



## Notes on powdery mildews (Erysiphales) in Thailand I. *Podosphaera* sect. *Sphaerotheca*

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### Abstract

*Podosphaera* sect. *Sphaerotheca* is a group of powdery mildews mainly infecting herbaceous plants. In tropical countries such as Thailand, asexual morph of *Podosphaera* is more commonly found than sexual morph. Therefore, studies on diversity and molecular phylogenetics of powdery mildews in Thailand are important. In this study, three species, *Po. xanthii*, *Po. aphanis* var. *aphanis* and *Po. pannosa*, were determined based on morphological and molecular phylogenetic analyses using ITS sequence. Nine plant species are new world host records of powdery mildews, viz. *Cyanthillium cinereum* and *Spilanthes iabadicensis* (Asteraceae), *Justicia comata* (Acanthaceae), *Millingtonia hortensis* (Bignoniaceae), *Pouzolzia zeylanica* (Urticaceae), *Hydrocleys nymphoides* (Alismataceae), *Raphistemma pulchellum*, *Gymnema inodorum* (Apocynaceae) and *Leucas decemdentata* (Lamiaceae). In addition, 22 new records of *Podosphaera* were found in Thailand. Phylogenetic affinity of *Podosphaera* species found in Thailand and related species from other regions is also provided.

**Key words** – anamorph – *Erysiphaceae* – *Podosphaera* – molecular phylogeny – tropics

### Introduction

*Podosphaera* Kunze [type species: *Po. myrtillina* (Schub. : Fr.) Kunze] is a genus of powdery mildew (PM) having ascomata with a single ascus and catenulent conidia with distinct fibrosin bodies (Braun & Takamatsu 2000, Takamatsu et al. 2010). This genus is divided into two sections, sect. *Podosphaera* and sect. *Sphaerotheca*. Taxonomic history of the genus was described in the latest manual of the Erysiphales (Braun & Cook et al. 2012).

Investigation of PM in Southeast Asia in the past 13 years, in particular Thailand, has contributed to the discovery of new taxa and new records mainly belonging to the tribe Erysipheae (To-anun 2003, 2005, Divarangkoon 2011, Meeboon et al. 2013). From the published data regarding biodiversity of PMs in Thailand, few species of *Podosphaera* and its asexual morph have been reported, and of these reports only worldwide species have been recorded such as *Po. xanthii* (Castagne) U. Braun & Shishkoff and *Po. pannosa* (Wallr. : Fr.) de Bary (Giatgong et al. 1980). This circumstance encouraged the authors to further intensely investigate the actual biodiversity of

*Podosphaera* in Thailand. In this paper, we report nine new host records of PM in the world and 22 new records of the PMs (*Po. xanthii*, *Po. aphanis* and *Podosphaera* spp.) in Thailand. Phylogenetic affinity of *Podosphaera* species [asexual morph: *Fibroidium* (R.T.A. Cook, A.J. Inman & C. Billings) R.T.A. Cook & U. Braun] found in Thailand and related species from other regions is also provided.

## Materials & Methods

### Morphological examination

Morphological examinations were conducted according to the procedure described by Meeboon & Takamatsu (2013). To examine the anamorph, hyphae, conidiophores and conidia of fresh collections were stripped off from the leaf surfaces with clear adhesive tape, mounted on a microscope slide with the fungal mycelium uppermost, and examined in water. Herbarium samples were rehydrated before examination by boiling a small piece of infected leaf containing the fungal mycelium downwards in a drop of lactic acid on an objective glass (Shin & La et al. 1993). After boiling, the rehydrated mycelium was scraped off, mounted in lactic acid and examined using a light microscope. Thirty conidia and conidiophores were measured for each specimen examined. The specimens were deposited at the National Museum of Nature and Science (TNS) and Mie University Mycological Herbarium (MUMH), Japan. List of abbreviation names provided in Table 1.

### Molecular phylogeny

Whole-cell DNA was extracted from mycelia using the Chelex method (Walsh et al. 1991) as described in Hirata & Takamatsu (1996). The internal transcribed spacer (ITS) region was amplified by polymerase chain reaction (PCR) using the respective primer pairs of PM5/ITS4 for ITS fragment 1 and ITS5/PM6 (Takamatsu & Kano et al. 2001) for ITS fragment 2. KOD FX NeoDNA polymerase (Toyobo, Japan) was used in the PCR reaction according to the manufacturer's protocol. The amplicons of ITS region were sent to SolGent Co. (Daejeon, South Korea) for sequencing using primer pair of ITS1 and ITS4 (White et al. 1990).

New representative sequences determined in this study were deposited in DNA Data Base of Japan (DDBJ) under the accession numbers of LC143446-LC145052. Sequences generated from the ITS region were aligned with other *Erysiphaceae* sequences retrieved from DNA databases (DDBJ, EMBL, NCBI) using MUSCLE (Multiple Sequence Comparison by Log Expectation) (Edgar 2004) implemented in MEGA 5 (Tamura et al. 2011). The alignments were deposited in TreeBASE (<http://www.treebase.org/>) under the accession number of S19157.

Phylogenetic trees were obtained from the data using the maximum parsimony (MP) analysis by using PAUP\* 4.0b10 (Swofford et al. 2002) with the heuristic search option using the tree bisection-reconstruction (TBR) algorithm. This search was repeated 100 times with different random starting points, using the stepwise addition option to increase the likelihood of finding the most parsimonious tree. All sites were treated as unordered and unweighted, with gaps treated as missing data. Tree scores, including tree length (TL), consistency index (CI), retention index (RI) and rescaled consistency index (RC), were also calculated. The strength of the internal branches of the resulting trees was tested with bootstrap (BS) analysis (Felsenstein et al. 1985), using 1000 replications with the stepwise addition option set to simple and a maximum tree number of 100.

## Results

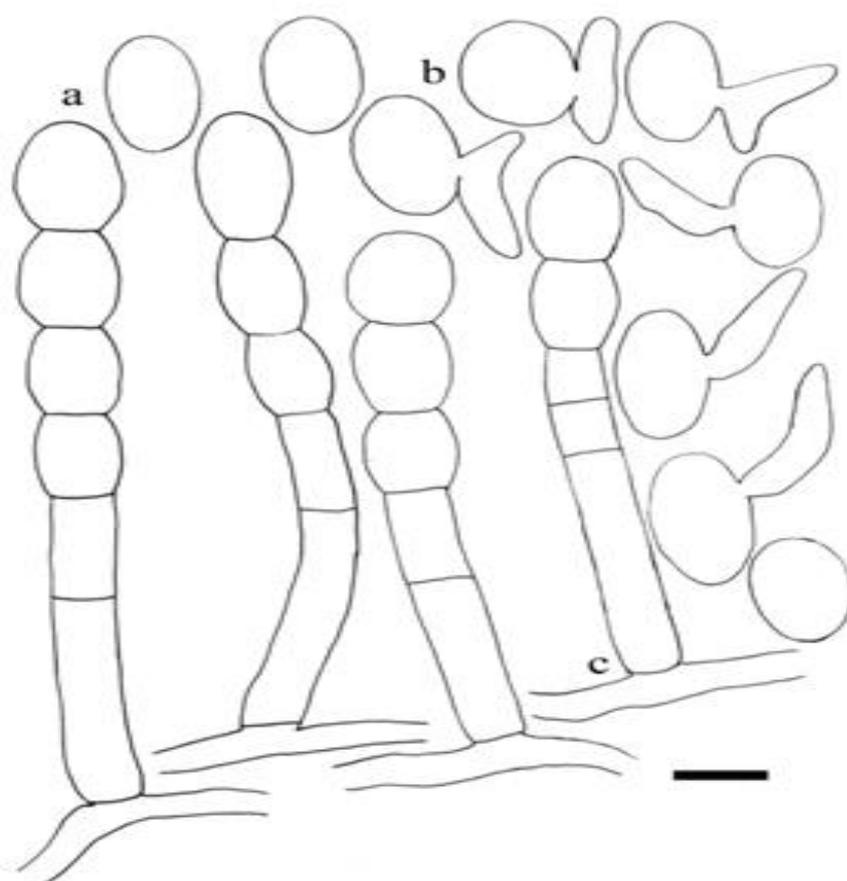
### Taxonomy

#### 1. *Podosphaera xanthii* (Castagne) U. Braun & Shishkoff

Fig. 1

Mycelium on stems and leaves, sometimes on fruits, often covering the entire surface of the leaves, amphigenous or epiphyllous, white to greyish sometimes turning into brown, at first

forming irregular patches, later effuse, thin to dense, evanescent to  $\pm$  persistent, with walls somewhat thickened, smooth to rough, 2–9  $\mu\text{m}$  wide; hyphae branched, substraight to wavy, septate, thin-walled, smooth or almost so, hyaline to subhyaline, 3–9  $\mu\text{m}$  wide; hyphal appressoria sometimes poorly developed, indistinct to nipple-shape, solitary, opposite in pairs or single; conidiophores erect, straight to flexuous, arising from the upper surface of hyphal mother cells, mostly towards one end of the cell but sometimes  $\pm$ centrally, single or occasionally two on a hyphal cell, (47–)90–200(–365)  $\times$  (5–)10–12.5  $\mu\text{m}$ ; foot cells cylindrical, straight, (13–)25–78(–112)  $\times$  (5–)11–16(–26)  $\mu\text{m}$ , sometimes slightly constricted at the basal septum or slightly swollen at the base, followed by 1–4(–8) shorter cells, forming 3–4(–10) catenulent conidia or in long chains, with a basal septum at the branching point of the mycelium; conidia ellipsoid-ovoid to doliiform, rarely cylindrical, (22.5–)28–38(–45)  $\times$  (12–)13–40(–43)  $\mu\text{m}$  with conspicuous fibrosin bodies; germ tubes  $\pm$ lateral, simple to forked, short (*brevitubus*-subtype of the *Podosphaera*-type). Sexual morph – not found.



**Fig. 1** – *Podosphaera xanthii* on *Justicia comata*. a conidia. b germ tubes. c conidiophores. – Bar = 20  $\mu\text{m}$ .

Further information – see Braun & Cook (2012).

Known distribution – almost circumglobal, North and South America, Asia, Australia, Africa, Europe, New Zealand (Braun & Cook et al. 2012).

Material examined – THAILAND, Chiang Mai Province, Suthep, on *Justicia comata* (L.) Lam. (Acanthaceae), 8 December 2002, S. Kom-un, MUMH1802; on *Cyanthillium cinereum* (L.) H. Rob. [syn. *Vernonia cinerea* (L.) Less.] (Asteraceae), 16 January 2003, S. Kom-un, MUMH1786, MUMH1796; on *Galinsoga parviflora* Cav. (Asteraceae), 6 December 2015, J.

Meeboon, MUMH3288; on *Impatiens balsamina* L. (Balsaminaceae), 6 December 2015, J. Meeboon, MUMH1749, MUMH1780, MUMH3716; on *Millingtonia hortensis* L. f. (Bignoniaceae), 8 December 2002, S. Kom-un, MUMH1801, MUMH1809; on *Heliotropium indicum* L. (Boraginaceae), 8 December 2002, S. Kom-un, MUMH1765, MUMH1839; on *Cleome rutidosperma* DC. (Cleomaceae), 8 December 2002, S. Kom-un, MUMH1753, MUMH1790, MUMH1814; on *Vigna radiata* (L.) R. Wilczek (Fabaceae), 18 January 2006, J. Meeboon, MUMH3720; Mae Jo, on *Macroptilium atropurpureum* (Moc. & Sessé ex DC.) Urb. (Fabaceae), 15 January 2014, J. Meeboon, MUMH1840; Mae Rim, on *Carica papaya* L. (Caricaceae), 9 January 2016, J. Meeboon, MUMH1853; on *Cucumis sativus* L. (Cucurbitaceae), 19 January 2016, J. Meeboon, MUMH3727; on *Dahlia* sp. Cav. (Asteraceae), 19 January 2016, J. Meeboon, MUMH6608; on *Gymnema inodorum* (Lour.) Decne. (Apocynaceae), 25 January 2003, S. Kom-un, MUMH1830; 12 January 2014, J. Meeboon, MUMH3709; on *Momordica charantia* L. (Cucurbitaceae), 9 January 2016, J. Meeboon, MUMH3721, MUMH3750; on *Euphorbia tithymaloides* L. [syn. *Pedilanthus tithymaloides* (L.) Poit] (Euphorbiaceae), 6 January 2002, S. Kom-un, MUMH1818; on *Phaseolus vulgaris* L. (Fabaceae), 6 January 2002, S. Kom-un, MUMH1743, MUMH1762; on *Senna occidentalis* (L.) Link (Fabaceae), 6 January 2002, S. Kom-un, MUMH1852, 12 January 2014, J. Meeboon, MUMH3706; on *Solanum melongena* L. (Solanaceae), 9 January 2016, J. Meeboon, MUMH1806, MUMH1812, MUMH1827; on *Physalis angulata* L. (Solanaceae), 9 January 2016, J. Meeboon, MUMH1768, MUMH1804, MUMH1820; Mae Jo, on *Macroptilium atropurpureum* (DC.) Urb. (Fabaceae), 7 January 2002, S. Kom-un, MUMH1840; on *Crotalaria pallida* Aiton (Fabaceae), 7 January 2002, S. Kom-un, MUMH1842; on *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc. (Fabaceae), 7 January 2002, S. Kom-un, MUMH1810, MUMH1834; on *Pouzolzia zeylanica* (L.) Benn. (Urticaceae), 6 January 2002, S. Kom-un, MUMH1844; on *Chamaesyce hirta* (L.) Millsp. (Euphorbiaceae), 9 January 2014, J. Meeboon, MUMH3318; Nan Province, on *Dahlia pinnata* Cav. (Asteraceae), 3 February 2002, S. Kom-un, MUMH1774; on *Spilanthes iabadicensis* A.H. Moore (Asteraceae), 3 February 2002, S. Kom-un, MUMH1763; Chiang Rai Province, Wiangpapao, on *Bidens pilosa* L. (Asteraceae), 5 January 2016, J. Meeboon, MUMH1773, MUMH1854; on *Cosmos sulphureus* Cav. (Asteraceae), 9 January 2016, J. Meeboon, MUMH1846; on *Cucurbita pepo* L. (Cucurbitaceae), 4 January 2016, J. Meeboon, MUMH1855, MUMH3305; on *Euphorbia hirta* L. (Euphorbiaceae), 4 January 2016, J. Meeboon, MUMH1751, MUMH1776, MUMH1789, MUMH1829.

Notes – In this study, six plant species are reported as new hosts of *Po. xanthii*. These are *Cy. cinereum* and *Spi. iabadicensis* (Asteraceae), *J. comata* (Acanthaceae), *Mi. hortensis* (Bignoniaceae), *M. atropurpureum* (Fabaceae) and *Pou. zeylanica* (Urticaceae). These plants, except *Pou. zeylanica*, are new hosts for this powdery mildew fungus in the world. In addition, 12 plant species are also reported here as new host records for *Po. xanthii* in Thailand. These are six species from Fabaceae (*Cr. pallida*, *Ph. vulgaris*, *Phy. angulata*, *Sen. occidentalis*, *V. unguiculata* subsp. *sesquipedalis*, *V. radiata*), two from Asteraceae (*D. pinnata*, *B. pilosa*), two from Euphorbiaceae (*Eu. hirta*, *Eu. tithymaloides*), *Cl. rutidosperma* (Cleomaceae), *Cu. pepo* (Cucurbitaceae) and *So. melongena* (Solanaceae).

Identification of *Po. xanthii* complex *sensu* Braun & Cook (2012) was based on a combination of morphological and molecular analysis of ITS sequences. The dataset of Hirata et al. (2000) was used to compare the molecular analysis with all PM sequences from Thailand. Notes on the PM specimens belonging to *Po. xanthii* complex found in Thailand are described below by plant family.

### Acanthaceae

*Erysiphe* sp., *Leveillula* sp. and *Oidium* sp. have been recorded on *Justicia* spp. (Braun & Cook et al. 2012). Because this fungus did not produce a sexual morph, PM on *J. comata* was sequenced and combined with the data matrix of Hirata et al. (2000). The result showed that this fungus has a nucleotide sequence identical to *Po. xanthii* on *Eu. hirta* (Euphorbiaceae), *Eu. tithymaloides* (Euphorbiaceae), *C. sativus* (Cucurbitaceae), *Cu. pepo* (Cucurbitaceae), *Sen.*

*occidentalis* (Fabaceae) and *Spi. iabadicensis* (Asteraceae). In addition, it has a sequence identical to haplotype 27 of Hirata (2000). The haplotypes 16–18 and haplotypes 19–27 belong to the group 3 *sensu* Hirata (2000). The haplotype of group 3 *sensu* Hirata (2000) referred to *Po. xanthii s. lat.* Braun & Cook (2012) also preferred to maintain powdery mildews on a wide range of plants as *Po. xanthii s. lat.* Therefore, based on the morphological and molecular characteristics, this fungus is identified as *Po. xanthii*. This is the first report of PM on *J. comata* in the world.

**Table 1** List of abbreviation names.

Names	Abbreviation	Names	Abbreviation
<i>Erysiphe</i>	<i>E.</i>	<i>Gymnema</i>	<i>Gy.</i>
<i>Fibroidium</i>	<i>F.</i>	<i>Helianthus</i>	<i>He.</i>
<i>Oidium</i>	<i>O.</i>	<i>Heliotropium</i>	<i>H.</i>
<i>Golovinomyces</i>	<i>G.</i>	<i>Hibiscus</i>	<i>Hi.</i>
<i>Neoerysiphe</i>	<i>N.</i>	<i>Impatiens</i>	<i>I.</i>
<i>Ovulariopsis</i>	<i>Ov.</i>	<i>Justicia</i>	<i>J.</i>
<i>Podosphaera</i>	<i>Po.</i>	<i>Lagenaria</i>	<i>L.</i>
<i>Pseudoidium</i>	<i>P.</i>	<i>Macroptilium</i>	<i>M.</i>
<i>Sphaerotheca</i>	<i>S.</i>	<i>Millingtonia</i>	<i>Mi.</i>
<i>Bidens</i>	<i>B.</i>	<i>Momordica</i>	<i>Mo.</i>
<i>Calendula</i>	<i>Cal.</i>	<i>Phaseolus</i>	<i>Ph.</i>
<i>Carica</i>	<i>Ca.</i>	<i>Physalis</i>	<i>Phy.</i>
<i>Cleome</i>	<i>Cl.</i>	<i>Pouzolzia</i>	<i>Pou.</i>
<i>Coccinia</i>	<i>Co.</i>	<i>Prunus</i>	<i>Pr.</i>
<i>Cosmos</i>	<i>Cos.</i>	<i>Senna</i>	<i>Sen.</i>
<i>Crotalaria</i>	<i>Cr.</i>	<i>Sesamum</i>	<i>Se.</i>
<i>Cucumis</i>	<i>C.</i>	<i>Solanum</i>	<i>So.</i>
<i>Cucurbita</i>	<i>Cu.</i>	<i>Spilanthes</i>	<i>Spi.</i>
<i>Cyanthillium</i>	<i>Cy.</i>	<i>Vigna</i>	<i>V.</i>
<i>Dahlia</i>	<i>D.</i>	<i>Viola</i>	<i>Vi.</i>
<i>Euphorbia</i>	<i>Eu.</i>	<i>Zinnia</i>	<i>Z.</i>
<i>Galinsoga</i>	<i>Ga.</i>		

### Apocynaceae

*Gymnema inodorum* belongs to the family Apocynaceae. This is the first report of PM on *Gy. inodorum* in the world. In this study, because we did not find sexual morph of this fungus, only the general morphological characteristics were described in detail. Based on the catenate conidia with fibrosin bodies, the PM on *Gy. inodorum* is determined as a member of the genus *Podosphaera*. The phylogenetic tree based on ITS sequence showed that the sequence of PM on *Gy. inodorum* is identical to the sequence from PM on *M. atropurpureum* (Fabaceae), *Pou. zeylanica* (Urticaceae), *So. melongena* (Solanaceae), *Cr. pallida* (Fabaceae), *V. radiata* (Fabaceae) and to haplotype 26 (group 3) of Hirata (2000) (Fig. 23). Based on the morphological and molecular characteristics, this fungus is identified as *Po. xanthii*. This is the first report of *Po. xanthii* on *Gy. inodorum* in the world.

### Asteraceae

Morphological characteristics of PMs infecting *Cos. sulphureus*, *Cy. cinereum*, *Spi. iabadicensis*, *D. pinnata*, *B. pilosa* and *Ga. parviflora* (Asteraceae) in Thailand resemble asexual morph of *Podosphaera*. PM specimen on *Cos. sulphureus* is very similar to the asexual morph of *Po.*

*xanthii*, which has been reported on various host plants including *Cosmos* species worldwide (Braun & Cook et al. 2012). Therefore, the PM on *Cos. sulphureus* is named here as *Po. xanthii*. In addition, there has been no record of PMs from *Cy. cinereum* worldwide. The molecular analysis showed that PM on *Cy. cinereum* has a nucleotide sequence identical to the sequences from *Po. xanthii* on *H. indicum* (Boraginaceae), *D. pinnata* (Asteraceae), *Phy. angulata* (Fabaceae) and haplotype 22 of Hirata (2000). Therefore, this PM is identified as *Po. xanthii*.

On *D. pinnata*, two PMs fungi, i.e., *Po. fusca* and *Golovinomyces cichoracearum* were reported from Korea (Shin & Lee 1999, Braun & Cook et al. 2012). In previous record of PMs from Thailand, *Oidium* sp. was found on *D. rosea* (Amano et al. 1986). The morphological characteristics of the present fungus is close to *Po. xanthii*. Based on molecular analysis, the sequence of this PM is also identical to nucleotide sequence of *Podosphaera* from *H. indicum* (Boraginaceae), *Cy. cinereum* (Asteraceae), *Phy. angulata* (Fabaceae) and haplotype 22 of Hirata (2000). Therefore, PM on *D. pilosa* is identified as *Po. xanthii*.

On *Spilanthes*, only *Spi. acmella* has been recorded as a host of *Oidium* sp. in the world (Amano 1986, Braun & Cook et al. 2012). The molecular analysis showed that sequence of PM on *Spi. iabadicensis* is identical to the sequence of *Podosphaera* on *Eu. hirta* and *Eu. tithymaloides* (Euphorbiaceae), *C. sativus* and *Cucur. pepo* (Cucurbitaceae), *Sen. occidentalis* (Fabaceae), *J. comatum* (Acanthaceae) and haplotype 27 of Hirata (2000). Therefore, this PM is identified as *Po. xanthii*.

On *B. pilosa*, three PMs, i.e., *G. cichoracearum*, *Neoerysiphe galeopsidis* and *Po. fuliginea* have been recorded worldwide (Amano 1986, Braun & Cook et al. 2012). *Podosphaera fusca* is well known as a PM fungus on *Bidens* and various host plants in India, Japan, Malaysia, Singapore, Sri Lanka, Taiwan and Korea (Braun & Cook et al. 2012). The phylogenetic tree showed that sequence of PM from *B. pilosa* formed a small clade with haplotypes 23 and 24 of Hirata et al. (2000) with 83% BS support (Fig. 23). Haplotypes 23 and 24 also belong to group 3 which is referred to as *Po. xanthii*.

On *Ga. parviflora*, *N. cumminsiana* (U. Braun) U. Braun is the only PM fungus found on the genus *Galinsoga* (on *Ga. parviflora*) (Braun & Cook et al. 2012). *Sphaerotheca fuliginea* var. *galinsogae* Y.S. Paul & J. Pal was excluded from valid taxa by Braun & Cook (2012). Molecular phylogenetic analysis based on the rDNA ITS sequence showed that sequence of *Ga. parviflora* has identical sequence with sequences of *Cy. cinereum* (Asteraceae), *Phy. angulata* (Fabaceae), *H. indicum* (Boraginaceae) and haplotype 22 of Hirata (2000) (Fig. 23). Therefore, the current specimen is assigned as *Po. xanthii*. This is the first report of *Podosphaera* found on *Ga. parviflora* in the world. *Galinsoga parviflora* is reported as new host of PM in Thailand.

### **Balsaminaceae**

The asexual morph of this fungus is in good agreement with *F. balsaminae*. According to Braun & Cook (2012), collections of PM on *I. balsamina*, *I. hawkeri*, *I. textori* and New Guinea hybrids, are genetically and biologically distinct from *Po. balsaminae* that is confined to *I. nolitangere*. PM on *I. balsamina*, *I. hawkeri*, *I. textor*, and New Guinea hybrids is, therefore, tentatively referred to as *Po. xanthii*, and asexual morph on these hosts can be assigned to *F. balsaminae* (Braun & Cook 2012). The current phylogenetic tree based on ITS showed that sequence of PM from *I. balsaminae* from Thailand (MUMH3716) is nested with sequence of *Po. xanthii* from various hosts in Thailand (Fig. 23). Therefore, based on the morphological characteristics and notes from Braun & Cook (2012), PM on *I. balsamina* from Thailand is identified as *Po. xanthii sensu* Braun & Cook (2012). This is the first record of PM on *I. balsamina* from Thailand.

### **Bignoniaceae**

Because sexual morph was not found, only asexual morph was described in detail. The phylogenetic tree based on the ITS sequence showed that this fungus groups with sequences of *Podosphaera* spp., including *Po. xanthii* (Fig. 23). Therefore, based on the morphological and

molecular phylogenetic analyses, this fungus is identified as *Po. xanthii sensu* Braun & Cook (2012). This is the first record of *Podosphaera* (*Sphaerotheca*) on *Mi. hortensis* in the world.

### **Boraginaceae**

*Fibroidium heliotropii-indici* and *P. heliotropii-strigosi* are two PM fungi recorded on *H. indicum* and *H. strigosum* Willd. worldwide (Amano et al. 1986). Sawada (1933) reported an asexual morph of *O. heliotropii-indica* on *H. indicum*. The general morphology of *Podosphaera* on *H. indicum* is in good agreement with the report of Sawada (1933). This fungus was sequenced and combined with data matrix of Hirata et al. (2000). The phylogenetic tree showed that the sequence on *H. indicum* in Thailand nested with sequence of *Po. xanthii* from various hosts in Thailand (Fig. 23). The result also showed that the ITS sequence of this fungus is identical to that of *Podosphaera* on two plants from family Asteraceae (*Cy. cinereum* and *D. pinnata*) and *Phy. angulata* (Fabaceae). Moreover, this fungus has a nucleotide sequence identical to the haplotype 22 of Hirata et al. (2000). Therefore, based on the morphological and molecular characteristics, PM on *H. indicum* is identified as *Po. xanthii sensu* Braun & Cook (2012). This is the first record of PM on *H. indicum* in Thailand.

### **Caricaceae**

Eight PM species have been recorded on *Ca. papaya* throughout the world (Braun & Cook et al. 2012), i.e. *O. caricae-papayae* J.M. Yen (*Oidium s. lat.*), *E. caricae* U. Braun & Bolay [(anamorph: *P. caricae* (F. Noack) U. Braun & R.T.A. Cook], *L. taurica s. lat.*, *Phyllactinia caricifolia* Viégas, *Ovulariopsis caricicola* U. Braun, *Ov. caricae* Sawada, *Ov. papayae* Van der Byl and *Po. xanthii* (Braun & Cook et al. 2012).

In the recent monograph of the Erysiphales, Braun & Cook (2012) noted *P. caricae* as the asexual morph of *E. caricae*. Another species, *O. caricae-papayae*, is often confused with *P. caricae*. In 1985, the occurrence of a PM on the stem of *Ca. papaya*, namely *S. caricae-papayae* (syn. *Po. caricae-papayae*) was reported (Tanda & Braun et al. 1985). This name is currently listed as a synonym of *Po. xanthii* (Braun & Cook et al. 2012). Until now, there is no record of PM occurring on fruit of *Ca. papaya*. The asexual morph of the PM on fruit and leaf of *Ca. papaya* from Thailand indicate that this fungus belongs to the genus *Podosphaera*. Braun & Cook (2012) noted this species as *Po. xanthii*. Based on the asexual morph and molecular characteristics, the present fungus is tentatively identified as *Po. xanthii* (syn. *Po. caricae-papayae*).

### **Cleomaceae**

Six PMs, i.e., *E. communis*, *E. radulescui*, *E. polyphaga*, *E. cruciferarum*, *L. taurica* and *S. fuliginea* have been recorded on *Cleome* spp. worldwide (Amano 1986, Braun & Cook et al. 2012). However, *Cl. rutidosperma* has never been recorded as a host of PM. *Erysiphe cruciferarum* has been recorded on *Cl. spinosa* by Junell (1967), Shin (1988), and Shin & La (1989) in Korea. The anamorphic characteristics of the current PM fungus clearly differs from *E. cruciferarum* due to having conspicuous fibrosin bodies, appressoria single, indistinct and poorly developed, sometimes slightly nipple-shaped, and producing catenescant conidia. The phylogenetic tree showed that the sequence from the current PM specimen has a nucleotide sequence identical to haplotype 21 including *Podosphaera* sp. on *Boehmeria nipononivea* (Urticaceae, AB026139). Therefore, based on the morphological and molecular analyses, this fungus is identified as *Po. xanthii sensu* Braun & Cook (2012). This is the first record of *Podosphaera* (*Sphaerotheca*) on *Cl. rutidosperma* in Thailand.

### **Cucurbitaceae**

*Podosphaera fusca* (Fr.) U. Braun & Shishkoff [= *S. fusca* (Fr.) S. Blumer] is a PM species in which the taxonomy is still confusing (Braun & Cook et al. 2012). Now, *Po. fusca* is confined to the fungus on Senecioneae of the Asteraceae, not including Cucurbitaceae (Braun & Cook et al. 2012). We found three PM specimens on *Cu. pepo*, *C. sativus* and *Mo. charantia* in Thailand. The

morphological characteristics of the three PM specimens are in good agreement with *Po. xanthii*. Park (2011) reported PM on bitter melon (*Mo. charantia*) caused by *Po. fusca* in Korea. This plant is also known as bitter melon and widely cultivated in tropical and subtropical regions for its edible immature fruit, which is used both as a vegetable and for medicinal purposes. Six PM species have been recorded on *Mo. charantia* (Farr & Rossman et al. 2010), viz. *G. cichoracearum* (from USA, China, South Africa and India), *G. orontii* (Castagne) Heluta (from United Kingdom and India), *G. biocellatus* (Ehrenb.) Heluta (from Thailand), *E. pisi* var. *pisi* (from Pakistan), *Po. fuliginea* (Schltdl. : Fr.) U. Braun & S. Takam. (from China, India and Japan) and *Po. xanthii*. (including *Po. fusca*) (from Taiwan, India and Korea).

The ITS sequence of PMs on *Cu. pepo*, *C. sativus* and *Mo. charantia* are also identical to each other. Molecular analysis of ITS sequence showed that these sequences have a nucleotide sequence identical to *Podosphaera* on *Eu. hirta*, *Eu. tithymaloides*, *Sen. occidentalis*, *J. comata*, *Spi. iabadicensis* and to haplotype 27 of Hirata (2000) (Fig. 23). Therefore, based on the general morphological characteristics and molecular analysis, this fungus is identified as *Po. xanthii sensu* Braun & Cook (2012). This is the first record of PMs on *Cu. pepo* and on *Mo. charantia* in Thailand.

### Euphorbiaceae

On *Eu. hirta*, *O. euphorbiae-hirtae* J.M. Yen (Yen 1966) and *O. pedilanthi* J.M. Yen (Yen et al. 1967) have been recorded. The later species was also found on *Eu. tithymaloides* (Yen et al. 1967). Braun & Cook (2012) noted *O. pedilanthi* as synonym to *O. euphorbiae-hirtae*. The asexual morph of current specimens is similar to *O. euphorbiae-hirtae*. DNA sequence of this PM fungus is identical to those of *Podosphaera* on *Eu. tithymaloides*. The phylogenetic tree showed that PM sequence on *Eu. hirta* from Thailand formed a small clade with a sequence of PM from *Spi. iabadicensis* at the terminal of phylogenetic tree with low bootstrap value. The ITS sequence of the current specimen has only one nucleotide difference from *Po. euphorbiae-hirtae* on *Acalypha australis* (haplotype 26) (Hirata et al. 2000). The identical nucleotide sequences between *Podosphaera* on *Eu. hirta* and *Eu. tithymaloides* may support the report of Yen (1967) that *O. pedilanthi* on *Pedilanthus* can cross-infect *Euphorbia*. The molecular analysis suggests that *O. euphorbiae-hirtae* and *O. pedilanthi* are conspecific. Based on the phylogenetic tree, *Po. euphorbiae-hirtae* should be a synonym of *Po. xanthii* (Fig. 23).

### Fabaceae

None of the seven specimens of PMs from the Fabaceae produced a sexual morph at the time of collection. The morphological structures of PMs from Fabaceae (*Sen. occidentalis*, *Ph. vulgaris*, *M. atropurpureum*, *Cr. pallida*, *V. unguiculata* subsp. *sesquipedalis*, *V. radiata*, *Phy. angulata*) resemble the asexual morph of the genus *Podosphaera*. The ITS sequences of these PMs are identical to several haplotypes in group 3 (Haplotype 22, 26 and 27) *sensu* Hirata (2000). The sequence of PM from *Sen. occidentalis* is identical to haplotype 27, while sequences of PMs from *Ph. vulgaris*, *M. atropurpureum*, *Cr. pallida*, *V. unguiculata* subsp. *sesquipedalis* and *V. radiata* are were identical to haplotype 26. Sequence from *Phy. angulata* is identical to haplotype 22. The haplotypes of the group 3 *sensu* Hirata (2000) referred to *Po. xanthii* (Hirata 2000, Ito & Takamatsu et al. 2010).

The phylogenetic tree showed that the sequence of PM from *Sen. occidentalis* formed a large clade at the terminal of phylogenetic tree with a bootstrap support (BS) of 83% (Fig. 23). The sequence of this fungus has also a nucleotide sequence identical to *Podosphaera* sequence from *Eu. hirta* and *Eu. tithymaloides* (Euphorbiaceae), *Cu. pepo* and *C. sativus* (Cucurbitaceae), *Spi. iabadicensis* (Asteraceae) and *J. comatum* (Acanthaceae).

On *Phaseolus* spp., seven PMs, i.e., *Erysiphe communis*, *E. pisi*, *E. polygoni*, *E. diffusa*, *L. taurica*, *Po. fuliginea* and *Po. astragali*, were recorded on twenty species of *Phaseolus* plants worldwide (Amano et al. 1986). Shin (2000) described *Po. phaseoli* on Fabaceae including *Ph. vulgaris* in Korea. Only asexual morph was described in that study. Our morphological observation

showed that the characters of this fungus are in good agreement with *Po. phaseoli*. However, the phylogenetic tree showed that the ITS sequence of this fungus forms a clade within the group 3 of Hirata (2000) with 65% BS. PM sequence from *Ph. vulgaris* is identical to the sequence from PM on *V. unguiculata* var. *sesquipedalis*. It is also identical to the nucleotide sequence of the fungi on *M. atropurpureum* (Fabaceae), *Pou. zeylanica* (Urticaceae), *So. melongena* (Solanaceae), *Cr. pallida* (Fabaceae), *V. radiata* (Fabaceae) and to haplotype 26 (group 3) of Hirata (2000).

The general morphology of PM from *V. unguiculata* var. *sesquipedalis* is similar to that of *Po. (Sphaerotheca) phaseoli* on *V. sinensis* (L.) Savi ex Hausskn. [current name: *V. unguiculata* (L.) Walp.] described by Shin & La (1992). *Podosphaera phaseoli* is currently listed as synonym of *Po. xanthii* (Braun & Cook 2012). In addition, *Po. xanthii* is the only species of PMs from the subtribe *Cystothecinae* found on plant genus *Vigna* (Fabaceae) (Braun & Cook et al. 2012). The PM specimen on *V. radiata* is slightly different from the asexual morph of *Po. xanthii* as described in Braun & Cook (2012) by having smaller foot cells (vs 30–100 × 10–13 µm of *Po. xanthii*). However, phylogenetic analysis based on ITS sequences showed that the current specimen is nested in the clade of *Po. xanthii*.

*Podosphaera fuliginea*, *E. communis* and *Oidium* sp. have been recorded on three species of *Macroptilium* worldwide (Amano 1986, Braun & Cook et al. 2012). Among them, only *Oidium* sp. has been recorded on *M. atropurpureum*. Molecular analysis showed that the ITS sequence of this PM has a sequence identical to the genus *Podosphaera* on *So. melongena* (Solanaceae) and *Pou. zeylanica* (Urticaceae).

Five PMs, i.e., *L. taurica*, *E. diffusa*, *E. communis*, *Po. fuliginea* and *Oidium* sp., have been recorded from nine species of *Crotalaria* worldwide (Amano 1986, Braun & Cook et al. 2012). Of them, only *Oidium* sp. has been recorded on *Cr. pallida*. In addition, *O. erysiphoides* f. *crotalariae* was described on *Crotalaria* (Braun et al. 1987), but the status of this species is uncertain.

On *Phy. angulata*, three PMs, i.e., *Po. fuliginea*, *G. cichoracearum* and *Oidium* sp. have been reported worldwide (Amano 1986, Braun & Cook et al. 2012). The asexual morph of the PM from *Phy. angulata* is very close to that of *Po. fusca*. Molecular analysis showed that this fungus has a nucleotide sequence identical to *Podosphaera* on *H. indicum* (Boraginaceae), *Cy. cinereum* (Asteraceae) and *D. pinnata* (Asteraceae).

## Solanaceae

*Euoidium longipes* (Noordel.& Loer.) U. Braun & R.T.A. Cook, *G. cichoracearum* (DC.) Heluta and *L. taurica* (Lév.) G. Arnaud have been recorded on *So. melongena* (Braun & Cook et al. 2012). Another PM, *Po. fusca* is also well known as PM infecting *Solanum* spp. worldwide (Braun & Cook et al. 2012). Characteristic of catenate conidia with fibrosin bodies clearly indicates that the present fungus belongs to the genus *Podosphaera*. Molecular analysis of the current specimen combined with the data set of Hirata et al. (2000) showed that the ITS sequence of the current specimen is identical to that of *Podosphaera* on *Ph. vulgaris*, *Cr. pallida*, *Pou. zeylanica*, *M. atropurpureum* and *V. sesquipedalis*. Moreover, it had a nucleotide sequence identical to the haplotype 26 of Hirata (2000). Therefore, based on the morphological and molecular characteristics, the current PM on *So. melongena* is identified as *Po. xanthii sensu* Braun & Cook (2012). This is the first record of PM on *So. melongena* from Thailand.

## Urticaceae

The family Urticaceae is commonly infected by numerous PM species worldwide (Amano 1986, Braun & Cook et al. 2012). However, there is no report on PMs on *Pou. zeylanica*. Present study is the first report of PM on *Pou. zeylanica* in the world. The ITS sequence of this fungus was identical to the sequence of *Podosphaera* on *So. melongena* (Solanaceae) and on several plants belonging to the family Fabaceae such as *Ph. vulgaris*, *Cr. pallida*, *M. atropurpureum* and *V. sesquipedalis*. In addition, the current PM sequence has a nucleotide sequence identical to the haplotype 26 of Hirata (2000). According to this analysis, *Podosphaera* on *Pou. zeylanica* is determined as *Po. xanthii sensu* Braun & Cook (2012).

## 2. *Podosphaera aphanis* (Wallr.) U. Braun & S. Takam. var. *aphanis*

Fig. 2

Mycelium on fruit, stems or leaves, amphigenous, forming irregular patches or effuse, evanescent to persistent; hyphae hyaline, thin-walled, smooth, 3–8 µm wide; hyphal appressoria indistinct to nipple-shaped; conidiophores arising from the upper surface of mother cells, generally towards one end of cell, (145–)172–244(–358) µm long; foot cells cylindrical, (60–)89 × 141(–160) µm, 8–12 µm wide near the base, followed by 3–4 shorter cells, basal septum somewhat elevated above the hyphal mother cells, forming catenulent conidia; conidia ellipsoid-ovoid to doliiform-limoniform, (25–)27–38(–43) × (14–)17–24(–26) µm, with fibrosin bodies; germ tubes unbranched, 30–70 × 3–4 µm wide with slightly swollen tip (*orthotubus*-subtype within *Podosphaera*-type).

Sexual morph – not found.

Further information – see Braun & Cook (2012)

Known distribution – almost circumglobal, Africa (South Africa, Zimbabwe), North America (Canada, USA, incl. Alaska), Asia (Central Asia, China, Taiwan, India, Iran, Japan, Siberia), Caucasus, all Europe, also in Iceland, South America (Argentina), Australia, New Zealand (Braun & Cook et al. 2012).

Material examined – THAILAND, Chiang Mai Province, Mae Rim, on *Fragaria* × *ananassa* (Duchesne ex Weston) Duchesne ex Rozier (Rosaceae), 9 January 2016, J. Meeboon, MUMH3739.

Notes – *Podosphaera aphanis* has been reported on various host plants including *Fragaria* species worldwide (Braun & Cook et al. 2012). Two varieties are described by Braun & Cook (2012), namely, var. *aphanis* and var. *hyalina* (U. Braun) U. Braun & S. Takamatsu. Based on the conidial characteristics, the current PM is close to var. *aphanis*. According to Braun & Cook (2012), *Po. aphanis* var. *hyalina* has narrow, hyaline and mostly very short appendages. We found this PM in Thailand, but unfortunately the sexual morph was absent from the specimen. The asexual morph clearly resembles the genus *Podosphaera*. The nucleotide sequence of this PM is identical to that of *Po. aphanis* on *Fragaria grandiflora* collected in Japan (AB026136) (Fig. 23). Therefore, based on the morphological and molecular characteristics, PM on *Fragaria* × *ananassa* was identified as *Po. aphanis*. This is the first report of *Po. aphanis* var. *aphanis* on *Fragaria* × *ananassa* from Thailand.

## 3. *Podosphaera pannosa* (Wallr : Fr.) de Bary

Fig. 3

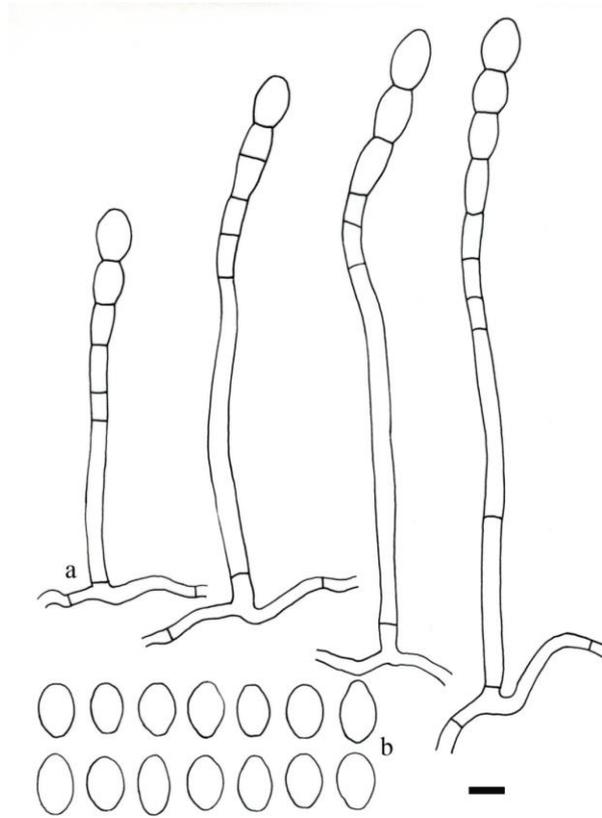
Mycelium amphigenous and on stems and inflorescences, in irregular patches or effuse, thin to dense, evanescent to ± persistent; hyphae thin-walled, smooth or almost so, 4–6 µm wide; hyphal appressoria indistinct to slightly nipple-shaped, solitary; conidiophores arising from the upper surface of hyphal mother cells, mostly towards one end of the cell but sometimes ± centrally, erect; foot cells cylindrical, (40–)57–68(–75) × 10–13 µm, sometimes slightly constricted at the basal septum or slightly swollen at the very base, followed by 1–2 shorter cells, forming catenulent conidia; conidia ellipsoid-ovoid to doliiform, (18–)25–30(–40) × (16–)18–20(–22) µm; germ tubes ± lateral, simple to forked, short (*brevitubus*-subtype of the *Podosphaera*-type).

Sexual morph – not found.

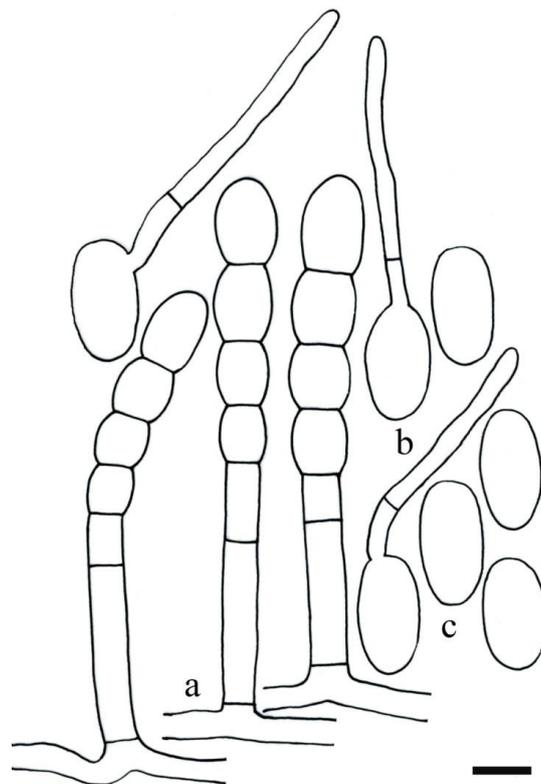
Further information – see Braun & Cook (2012).

Material examined – THAILAND, Chiang Mai Province, Suthep, on *Rosa hybrida* L. (Rosaceae), 18 January 2006, J. Meeboon, MUMH3719.

Notes – *Podosphaera pannosa* is commonly found on *Rosa* spp. and *Prunus s. lat.* (Rosaceae) worldwide (Braun & Cook et al. 2012). Morphological characteristics of this specimen clearly resembled the asexual morph of *Podosphaera*. Phylogenetic tree generated from ITS sequences showed that sequence of PM on *Rosa hybrida* from Thailand nested in the same clade with sequence of *Po. pannosa* on *Rosa* sp. (AB022348) (Fig. 23). Therefore, the current specimen is determined as *Po. pannosa*.



**Fig. 2** – *Podosphaera aphanis* var. *aphanis* on *Fragaria* × *ananassa*. a conidiophores. b conidia. – Bar = 20 μm.



**Fig. 3** – *Podosphaera pannosa* on *Rosa hybrida* L. a conidiophores. b germ tubes. c conidia. – Bar = 20 μm.

## Unknown species of *Podosphaera*

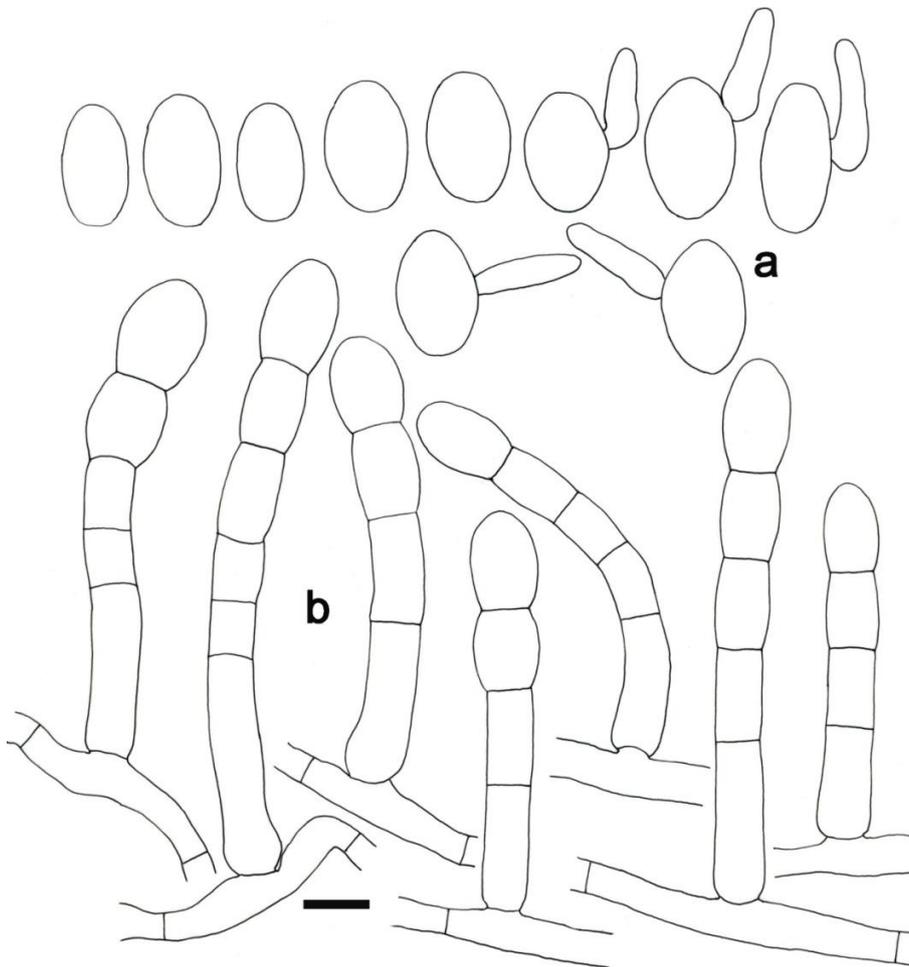
### 4. *Podosphaera* sp. on *Hydrocleys nymphoides*

Fig. 4

Mycelium amphigenous, thin, forming irregular patches or effuse, evanescent or  $\pm$  persistent, white or greyish white; hyphae 6.5–7.5  $\mu\text{m}$  wide, hyaline, septate, thin-walled, smooth or almost so; hyphal appressoria solitary, slightly to distinctly nipple-shaped, 3–6  $\mu\text{m}$  diam.; conidiophores arising from superficial hyphae, on the upper surface of mother cells, erect, straight, (78–)105–143(–170)  $\mu\text{m}$  long; foot cells cylindrical, (30–)35–55(–63)  $\times$  11–12.5  $\mu\text{m}$ , followed by 1–3 shorter cells, forming catenescent conidia; conidia ellipsoid-ovoid, doliiform, (30–)32.5–35(–37.5)  $\times$  (15–)16–17.5(–20)  $\mu\text{m}$ .

Material examined – THAILAND, Chiang Mai Province, Suthep, on *Hydrocleys nymphoides* (Humb. & Bonpl. ex Willd.) Buchenau (Alismataceae), 20 January 2006, J. Meeboon, MUMH3738.

Notes – Asexual morph indicated that the present fungus belongs to the genus *Podosphaera*. This is the first report of PM found on *Hyd. nymphoides* in the world. Molecular analysis is necessary to resolve the identity of this fungus.



**Fig. 4** – Line drawing of *Podosphaera* sp. on *Hydrocleys nymphoides*. a conidia. b conidiophores. – Bar = 20  $\mu\text{m}$ .

### 5. *Podosphaera* sp. on *Raphistemma pulchellum*

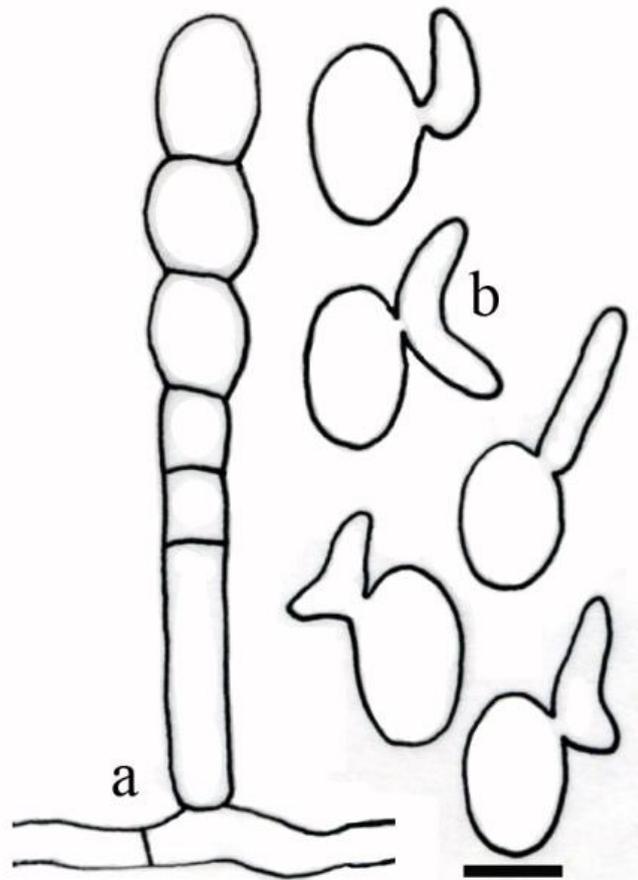
Fig. 5

Mycelium amphigenous, mainly epiphyllous, white, later turning brown, at first forming distinct patches, later effuse; hyphae branched, septate, subhyaline, 4–6  $\mu\text{m}$  wide; hyphal appressoria nipple-shape, opposite in pairs or single; conidiophores erect, single on a hyphal cell

arising from the side of mother cell; foot cells straight, forming catenescent conidia, with basal septum at the branching point of mycelium; conidia ovoid,  $30\text{--}35 \times 15\text{--}18 \mu\text{m}$ , with conspicuous fibrosin bodies.

Material examined – THAILAND, Nan Province, on *Raphistemma pulchellum* (Roxb.) Wall. (Apocynaceae), 3 February 2002, S. Kom-un, MUMH1759.

Notes – This study is the first report of PM on *Rap. pulchellum* in the world. Because we did not find the sexual morph, only the general morphological characteristics of asexual morph are described. Based on the catenate conidia with fibrosin bodies, the PM on *Rap. pulchellum* belongs to the genus *Podosphaera*. Comprehensive morphological and molecular studies are necessary to resolve the taxonomic position of this fungus. Unfortunately, we could not obtain complete morphological characteristics and also ITS sequence of this PM for molecular analysis to investigate the taxonomic position of this fungus.



**Fig. 5** – *Podosphaera* sp. on *Raphistemma pulchellum*. a conidiophore. b conidia with germ tubes. – Bar =  $20 \mu\text{m}$ .

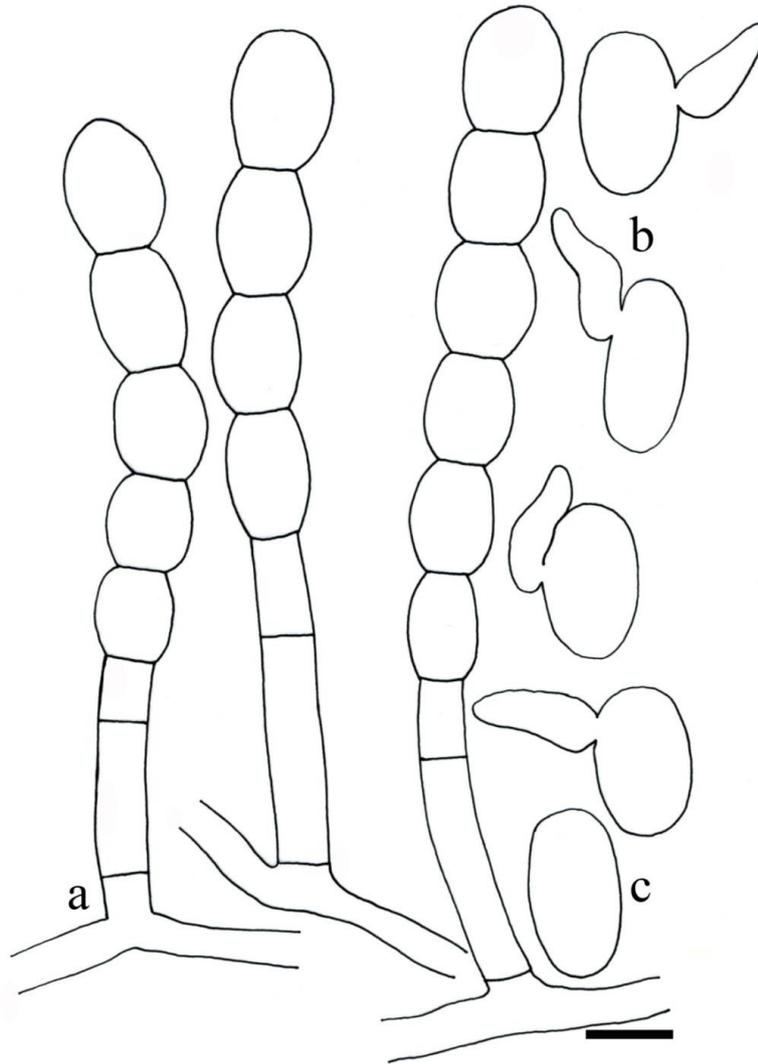
#### 6. *Podosphaera* sp. on *Aster* sp.

Fig. 6

Mycelium amphigenous, thin, white, effuse or in irregular patches, persistent; hyphae at first hyaline, later turning brown, thin-walled, smooth,  $4\text{--}8 \mu\text{m}$  wide; hyphal appressoria indistinct; conidiophores arising from the upper surface of superficial hyphae or mother cells, erect, straight; foot cells cylindrical,  $(34.5\text{--})53\text{--}62(\text{--}70) \times (8\text{--})9\text{--}11(\text{--}12) \mu\text{m}$ , followed by 2–3 shorter cells, forming catenescent conidia; conidia ellipsoid-ovoid to doliiform,  $(26\text{--})28\text{--}29.5(\text{--}31.5) \times (12\text{--})15\text{--}16(\text{--}17) \mu\text{m}$ .

Material examined – THAILAND, Chiang Rai Province, Wiangpapao, on *Aster* sp. (Asteraceae), 6 January 2016, J. Meeboon, MUMH6708.

Notes – *Podosphaera fusca* is well known as a PM fungus on various host plants including *Aster* species worldwide (Braun & Cook et al. 2012). Shin (1988) reported *Po. fusca* on *Aster* sp. in Korea. The morphological observation suggested that the PM on *Aster* of Thailand belongs to genus *Podosphaera*. This is the first record of PM on *Aster* sp. in Thailand.



**Fig. 6** – *Podosphaera* sp. on *Aster* sp. a conidiophores. b germ tubes. c conidia. – Bar = 20  $\mu$ m.

### 7. *Podosphaera* sp. on *Zinnia elegans*

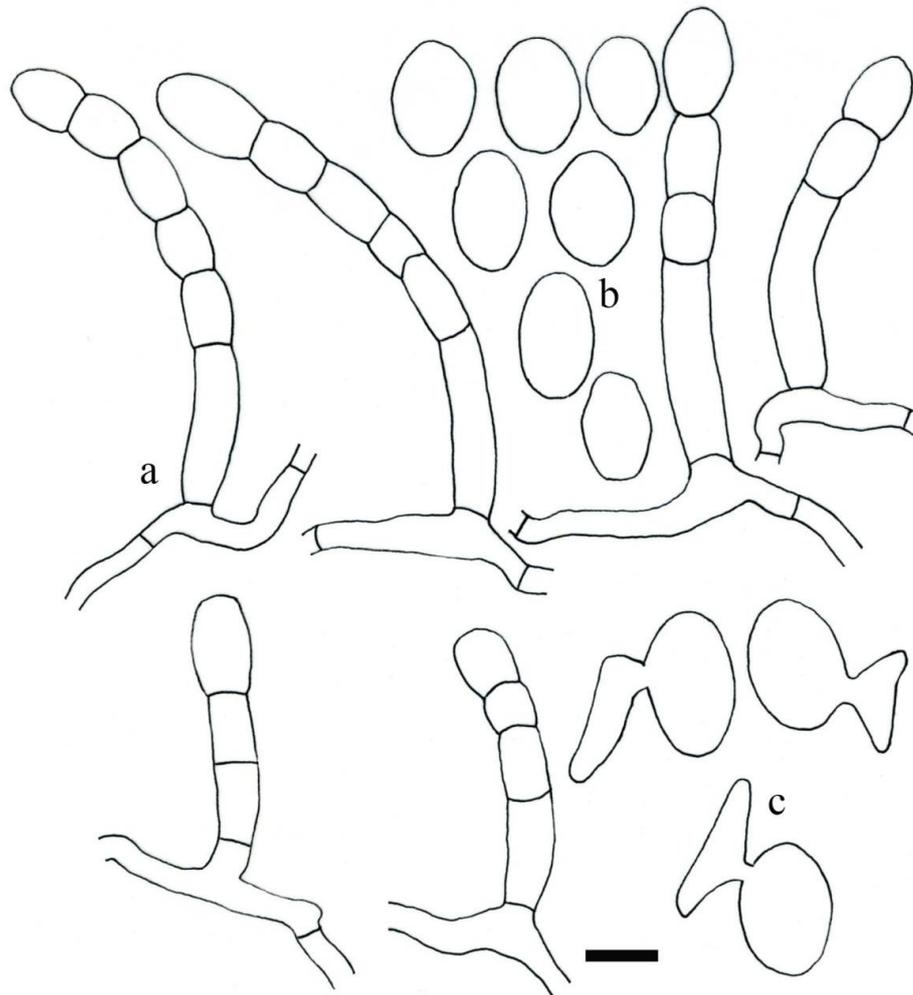
Fig. 7

Mycelium amphigenous, mainly epiphyllous, effuse or in patches, evanescent to persistent; hyphae hyaline, later gradually turning brown, 5–8  $\mu$ m wide, walls somewhat thickened; hyphal appressoria indistinct, sometimes slightly nipple-shaped; conidiophores arising from the upper surface of hyphal mother cells, erect, straight; foot cells cylindrical, (25.5–)43–71(–85)  $\times$  (9–)11–13(–14)  $\mu$ m, followed by 1–3 shorter cells, forming catenescence conidia; conidia ellipsoid to ovoid or doliiform, (26–)28.5–31(–35)  $\times$  (14–)15–17(–18)  $\mu$ m, with fibrosin bodies; germ tubes  $\pm$  lateral, simple to forked, short (*brevitubus*-subtype of the *Podosphaera*-type).

Material examined – THAILAND, Sukhothai Province, on *Zinnia elegans* L. (Asteraceae), 5 February 2002, S. Kom-un, MUMH1797.

Notes – *Golovinomyces spadiceus* (Berk. & M.A. Curtis) U. Braun and *O. erysiphoides* f. *zinniae* Cif. have been recorded as PM species found on *Z. elegans* in the world (Braun & Cook et al. 2012). However, the latter species is considered doubtful by Braun & Cook (2012). In addition, *Po. fusca* is also known as a PM fungus on various host plants including *Zinnia* species (Braun &

Cook et al. 2012). Based on the general morphological characteristics of the PM on *Z. elegans*, this fungus belongs to the genus *Podosphaera*. This is the first report of *Podosphaera* on *Z. elegans* from Thailand. Molecular analysis of the PM on *Z. elegans* is necessary to resolve the identity of this fungus.



**Fig. 7** – *Podosphaera* sp. on *Zinnia elegans*. a conidiophores. b conidia. c germ tubes. – Bar = 20  $\mu$ m.

**8. *Podosphaera* sp. on *Calendula officinalis***

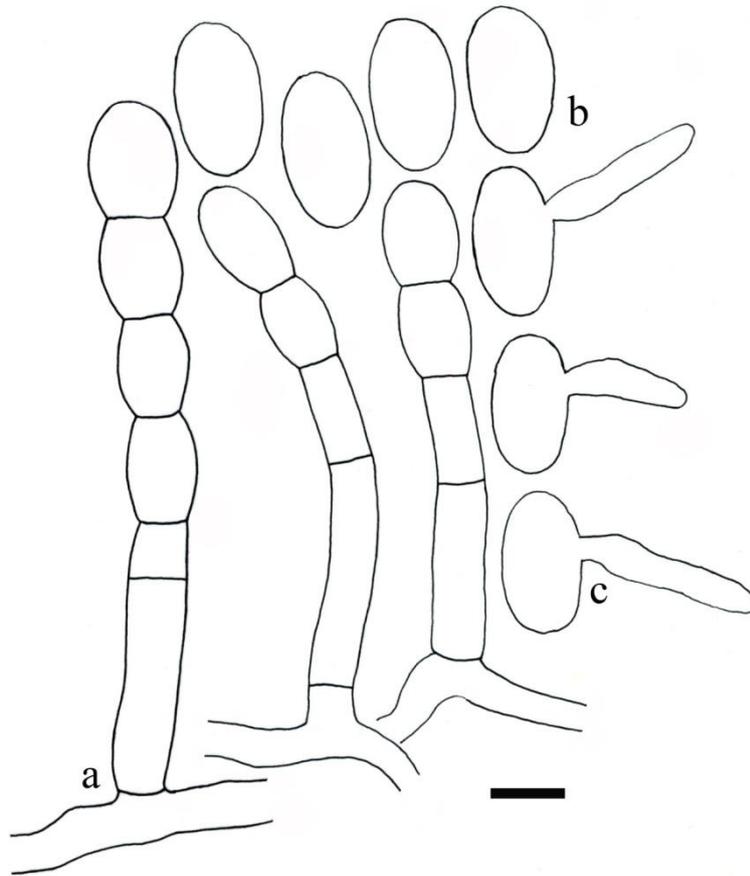
Fig. 8

Mycelium amphigenous, white, dense, effuse or in patches, persistent; hyphae hyaline, thin-walled, 5–7  $\mu$ m wide; hyphal appressoria nipple-shaped; conidiophores erect, straight, arising from the upper part of mother cells, position central to non-central, (118–)132  $\times$  174(–185)  $\mu$ m long; foot cells cylindrical, (36–)38–55(–80)  $\times$  (9.5–)10–11(–12.5)  $\mu$ m, followed by 2–3 shorter cells, forming catenescent conidia; conidia ellipsoid-ovoid, (28–)30–38(–40)  $\times$  (15–)17.5–18.5(–21)  $\mu$ m.

Material examined – THAILAND, Chiang Mai Province, Mae Jo, on *Calendula officinalis* L. (Asteraceae), 8 December 2002, S. Kom-un, MUMH1845.

Notes – Based on the catenate conidia with fibrosin bodies, this PM belongs to the genus *Podosphaera*. Three PM species, viz, *Po. fusca* (*Po. xanthii* s. lat.), *L. taurica* s. lat. and *E. cichoracearum* [current name: *G. cichoracearum* (DC.) Heluta] have been recorded on *Calendula* spp. (Braun 1987, Braun & Cook et al. 2012). In Korea, *Po. fusca* and *E. polygoni* were found on *Calendula* (Shin et al. 2000). The morphological features of the present fungus are in good

agreement with *Po. fusca*. Molecular phylogenetic analysis is necessary to confirm the identity of the current specimen. This is the first report of PM on *Cal. officinalis* in Thailand.



**Fig. 8** – *Podosphaera* sp. on *Calendula officinalis*. a conidiophores. b conidia. c germ tubes. – Bar = 20  $\mu$ m.

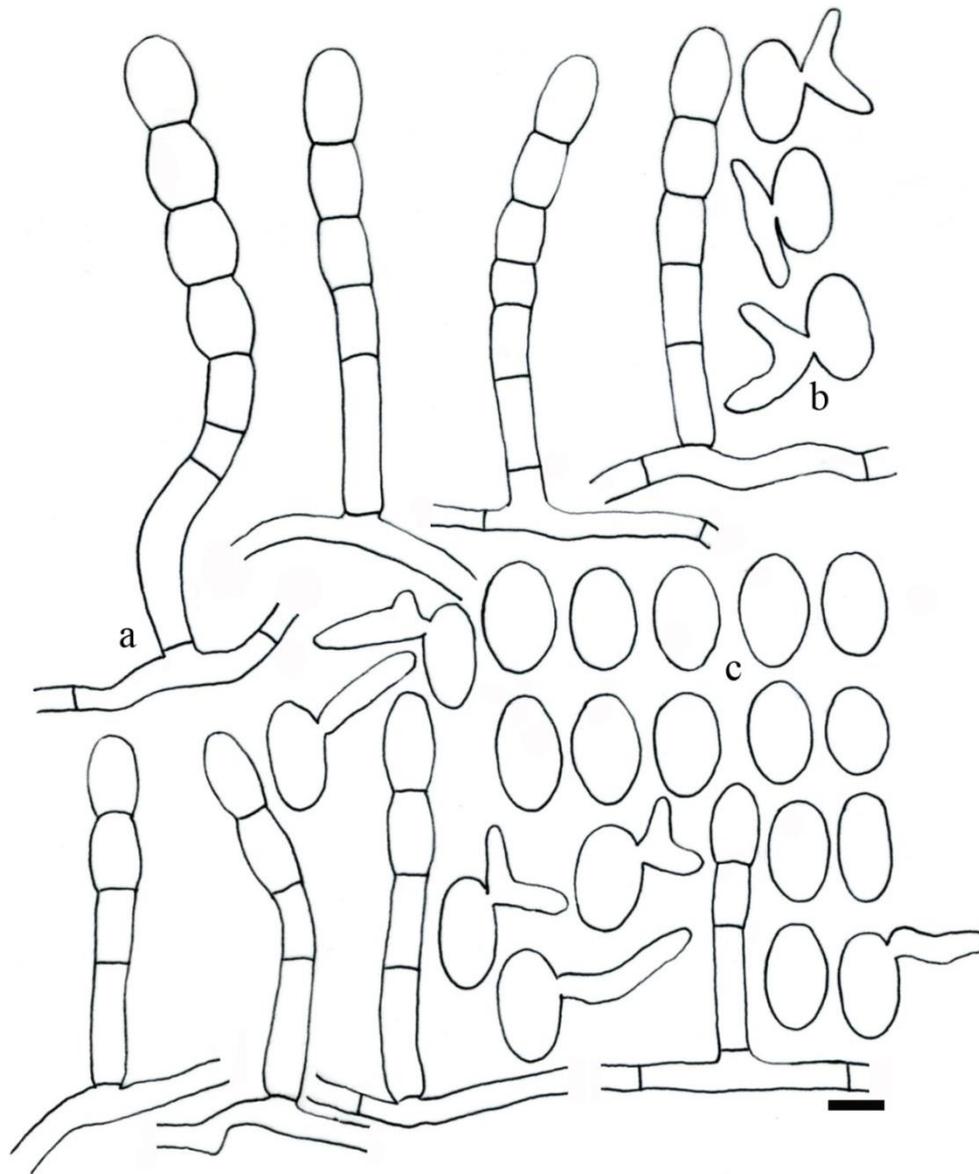
**9. *Podosphaera* sp. on *Helianthus annuus***

Fig. 9

Mycelium amphigenous, mainly epiphyllous, effuse or in irregular patches, thin to dense, evanescent to  $\pm$  persistent; hyphae thin-walled, smooth or almost so, 4–8  $\mu$ m wide; hyphal appressoria indistinct to slightly nipple-shaped, solitary; conidiophores arising from the upper surface of hyphal mother cells, mostly towards one end of the cell but sometimes  $\pm$  centrally, erect, about 60–180  $\mu$ m long; foot cells cylindrical, 40–70  $\times$  10–13  $\mu$ m, sometimes slightly constricted at the basal septum or slightly swollen at the very base, followed by 1–2 shorter cells, forming catenescent conidia, in long chains; conidia ellipsoid-ovoid to doliiform, 25–45  $\times$  14–22  $\mu$ m; germ tubes  $\pm$  lateral, simple to forked, short (*brevitubus*-subtype of the *Podosphaera*-type).

Material examined – THAILAND, Chiang Mai Province, Mae Rim, on *Helianthus annuus* L. (Asteraceae), 9 January 2016, J. Meeboon, MUMH6683.

Notes – The morphological characters of the current specimen are close to *Po. xanthii*. However, because only asexual morph was found, molecular phylogenetic analysis is necessary to determine the identity of the current specimen. The current specimen is tentatively identified as *Podosphaera* sp. This is the first report of *Podosphaera* on *He. annuus* from Thailand.



**Fig. 9** – *Podosphaera* sp. on *Helianthus annuus*. a conidiophores. b germ tubes. c conidia. – Bar = 20  $\mu$ m.

**10. *Podosphaera* sp. on *Cleome viscosa***

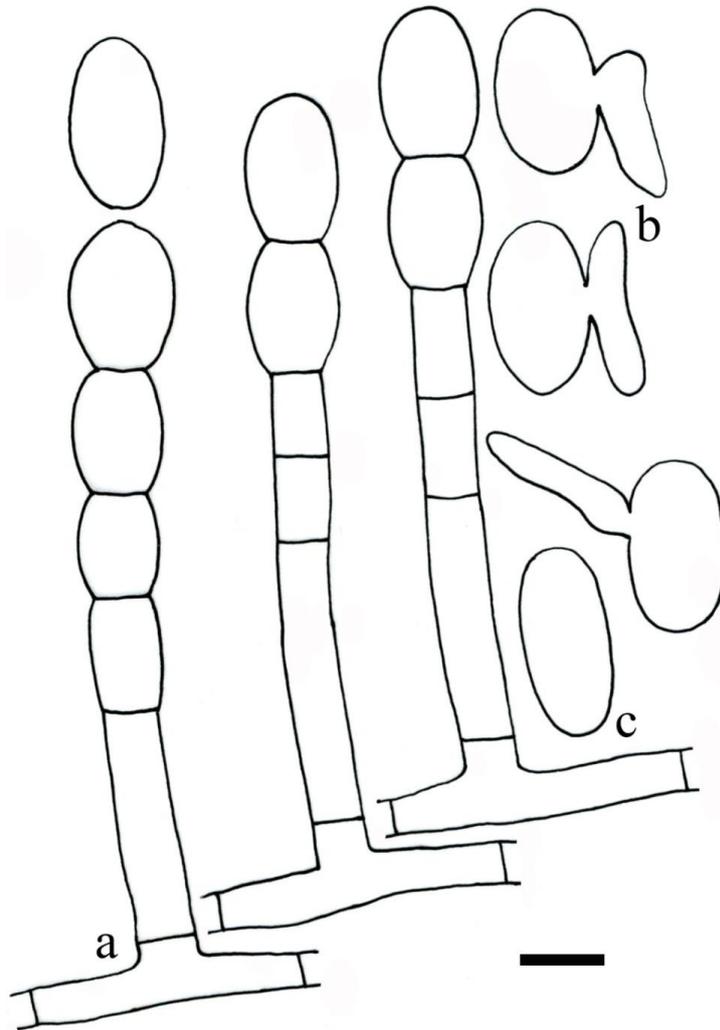
Fig. 10

Mycelium amphigenous, in irregular patches or effuse, thin to dense, evanescent to  $\pm$  persistent; hyphae thin-walled, smooth, 4–7  $\mu$ m wide; hyphal appressoria indistinct to slightly nipple-shaped, solitary; conidiophores arising from the upper surface of hyphal mother cells, erect; foot cells cylindrical, 75–100  $\times$  12–13  $\mu$ m, sometimes slightly constricted at the basal septum or slightly swollen at the very base, followed by 1–2 shorter cells, forming catenulate conidia; conidia ellipsoid-ovoid to doliiform, 35–40  $\times$  18–21  $\mu$ m; germ tubes  $\pm$ lateral, simple to forked, short (*brevitubus*-subtype of the *Podosphaera*-type).

Material examined – THAILAND, Chiang Mai Province, Mae Rim, on *Cleome viscosa* DC. (Cleomaceae), 9 January 2016, J. Meeboon, MUMH3344.

Notes – *Leveillula cleomis* Simonyan & Heluta, *E. cruciferarum* Opiz ex L. Junell, *O. capparidacearum* V.K. Pal, Akhtar, Kamal & N. Ahmad, *G. orontii* and *S. fuliginea* have been listed as PMs on *Cleome* spp. (Amano 1986, Braun & Cook et al. 2012). However, the morphological characteristics of the current specimen resemble the genus *Podosphaera*. Although several morphological characters of this specimen are similar to asexual morph of *Po. xanthii*,

molecular analysis is necessary to determine its identity. This is the first report of *Podosphaera* on *Cl. viscosa* in Thailand.



**Fig. 10** – *Podosphaera* sp. on *Cleome viscosa*. a conidiophores. b germ tubes. c conidia. – Bar = 20  $\mu\text{m}$ .

**11. *Podosphaera* sp. on *Lagenaria siceraria* var. *gourda***

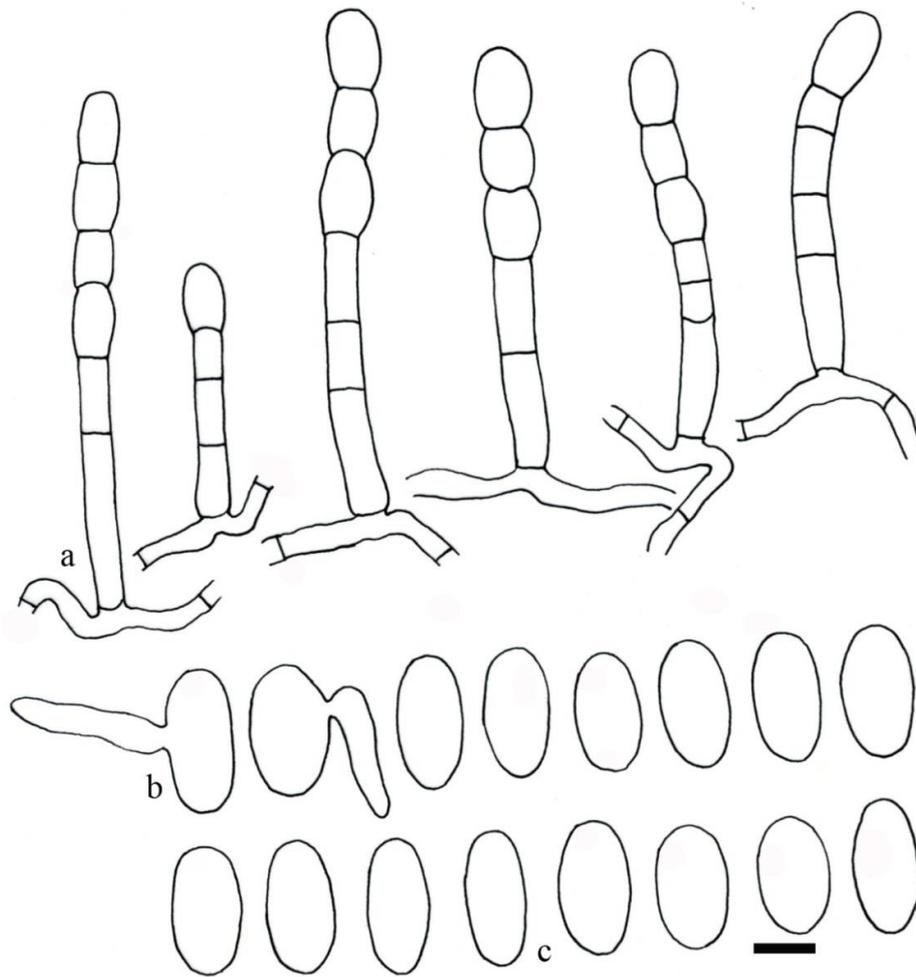
Fig. 11

Mycelium amphigenous, in irregular patches or effuse, thin to dense, evanescent to  $\pm$  persistent; hyphae thin-walled, smooth or almost so, 5–8  $\mu\text{m}$  wide; hyphal appressoria indistinct to slightly nipple-shaped, solitary; conidiophores arising from the upper surface of hyphal mother cells, mostly towards one end of the cell but sometimes  $\pm$  centrally, erect; foot cells cylindrical, 45–97  $\times$  9–13  $\mu\text{m}$ , sometimes slightly constricted at the basal septum or slightly swollen at the very base, followed by 1–3 shorter cells, forming catenescant conidia, in long chains; conidia ellipsoid-ovoid, 27–42  $\times$  13–22  $\mu\text{m}$ .

Material examined – THAILAND, Chiang Mai Province, Mae Rim, on *Lagenaria siceraria* (Molina) Standl. var. *gourda* (Cucurbitaceae), 19 January 2016, J. Meeboon, MUMH6709.

Notes – In the latest monograph of Erysiphales (Braun & Cook et al. 2012), *Po. xanthii* and *G. cucurbitacearum* (R.Y. Zheng & G.Q. Chen) Vokal. & Kliron. have been recorded as PMs on the genus *Lagenaria*. The present fungus resembles morphological characteristics of *Podosphaera*. Because no sexual morph was found in this specimen, it is difficult to assign this specimen as *Po. xanthii*. Molecular phylogenetic analyses could not be carried out due to failure of DNA extraction.

Thus, this specimen is tentatively assigned as *Podosphaera* sp. This is the first report of PM on *L. siceraria* var. *gourda* in Thailand.



**Fig. 11** – *Podosphaera* sp. on *Lagenaria siceraria* var. *gourda*. a conidiophores. b germ tubes. c conidia. – Bar = 20  $\mu$ m.

### 12. *Podosphaera* sp. on *Cucumis melo*

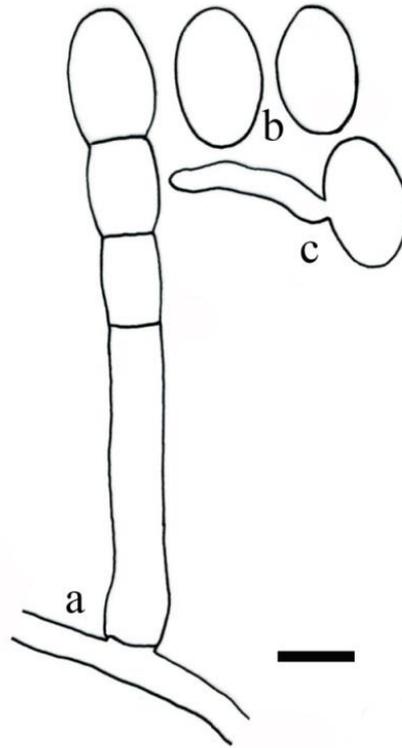
Fig. 12

Mycelium amphigenous, effused, sub-evanescent; hyphae substraight to somewhat wavy, branching at right or narrow angle, with a septum near the branching point; appressoria indistinct, sometimes slightly nipple-shaped, single; conidiophores erect, single or occasionally two on a hyphal cell, arising from the upper part of mother cells, position central to non-central; foot cells cylindrical, forming catenescence conidia, with a basal septum at the branching point of the mycelium; conidia ellipsoid-ovoid, containing conspicuous fibrosin bodies.

Material examined – THAILAND, Chiang Mai Province, Mae Rim, on *Cucumis melo* L. (Cucurbitaceae), 9 January 2014, J. Meeboon, MUMH3707.

Notes – *Erysiphe actinostemmatis* U. Braun, *E. pisi* var. *pisi*, *E. polygoni* DC., *G. cichoracearum*, *G. orontii* and *Po. xanthii* are PM species found on *C. melo* (Farr & Rossman 2010, Braun & Cook et al. 2003). Among them, *Po. xanthii* is the most common powdery mildew on this host (Farr & Rossman et al. 2010). The asexual morph of the present fungus resembles the genus *Podosphaera*. *Podosphaera xanthii* has been reported on various cucurbitaceous species around the world (Braun & Cook et al. 2012). Because the current specimen did not produce sexual morph, it is difficult to determine the species name of this specimen. Molecular analysis is

necessary to determine the identity of the PM on *C. melo* in Thailand. This is the first record of *Podosphaera* on *C. melo* from Thailand.



**Fig. 12** – *Podosphaera* sp. on *Cucumis melo*. a conidiophore. b conidia. c germ tube. – Bar = 20  $\mu\text{m}$ .

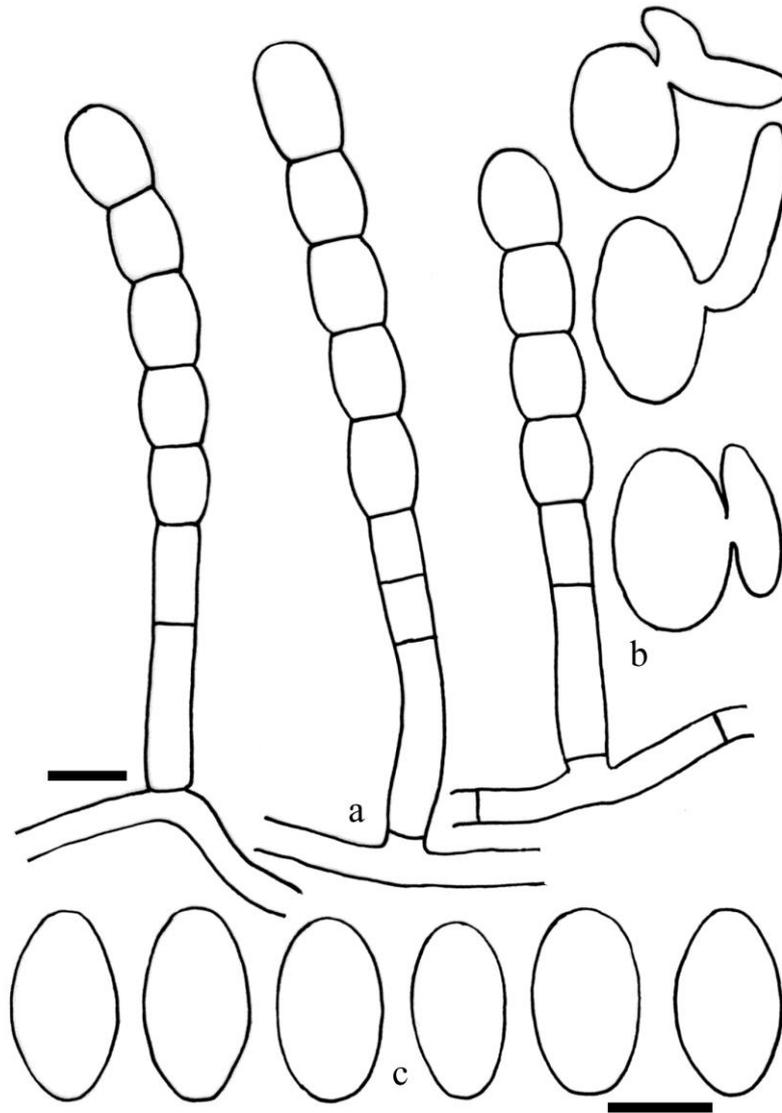
**13. *Podosphaera* sp. on *Cucurbita moschata***

Fig. 13

Mycelium mostly amphigenous, effuse or in irregular thick patches, evanescent to  $\pm$  persistent; hyphae straight to sinuous, hyaline, thin-walled, 8–10  $\mu\text{m}$  wide, mostly lacking pigmented persistent hyphae; hyphal appressoria nipple-shaped; conidiophores arising from the upper surface of hyphal mother cells, usually towards one end of cell, erect, (115–)152–170(–200)  $\mu\text{m}$  long; foot cells cylindrical, (32.5–)37.5–62.5(–72.5)  $\times$  10–12.5  $\mu\text{m}$ , followed by 1–2 shorter cells, forming catenulent conidia; conidia ellipsoid-ovoid to doliiform, (28–)32.5–33(–36)  $\times$  (16–)18–20(–22)  $\mu\text{m}$ , containing conspicuous fibrosin bodies.

Material examined – THAILAND, Chiang Mai Province, Mae Rim, on *Cucurbita moschata* Duchesne (Cucurbitaceae), 6 January 2002, S. Kom-un, MUMH1836.

Notes – The asexual morph indicates that this specimen belongs to the genus *Podosphaera*. Three *Podosphaera* species, i.e., *Po. fusca*, *Po. fuliginea* and *Po. macularis* have been recorded on *Cu. moschata* worldwide (Farr & Rossman et al. 2010). Morphologically, this fungus is similar to the asexual morph of *Po. xanthii*, which has been reported on various host plants including various *Cucurbita* species worldwide (Braun & Cook 2012). However, molecular analysis is necessary to confirm the morphological identification. In Thailand, *G. biocellatus* (Ehrenb.) Heluta is recorded as PM found on *Cu. moschata* (Giatgong et al. 1980). This is the first report of *Podosphaera* on *Cu. moschata* in Thailand.



**Fig. 13** – *Podosphaera* sp. on *Cucurbita moschata*. a conidiophores. b germ tubes. c conidia. – Bar = 20  $\mu$ m.

**14. *Podosphaera* sp. on *Coccinia grandis***

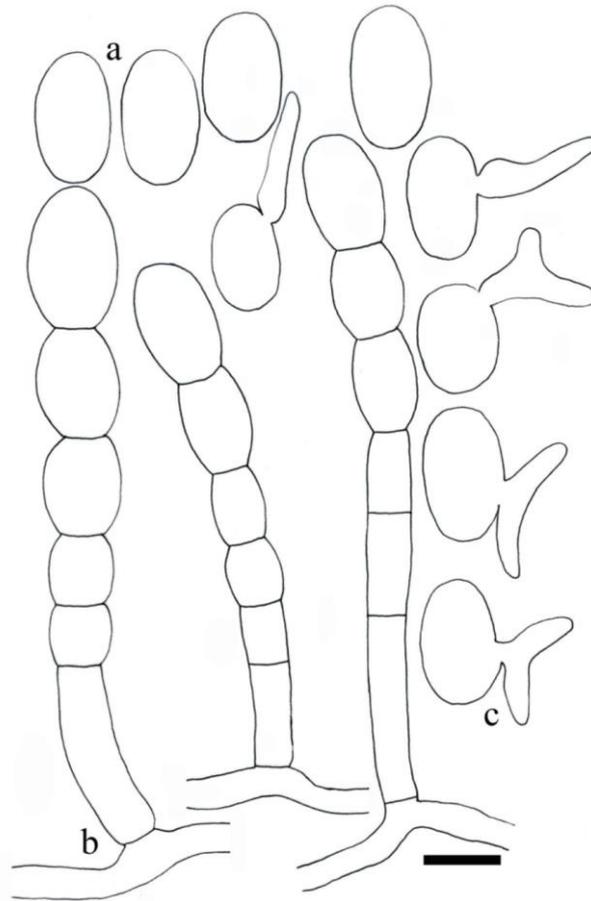
Fig. 14

Mycelium amphigenous, in irregular white patches or effuse, thin to dense, evanescent to  $\pm$  persistent; hyphae thin-walled, smooth, 4–6  $\mu$ m wide; hyphal appressoria indistinct to slightly nipple-shaped, solitary; conidiophores arising from the upper surface of hyphal mother cells, erect or slightly curved; foot cells cylindrical, 40–70  $\times$  12–13  $\mu$ m, sometimes slightly constricted at the basal septum or slightly swollen at the very base, followed by 0–2 shorter cells, forming catenulent conidia; conidia ellipsoid-ovoid to doliiform, (30–)35–40(–45)  $\times$  (18–)20–22(–24)  $\mu$ m; germ tubes  $\pm$  lateral, simple to forked, short (*brevitubus*-subtype of the *Podosphaera*-type).

Material examined – THAILAND, Chiang Rai Province, Wiangpapao, on *Coccinia grandis* (L.) Voigt (Cucurbitaceae), 5 January 2016, J. Meeboon, MUMH6613.

Notes – *Podosphaera fuliginea* (in Bangladesh) and *E. actinostemmatidis* U. Braun (in Japan and China) are PM fungi found on *Co. grandis* in the world (Amano 1986, Braun & Cook et al. 2012). The morphological characteristics of the current specimen resemble the genus *Podosphaera*. This is the first record of the genus *Podosphaera* found on *Co. grandis* (Cucurbitaceae) in Thailand. *Podosphaera xanthii* has been commonly reported from cucurbitaceous plants. We did not obtain DNA sequence of the current specimen, but the phylogenetic analysis based on ITS

sequence of other *Podosphaera* on Cucurbitaceae from Southeast Asia (e.g. *C. sativus*, *Cu. pepo*, etc.) showed that these sequences nested in the clade of *Po. xanthii*.



**Fig. 14** – *Podosphaera* sp. on *Coccinia grandis*. a conidia. b conidiophores. c germ tubes. – Bar = 20  $\mu$ m.

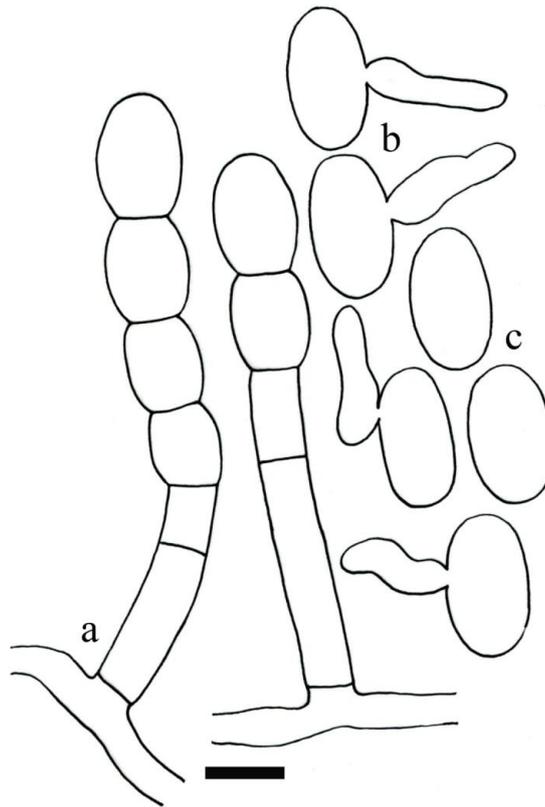
**15. *Podosphaera* sp. on *Leucas decemdentata***

Fig. 15

Mycelium on stems (caulicolous) and leaves (foliicolous), amphigenous, in dense patches, white; hyphae 3–6  $\mu$ m wide; appressoria nipple-shaped; conidiophores erect, arising from the upper surface of hyphal mother cells, about 80–155  $\mu$ m long; foot cells straight, cylindrical about 45–80  $\times$  8–10  $\mu$ m, followed by shorter cells, forming catenescant conidia; conidia ellipsoid to obovate, 25–35  $\times$  9–12  $\mu$ m, with fibrosin bodies; germ tubes  $\pm$  lateral, simple to forked, short (*brevitubus*-subtype of the *Podosphaera*-type).

Material examined – THAILAND, Petchaboon Province, Num Nao National Park, on *Leucas decemdentata* (Willd.) Sm. (Lamiaceae), 31 January 2004, J. Meeboon, MUMH3317.

Notes – This specimen is the first find of *Podosphaera* on the plant genus *Leucas* in the world. In the latest monograph of the Erysiphales (Braun & Cook et al. 2012), *N. galeopsidis* (DC.) U. Braun and its anamorph is the only PM species found on this plant worldwide. Further study in molecular analysis is important to determine the identity of this specimen.



**Fig. 15** – *Podosphaera* sp. on *Leucas decemdentata*. a conidiophores. b germ tubes. c conidia. – Bar = 20  $\mu\text{m}$ .

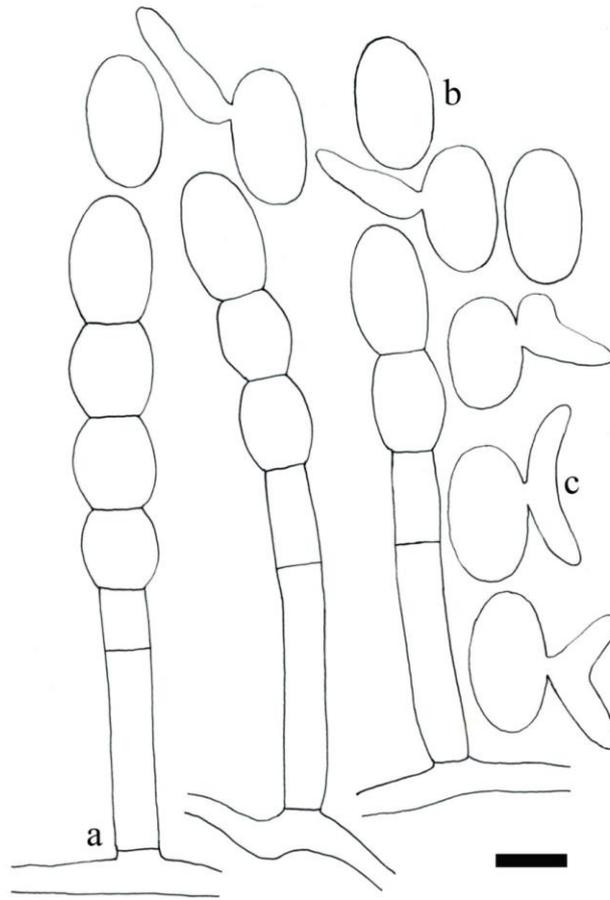
**16. *Podosphaera* sp. on *Hibiscus mutabilis***

Fig. 16

Mycelium amphigenous, thin, in patches or effuse, evanescent to  $\pm$  persistent, usually inconspicuous; hyphae smooth or almost so, 5–8  $\mu\text{m}$  wide, thin-walled; hyphal appressoria indistinct; conidiophores straight, erect, arising from the upper surface of hyphal mother cells, usually centrally, occasionally towards one end of the cell, up to 220  $\mu\text{m}$  long; foot cells cylindrical, about 40–65  $\times$  9–12  $\mu\text{m}$ , followed by 1–2 shorter cells, forming catenescence conidia; conidia ellipsoid-ovoid, (28–)33–38(–41)  $\times$  (15–)18–20(–22)  $\mu\text{m}$ , containing fibrosin body; germ tubes  $\pm$  lateral, simple to forked, short (*brevitubus*-subtype of the *Podosphaera*-type).

Material examined – THAILAND, Chiang Mai Province, Mae Rim, on *Hibiscus mutabilis* L. (Malvaceae), 9 January 2016, J. Meeboon, MUMH3752.

Notes – *Podosphaera fuliginea*, *Po. hibiscicola* (Z.Y. Zhao) U. Braun & S. Takam. on *Hi. mutabilis*, *F. abelmoschi* (Thüm.) U. Braun & R.T.A. Cook on *Hi. esculentus*, and *F. balakrishnani* (Hosag., Vijay., Udaiyan & Manian) U. Braun & R.T.A. Cook on *Hibiscus* spp. have been recorded as PMs from the tribe *Cystothecaceae* worldwide (Amano 1986, Braun & Cook et al. 2012). The morphological characters of the current specimen are more similar to *F. abelmoschi* (Thüm.) U. Braun & R.T.A. Cook than to *F. balakrishnani* (Hosag., Vijay., Udaiyan & Manian) U. Braun & R.T.A. Cook. Although *Po. hibiscicola* (Z.Y. Zhao) U. Braun & S. Takam. is recorded on the same host, we could not compare the current species with *Po. hibiscicola* due to lack of description of asexual morph. Therefore, the current specimen is identified as *Podosphaera* sp. This is the first report of *Podosphaera* on *Hi. mutabilis* in Thailand.



**Fig. 16** – *Podosphaera* sp. on *Hibiscus mutabilis*. a conidiophores. b conidia. c germ tubes. – Bar = 20  $\mu$ m.

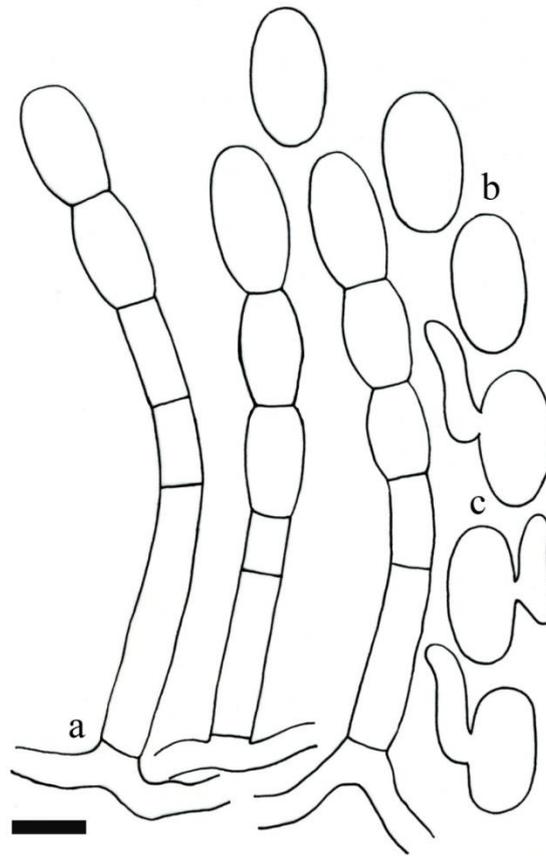
**17. *Podosphaera* sp. on *Hibiscus sabdariffa***

Fig. 17

Mycelium amphigenous, in irregular patches or effuse, thin to dense, evanescent to  $\pm$  persistent; hyphae thin-walled, smooth, 5–6  $\mu$ m wide; *hyphal appressoria* indistinct to slightly nipple-shaped, solitary; conidiophores erect or slightly curved, arising from the upper surface of hyphal mother cells; foot cells cylindrical, 50–85  $\times$  12–14  $\mu$ m, sometimes slightly constricted at the basal septum or slightly swollen at the very base, followed by 1–2 shorter cells, forming catenescence conidia; conidia ellipsoid-ovoid to doliiiform, (33–)35–38(–40)  $\times$  19–20(–21)  $\mu$ m; germ tubes  $\pm$  lateral, simple to forked, short (*brevitubus*-subtype of the *Podosphaera*-type).

Material examined – THAILAND, Chiang Mai Province, Mae Rim, on *Hibiscus sabdariffa* L. (Malvaceae), 9 January 2016, J. Meeboon, MUMH3715.

Notes – *Fibroidium abelmoschi* (Thüm.) U. Braun & R.T.A. Cook on *Hi. esculentus* from Egypt (Africa) and *F. balakrishnanii* (Hosag., Vijay., Udaiyan & Manian) U. Braun & R.T.A. Cook on *Hibiscus* sp. from India (Asia) have been recorded on this plant (Braun & Cook et al. 2012). However, it is difficult to differentiate the current specimen from *F. abelmoschi* and *F. balakrishnanii* based on morphological characteristics. Thus, it is necessary to use molecular analysis in determining the status of the current specimen. This is the first report of *Podosphaera* on *Hi. sabdariffa* in the world.



**Fig. 17** – *Podosphaera* sp. on *Hibiscus sabdariffa*. a conidiophores. b conidia. c germ tubes. – Bar = 20  $\mu$ m.

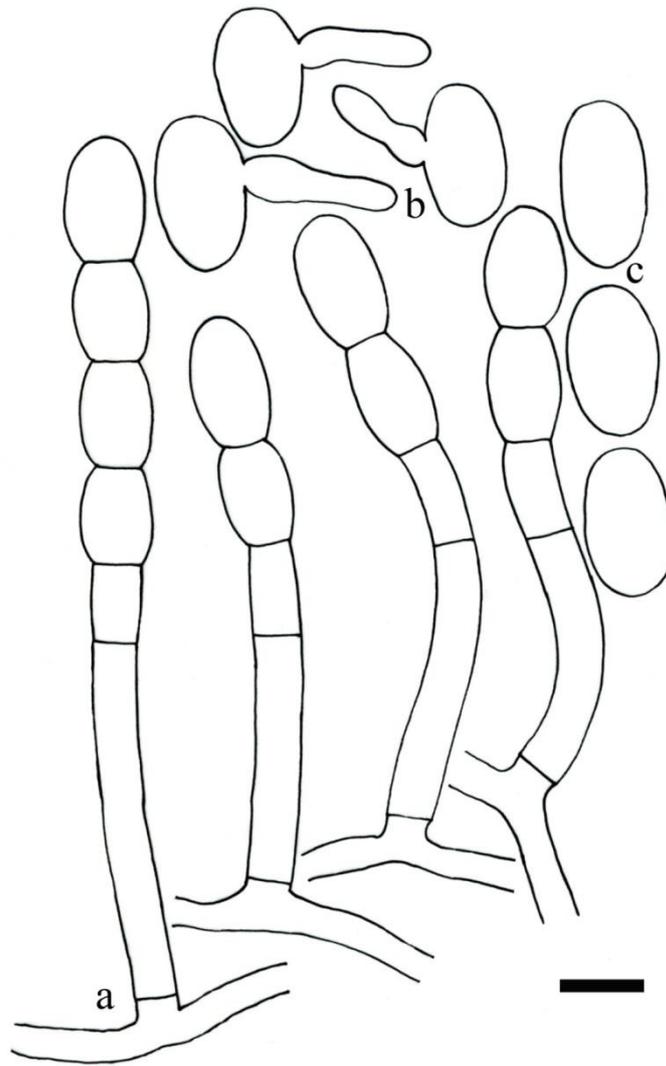
**18. *Podosphaera* sp. on *Kydia* sp.**

Fig. 18

Mycelium amphigenous, in irregular patches or effuse, thin to dense, evanescent to  $\pm$  persistent; hyphae thin-walled, smooth, 4–6  $\mu$ m wide; hyphal appressoria indistinct to slightly nipple-shaped, solitary; conidiophores erect or slightly curved, arising from the upper surface of hyphal mother cells; foot cells cylindrical, 60–95  $\times$  12–13  $\mu$ m, sometimes slightly constricted at the basal septum or slightly swollen at the very base, followed by 1–2 shorter cells, forming catenulent conidia; conidia ellipsoid-ovoid to doliiform, (35–)40–42(–43)  $\times$  19–22  $\mu$ m; germ tubes  $\pm$  lateral, simple to forked, short (*brevitubus*-subtype of the *Podosphaera*-type).

Material examined – THAILAND, Chiang Mai Province, Mae Rim, on *Kydia* sp. (Malvaceae), 9 January 2016, J. Meeboon, MUMH3298.

Notes – *Erysiphe kydiae-calycinae* (R.K. Verma, Chand & Kamal) U. Braun & S. Takam. from Nepal (Asia) and *P. kydiae* (Hosag.) U. Braun & R.T.A. Cook from India have been recorded as PMs on plant genus *Kydia* (Braun & Cook et al. 2012). Therefore, this is the first report of the genus *Podosphaera* found on *Kydia* in the world.



**Fig. 18** – *Podospaera* sp. on *Kydia* sp. a conidiophores. b germ tubes. c conidia. – Bar = 20  $\mu$ m.

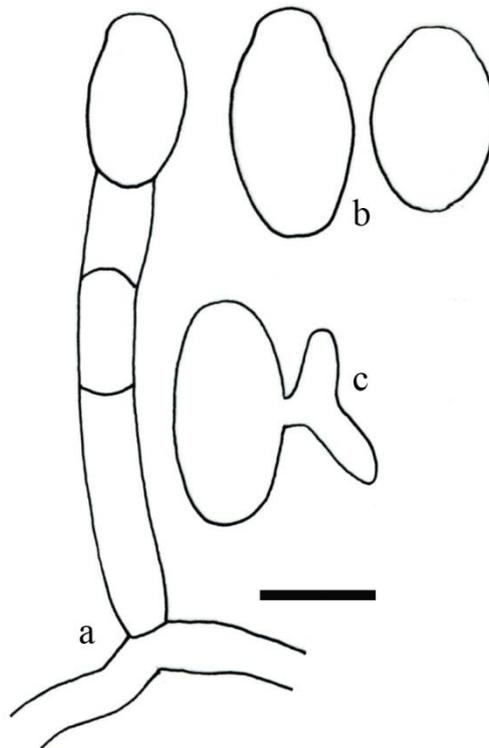
**19. *Podospaera* sp. on *Sesamum indicum***

Fig. 19

Mycelium amphigenous, effuse or forming patches, confluent, dense, white, evanescent to persistent; hyphae hyaline, thin-walled, smooth, 5–8  $\mu$ m wide; hyphal appressoria nipple-shaped; conidiophores straight, erect, arising from the upper surface of superficial hyphae, about 100–190  $\mu$ m long; foot cells straight to slightly curved, cylindrical, 50–70  $\times$  13–16  $\mu$ m, followed by 1–2 shorter cells, forming catenescence conidia; conidia ellipsoid-ovoid to cylindrical or doliiform, (25–)28–35(–42)  $\times$  15–20  $\mu$ m, with fibrosin bodies; germ tubes  $\pm$  lateral, simple to forked, short (*brevitubus*-subtype of the *Podospaera*-type).

Material examined – THAILAND, Chiang Mai Province, Mae Rim, on *Sesamum indicum* L. (Pedaliaceae), 9 January 2016, J. Meeboon, MUMH3748.

Notes – *Podospaera xanthii*, *Po. fuliginea* and *F. sesami* U. Braun & R.T.A. Cook are PM fungi found on the genus *Sesamum* worldwide (Thaug 2007, Braun & Cook et al. 2012). Analysis of molecular phylogeny is necessary to determine the identity of the current specimen. This is the first report of *Podospaera* on *Se. indicum* in Thailand.



**Fig. 19** – *Podosphaera* sp. on *Sesamum indicum*. a conidiophore. b conidia. c germ tube. – Bar = 20  $\mu\text{m}$ .

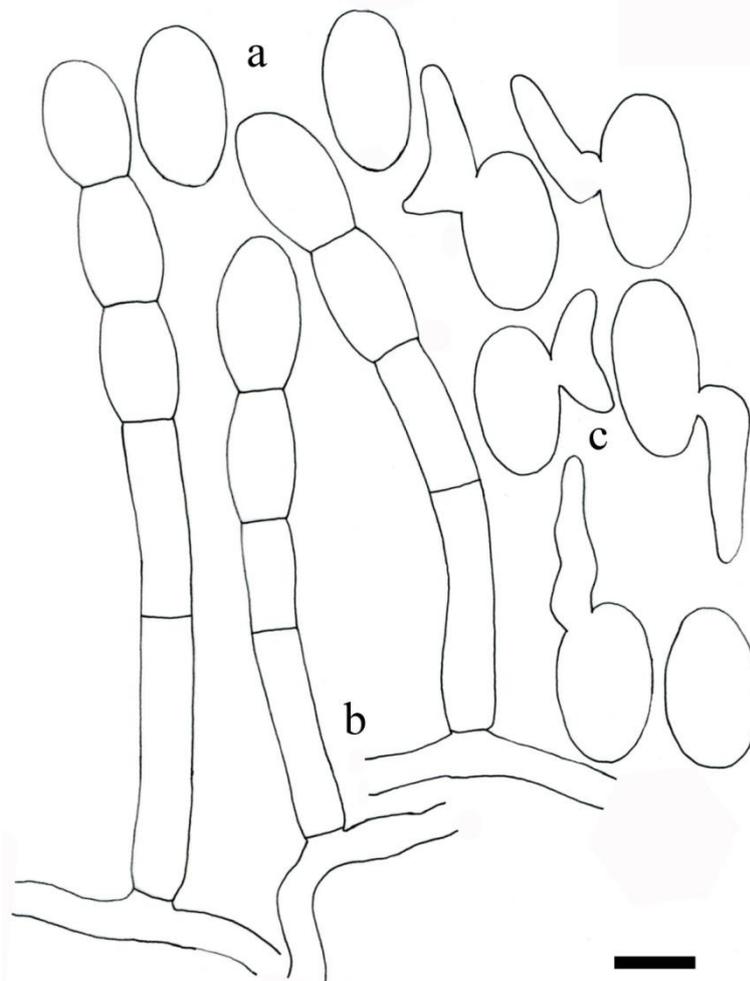
**20. *Podosphaera* sp. on *Prunus persica***

Fig. 20

Mycelium amphigenous, persistent, in dense patches; hyphal cells 4–6  $\mu\text{m}$ , branching at right angles, with a septum at the branching point; hyphal appressoria nipple-shaped; conidiophores arising from the upper surface of hyphal mother cells, position central to non-central, (90–221)  $\mu\text{m}$  long; foot cells cylindrical, (30–)35–65(–75)  $\times$  (8–)10–11(–11.5)  $\mu\text{m}$ , followed by 1–2 shorter cells, forming catenescence conidia; conidia ellipsoid-ovoid to doliiform, (28–)29–33(–34.5)  $\times$  (15–)15.5(–19)  $\mu\text{m}$ , containing conspicuous fibrosin bodies.

Material examined – THAILAND, Chiang Mai Province, Mae Rim, on *Prunus persica* (L.) Batsch (Rosaceae), 9 January 2016, J. Meeboon, MUMH1856.

Notes – *Podosphaera leucotricha* (Ellis & Everh.) E.S. Salmon, *Po. clandestina* (Wallr. : Fr.) Lév., *Po. pannosa* (Wallr. : Fr.) de Bary and *Po. tridactyla* (Wallr.) de Bary have been recorded on various host plants including *Prunus s. lat.* (Farr & Rossman 2010, Braun & Cook et al. 2012). These works provided additional information of taxonomic value by describing the mycelial morphology and conidiophore position on mother cell. However, Takamatsu (2010) considered that *Po. longiseta* [previously included in *Po. tridactyla s. lat. sensu* Braun (1987)] from *Pr. guyana* and *Pr. buergeriana* (endemic to Japan) must be considered a separate species. Takamatsu (2010) noted that lectotypification of *Po. longiseta* from *Prunus* spp. is necessary due to unavailable type material. Asexual morph characteristics of the present fungus clearly resemble the genus *Podosphaera*. Molecular analysis is necessary to resolve the identity of this fungus to species level. This is the first report of *Podosphaera* on *Pr. persica* in Thailand.



**Fig. 20** – *Podosphaera* sp. on *Prunus persica*. a conidia. b conidiophores. c germ tubes. – Bar = 20  $\mu\text{m}$ .

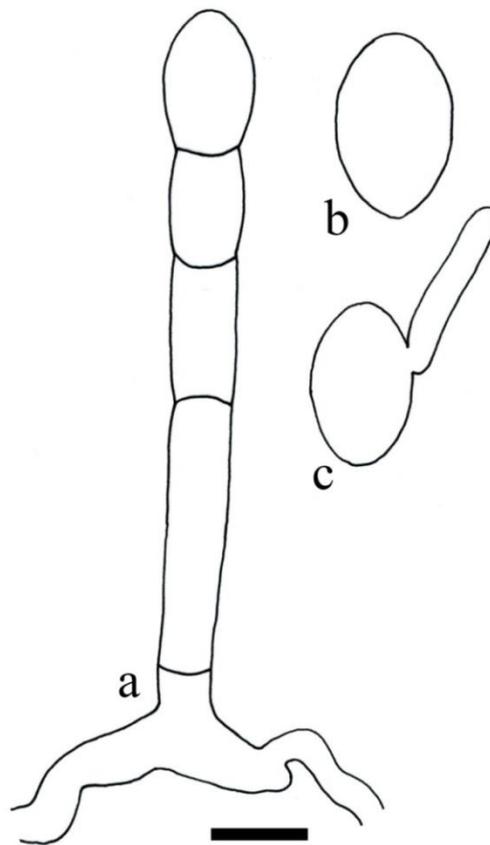
**21. *Podosphaera* sp. on *Prunus mume***

Fig. 21

Mycelium amphigenous, effuse or in irregular patches, evanescent to  $\pm$  persistent, white or greyish white; hyphae septate, branched, thin-walled, smooth, 5–7  $\mu\text{m}$  wide; hyphal appressoria poorly developed to nipple-shaped; conidiophores straight, arising  $\pm$  centrally from the upper surface or somewhat towards one end of the mother cell; foot cells subcylindrical, (45–)50–65(–76)  $\times$  8–10(–11.5)  $\mu\text{m}$ , followed by 1–3 shorter cells, forming catenescence conidia; conidia ellipsoid-ovoid to doliiform-subcylindrical, (23–)27–30(–35)  $\times$  (12–)14–18(–20)  $\mu\text{m}$ .

Material examined – THAILAND, Chiang Mai Province, Mae Rim, on *Prunus mume* (Siebold) Siebold & Zucc. (Rosaceae), 9 January 2016, J. Meeboon, MUMH3717.

Notes – Anamorphic characteristics indicated that the present fungus belongs to the genus *Podosphaera*. *Podosphaera tridactyla* (Wallr.) de Bary has been reported as a PM on *Prunus s. lat.* including *Pr. mume* (Braun & Cook et al. 2012). Although the morphological characteristics of this fungus are close to the asexual morph of *Po. tridactyla*, molecular analyses is necessary to resolve the identity of the fungus. This is the first report of *Podosphaera* on *Pr. mume* in Thailand.



**Fig. 21** – *Podosphaera* sp. on *Prunus mume*. a conidiophore. b conidium. c germ tube. – Bar = 20  $\mu\text{m}$ .

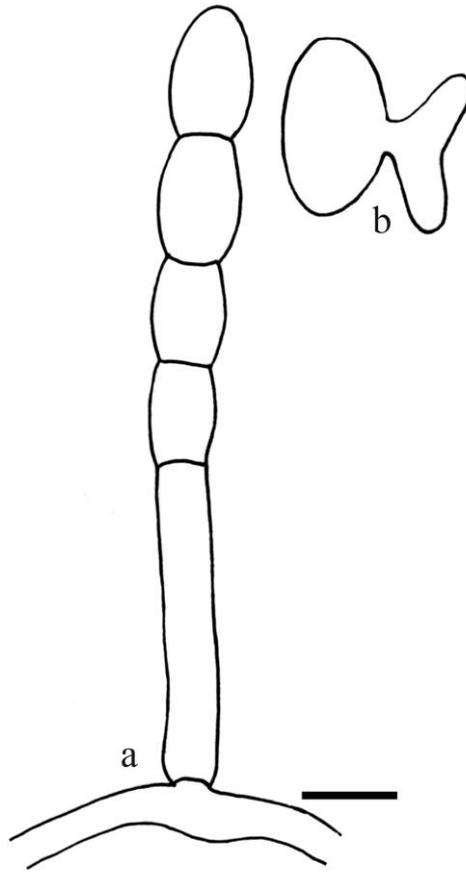
**22. *Podosphaera* sp. on *Viola tricolor***

Fig. 22

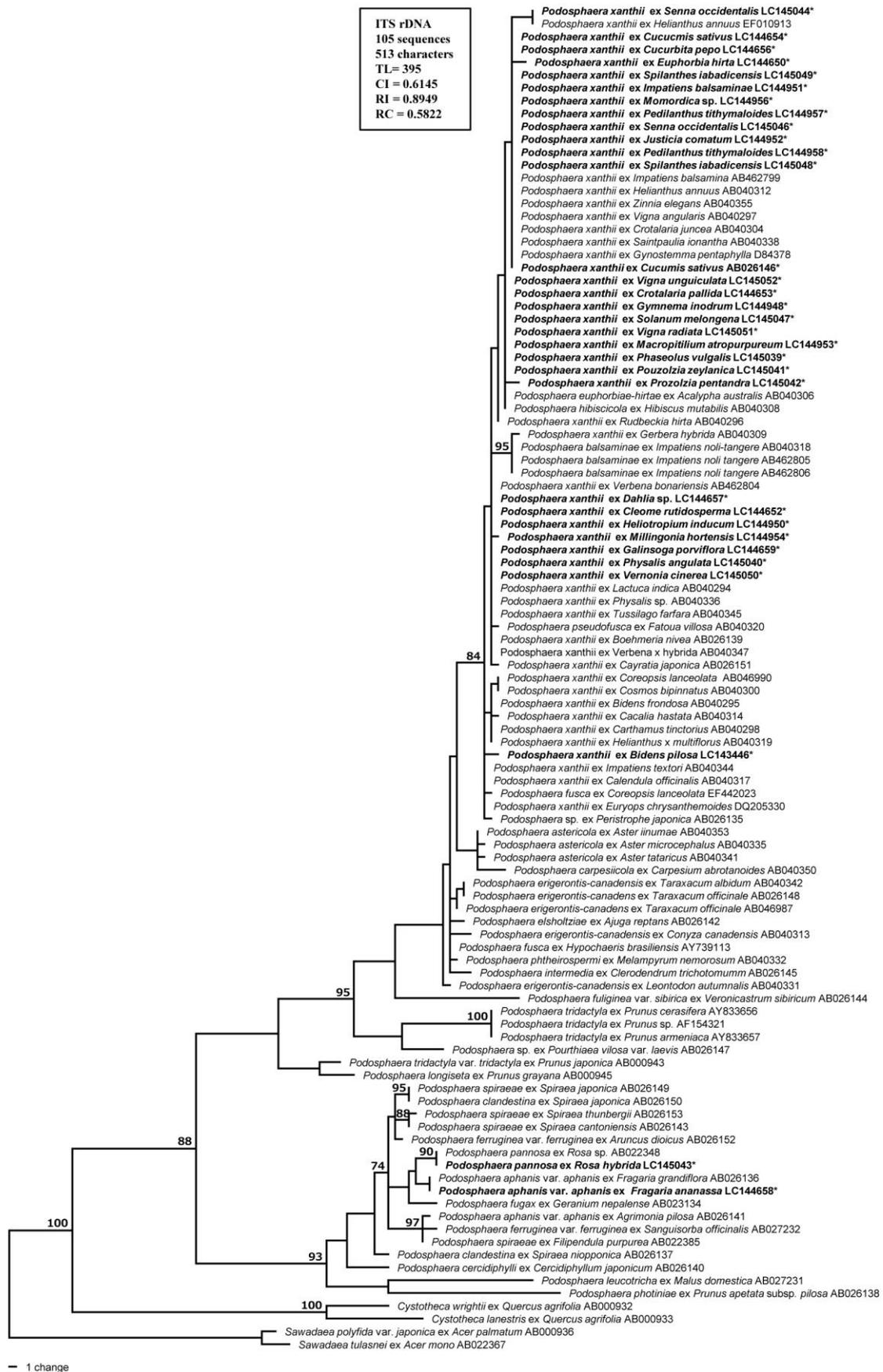
Mycelium amphigenous, in white irregular patches or effuse, thin to dense, evanescent to persistent; hyphae thin-walled, smooth, 4–6  $\mu\text{m}$  wide; hyphal appressoria indistinct to slightly nipple-shaped, solitary; conidiophores arising from the upper surface of hyphal mother cells, erect or slightly curved; foot cells cylindrical, 60–80  $\times$  11–12  $\mu\text{m}$ , sometimes slightly constricted at the basal septum or slightly swollen at the very base, followed by 1–2 shorter cells, forming catenescence conidia; conidia ellipsoid-ovoid to doliiform, 38–41  $\times$  19–21  $\mu\text{m}$ ; germ tubes  $\pm$  lateral, simple to forked, short (*brevitubus*-subtype of the *Podosphaera*-type).

Material examined – THAILAND, Chiang Mai Province, Suthep, on *Viola tricolor* L. (Violaceae), 9 January 2016, J. Meeboon, MUMH3286.

Notes – *Podosphaera fuliginea*, *Po. macularis* (Wallr. : Fr.) U. Braun & S. Takam. and *Po. violae* (U. Braun) U. Braun & S. Takam. from North America are species from *Podosphaera* sect. *Sphaerotheca* found on *Vi. tricolor* (Violaceae) worldwide (Braun & Cook et al. 2012). Furthermore, Braun & Cook (2012) doubted the report of *Podosphaera* (*S. fuliginea* auct.) on *Viola* spp. in Asia and Europe, and noted these specimens as *Po. violae*. However, the description of *Po. violae* anamorph only covers conidia and colony appearance. The current specimen is distinct from asexual morph of *Po. violae* by having larger conidia (vs 25–35  $\times$  13–18  $\mu\text{m}$  of *Po. violae*). Since there is limitation in comparing the morphological characteristics, molecular analysis is necessary to determine the relationship of the current specimen with *Po. violae*. This is the first report of *Podosphaera* on *Vi. tricolor* from Thailand.



**Fig. 22** – *Podosphaera* sp. on *Viola tricolor*. a conidiophore. b germ tube. – Bar = 20  $\mu$ m.



**Fig. 23** – One of the most parsimonious trees reconstructed by analysis of ITS sequence data of genus *Podosphaera* with 79 steps. Bootstrap values of 1,000 replications >70% are given on each branch. Sequences determined in this study are shown in boldface and asterisk. The GenBank number for each sequence is presented after species name on the tree.

## Acknowledgements

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