel nor at a right angle to a specified or implied line; slanting.

obtuse not sharp-pointed or sharp-edged; blunt; (of an angle) more than 90° and less than 180°.

orifice an opening, as of a pipe or tube.

ostiole (pl. -ia), a frequently + flask-shaped conidioma of fungal tissue with a circular or longitudinal ostiole, the inner surface of which is lined entirely or partially by conidiogenous cells; pycnidial.

ovoid oval, esp. with one end more pointed than the other.

paraphysis (pl. **paraphyses**), a sterile upward growing, basally attached hyphal element in a hymenium, esp. in ascomycetes where they are generally filiform, unbranched or branched, and the free ends frequently make an epithecium over the asci.

penicillate in the shape of a brush.

perithecium (pl. **perithecia**) a subglobose or flask-like ostiolate ascoma; sometimes limited to ascohymenial types formed from the development ascogonium (not of stromatic origin), but now widely used as a general term regardless of the ontogenic type.

phialide (after Vuillemin), a cell which develops one or more (the **polyphialide** of Hughes, Mycol. Pap. 45, 1951) open ended conidiogenous loci from which a basipetal succession of conidia, **phialospore**, develops without an increase in length of the phialide itself (Hughes, loc. cit.); cf. annellophore; sterigma. In some fungi, e.g. Acremonium, the phialide may be the conidiophore; more frequently the phialide is either an end cell of a conidiophore or attached to a conidiophore (or **phialophore**).

phialospore (Gr. *phialis,dim.* Of *phiale,* small glass, bottle + *spora,* spore): *Conidiogenesis.* An asexual reproductive spore formed by abstriction from the tip of a phialide; applied mainly to conidial and spermatial states of fungi.

phylogeny the branch of biology that deals with the evolutionary development and diversification of a species or group of organisms, or of a particular feature of an organism.

polyphialide A bottle-shaped conidiogenous cell that produces phialoconidia (phialospores) through several openings that are formed in synchronous or irregularly sympodial succession in the cell wall, as is observed in *Fusarium moniliforme* var. *subglutinans.*

pulvinate cushion-like in form.

pycnidium (pl. **pycnidia**) an asexual fruiting body, generally flask-shaped or spherical, with an internal cavity, the inner surface of which is lined entirely or partially by conidiogenous cells.

scutate like a round plate or shield.

septate having septa.
(pl. **sporodochia**) a small compact, cushion-shaped stroma on which are borne short

sporodochium conidiophores that produce spores (conidia).

sporulation production or formation of a spore or spores.

sterigma (pl. **sterigmata**)(Gr. sterigma, support): **1.** Basidiomycetes. Each of the small diverticula (usually 4) that form on the apex of each basidium, and which support basidiospores. **2.** Conidial fungi. The small tapered hyphal branch which bears a ballistospore (holoblastic conidium) of *Itersonilia* and *Sporobolomyces*). **3.** Oomycota. The small, sporangium-bearing structure of the sporangiophores of Basidiophora **4.** Lichens. Elongated cells, simple or slightly branched, aseptate, situated in the interior of the spermogonium and which produce spermatia.

stipe (L. *sipes*, *genit. stipitis*, stem, pedicel, foot): **1.** The part of the conidiophore that supports the conidiogenous cells, **2.** A foot or stalk that supports the pileus or a basidiocarp or the cap of a stipitate ascocarp. Another term for pseudopodetium. **3.** A more or less parallel tissue system which supports the gleba but has no direct structural connection with it.

stroma (pl. **stromata**): (Gr. *stroma*, bed, cushion): a compact mass of somatic hyphae made up of plectenchyma (prosenchyma, pseudoparenchyma, or both) on or in which are commonly produced fertile hyphae that generate asexual or sexual reproductive organs, such as sporodochia, pycnidia, perithecia, apothecia, etc.

subcylindrical somewhat or slightly cylindrical.

subglobose somewhat or slightly globose.

synnema pl. **synnemata** (Gr. *syn*, with, together + *nema*, filament): a compact, erect bundle of conidiophores that bear conidia at the apex and sometimes along the sides; the individual conidiophores may or may not be united laterally.

synnematous with synnema, cf. mononematous.

teleomorph Gr. *teleos*, complete, perfect + *morphe*, shape): the sexual (perfect) state of a fungus (ascogenous or basidiogenous), whose spores are produced by meiosis.

tubercle a small rounded projection or protuberance.

umbilicate (esp. of the cap of an agaric) having a central depression.

undulate having a wavy surface or edge.

verrucose (L. *verrucosus*, warted <*verruca*, wart, a height + -*osus*, full of, augmented, prone to> ME. -*ose*): with prominences in a manner of warts on the surface.
(NL. *verticillatus*, arranged in a verticil <L. *verticillus*, whorl + suf. -*atus*> E. -*ate*,

verticillate provided with or likeness): a type of branching in which the branches (pedicels, metulae, phialides, etc.) are borne at the same level on the hypha or support (sporangiophore, conidiophore, etc.) and they grow obliquely upward with respect to the central axis, generally reaching the same length and surrounding the hypha or support.

vesicle (L. *vesicula,* dim. of *vesica*, bladder): **1.** A receptacle or purse-shaped like a bladder or ampoule; applied especially to the mucilagenous structure produced by the zoosporangia in some Chytridiales and Peronosporales within which the zoospores mature before being liberated. **2.** The subsporangial swelling of species of Pilobolus **3.** The vesicular structures of the hyphae, with a thick cell wall, that probably constitute reserve deposits or resistant structures, and which mycorrhizogenous fungi form in the interior of the cells of the associated plant. The vesicles are one of the forms (the other constitute the arbuscles) present in endotrophic mycorrhizae). **4.** A swelling in the apical part of the conidiophores of the genus Aspergillus, which has various shapes, depending upon the species (claviform. spheroid, etc.), and which gives rise to phialides, producers of conidia (in species with a uniseriate conidial head), or to metulae and phialides (in those that have biseriate conidial head).

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