

Studies on the genus *Paecilomyces* in China V. *Taifanglania* gen. nov. for some monophialidic species

Liang, Z.Q.^{1*}, Han, Y.F.², Chu, H.L.³ and Fox, Roland T.V.³

¹Institute of Fungus Resources, Guizhou University, Guiyang 550025, P.R. China

²Hainan University, Haikou 570228, P.R. China

³School of Biological Sciences, The University of Reading, Reading RG6 6AU, UK

Liang, Z.Q., Han, Y.F., Chu, H.L. and Fox, R.T.V. (2009). Studies on the genus *Paecilomyces* in China V. *Taifanglania* gen. nov. for some monophialidic species. *Fungal Diversity* 34: 69-77.

A rare monophialidic fungus, *Taifanglania hechuanensis* gen. & sp. nov., was isolated from soil on the banks of Jialin River, Hechuan, Chongqing City during a survey of soil-borne filamentous fungi from different phytogeographical areas in China. It is described and illustrated in this paper. A further eight monophialidic species of *Paecilomyces* are transferred to the genus. Diagnosis features of the new genus are white, grey, straw yellow or brown to black colonies on Czapek agar. Conidiophores are always absent or simple. Phialides are solitary, consisting of a cylindrical or ellipsoidal swollen basal portion, tapering into a thin neck, directly arising on vegetative hyphae or prophyllides, sometimes consisting of a whorl of 2 to 3 phialides on simple conidiophores. Conidia are one-celled, hyaline, smooth-walled, subglobose, ellipsoidal or fusiform, having or no the connective between conidia and being thermotolerant. The new species is characterized by pale yellow to grey-yellow colonies, solitary phialides with an ellipsoidal or fusiform basal portion that arise directly from the vegetative hyphae, big conidia $(3.1-3.9-8.7 \times (1.7-2.1-4.7(-5.1) \mu\text{m})$ with the connective, and thermotolerant growth. A molecular study based on the nucleotidic sequences of the SSU rDNA and ITS regions support the status of *T. hechuanensis* as a new species and *Taifanglania* as a new genus.

Key words: taxonomy, morphology, molecular phylogeny, thermotolerant fungi

Article Information

Received January 17, 2008

Accepted April 28, 2008

Published online 15 January 2009

*Corresponding author: Zongqi Liang; e-mail: zqliang472@yahoo.com.cn

Introduction

The monophialidic species, *Paecilomyces flavescens* A.H.S. Br. & G. Sm. (= *P. inflatus* (Burnside) J.W. Carmich.) was first recorded by Brown and Smith (1957). Later, Onions and Barron (1967) grouped 10 species within the genus *Paecilomyces* as a monophialidic series but did not state whether the main axes of the conidiophore is lacking in these fungi, the sporogenous cell is borne singly either directly on the vegetative hyphae or less frequently in groups of two or three on very short conidiophores. Gams (1971) transferred these monophialidic species with awl-shaped phialides to the genus *Acremonium*, leaving only *P. inflatus* in the genus *Paecilomyces* for the reason that its phialides are flask-shaped with a somewhat inflated basal portion and sometimes clustered in small groups on well-defined, very short

conidiophores. Subsequently, Subramanian (1972) placed *P. bacillisporus*, *P. humicola*, *P. roseolus*, *P. striatisporus* and *P. variabilis*, together with *Gliomastix murorum*, in a new genus, *Sagrahamala* Subram.

Paecilomyces inflatus can be regarded as an intermediate form between the genera *Paecilomyces* and *Acremonium*, because the phialides are often solitary and orthotropic; however, the inflated basal portion and distinct neck classify it in *Paecilomyces* (Samson, 1974). Three other monophialidic species, *P. ampullaris* Matsush. (Matsushima, 1971), *P. ampulliphorus* Matsush. and *P. iriomoteanus* Matsush. (Matsushima, 1975) were later reported.

Obornik *et al.* (2001) analyzed sequences of the divergent domain at the 5' end of the LSU rRNA gene from some entomopathogenic fungi: *Paecilomyces* spp., *Verticillium* spp.,

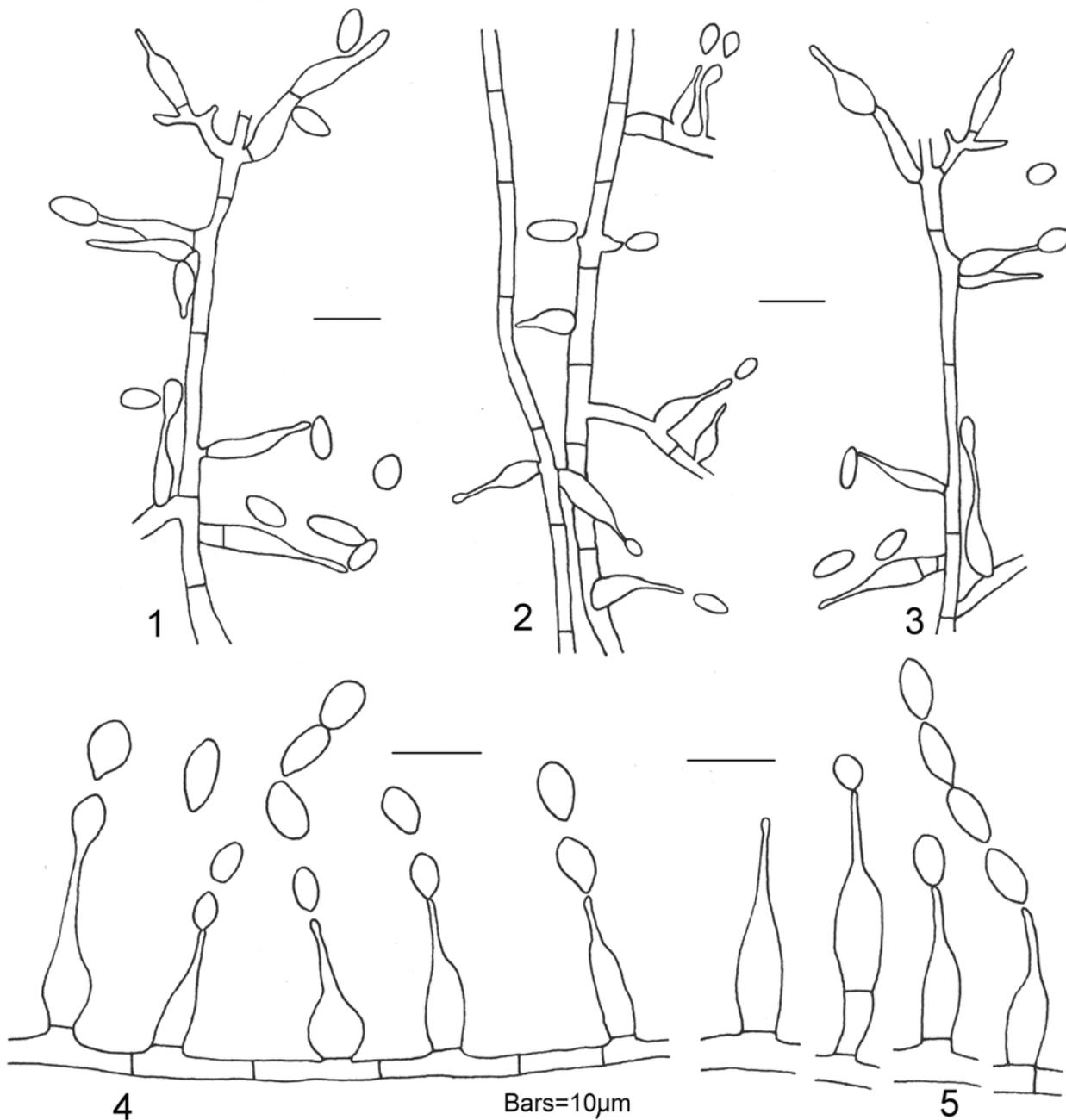


Fig. 1. The conidiogenous structures of *Taifanglania hechuanensis*. Bars= 10 µm

Beauveria bassiana, *Aschersonia* spp., and *Cordyceps* spp. Based on phylogenetic analysis, they proposed polyphyly of the genus *Paecilomyces* and close relationships among entomopathogenic species of the genera *Verticillium*, *Paecilomyces* and *Beauveria*.

Luangsa-ard *et al.* (2004, 2005) examined the nuclear-encoded SSR DNA sequence of *Paecilomyces* strains from Thailand and of some others held in CBS. A phylogenetic analysis based on the 18S nr DNA demonstrated that *Paecilomyces* is polyphyletic across two subclasses, *Sordariomycetidae* and *Eurotiomycetidae*. *Paecilomyces*

variotii and hemophilic relatives belong in the order *Eurotiales* (*Trichocomaceae*), while mesophilic species related to *Paecilomyces farinosus* are in the order *Hypocreales* (*Clavicipitaceae* and *Hypocreaceae*). Subsequently, they used the β -tubulin gene and ITS rDNA and examined the phylogenetic relationships of *Paecilomyces* sect. *Isariodea* (Luangsa-ard *et al.* 2005). Maximum parsimony analysis showed that the section is also polyphyletic within the *Hypocreales*. However *P. inflatus* has affinities with the order *Sordariales*. Its conidio-genous structure is very different from other *Paecilomyces*.

Fungi are important organisms for potential novel compound discovery for medicinal, biofungicide and pesticide use (Huang *et al.*, 2008; Hyde and Soyong, 2008; Rungjindamai *et al.*, 2008). This is particularly true of *Paecilomyces* (Liang *et al.*, 2005, 2007; Song *et al.*, 2007; Wang *et al.*, 2008) and we have been studying this genus in China. During a survey of soil-borne filamentous fungi from 2003-2006 in China, many novel species of the genus *Paecilomyces* were encountered (Table 1). Including the monophialidic and thermotolerant *P. biformis* Z.Q. Liang, H.L. Chu & Y.F. Han, *P. major* (Z.Q. Liang, H.L. Chu & Y.F. Han) Z.Q. Liang, H.L. Chu & Y.F. Han and *P. furcatus* Z.Q. Liang, H.L. Chu & Y.F. Han. Although *P. biformis* and *P. major* were found to produce laccase (Chu *et al.*, 2004; Han *et al.*, 2005a,b,c, 2007; Li *et al.*, 2006; Liang *et al.*, 2006a,b) the relevance of this not clear to determine the taxonomic position of these monophialidic species, we have used both macro- and micro- morphological studies and molecular analyses. Based on these results, we propose that a new genus *Taifanglania* be established, into which we transfer the monophialidic species of *Paecilomyces*.

Table 1. Some taxa of *Paecilomyces* newly discovered in China (2003-2006).*

Name	References
<i>P. huaxiensis</i>	Han <i>et al.</i> , 2005a
<i>P. stipitatus</i>	Han <i>et al.</i> , 2005c
<i>P. vinaceus</i>	Han <i>et al.</i> , 2005c
<i>P. parvosporus</i>	Han <i>et al.</i> , 2005b
<i>P. cylindricosporus</i>	Liang <i>et al.</i> , 2005
<i>P. biformis</i> [M]	Liang <i>et al.</i> , 2007
<i>P. cinereus</i> [M]	Liang <i>et al.</i> , 2006b
<i>P. curticatenatus</i> [M]	Han <i>et al.</i> , 2007
<i>P. major</i> [M]	Liang <i>et al.</i> , 2006a
<i>P. furcatus</i> [M]	Liang <i>et al.</i> , 2006b
<i>P. verticillatus</i>	Li <i>et al.</i> , 2006
<i>T. hechuanensis</i>	Liang <i>et al.</i> , this work

*A species with a bracket containing a letter M is monophialidic.

Materials and Methods

Sample collection and strain isolation

Strain GZUIFR-H08-1 was isolated from soil samples from Hechuan, Chongqing City. Two grams of soil were added to a flask

containing 20 ml sterilized water and some glass beads. Each soil suspension was shaken for about 10 min and then diluted to concentrations of 10^{-1} - 10^{-2} . One ml suspension (10^{-2}) was mixed with Martin medium in a sterilized Petri dish of 9 cm diam. The cultures were incubated at 40°C for 7 days.

Strain identification

The studied strains were transferred to Czapek agar. After incubation at 40 °C for 7 days, the strains were identified based on colony characters and conidiogenous structures according to Brown and Smith (1957) and Samson (1974).

Reagent and DNA extraction

Taq enzyme and dNTP was obtained from Shanghai Sangon, An Agarose Gel DNA Purification kit ver 2.0 was from TRKARA Company.

Fresh, sporulating cultures on Czapek agar were used for DNA extraction following Tigano-Milani *et al.* (1995); the extracted DNA is stored at -20°C.

PCR amplification and determination of ITS and 18S rDNA sequencing

To amplify ITS1-5.8S-ITS2 rDNA sequence, the following primers were used: ITS4: 5'-TCCTCCGCTTATTGATATGC-3' and ITS5: 5'-GGAAGTAAAAGTCGTAA CAAGG-3'. Polymerase chain reaction (PCR) amplification was performed as follows: 50 µL reaction system: 10× reaction buffer 5 µL, dNTP 1 µL, primer 1Ml each, Pfu buffer 0.5 µl, 2 µL of template DNA and ddH₂O 39.5 µL. The amplification program: a first step of 94°C for 5 min, then 35 cycles consisting of 94°C for 40 s, 49°C for 40 s, and 72°C for 1 min, and a final step of 72°C for 10 min. To amplify 18S rDNA sequence, the following primers were used: NS1: 5'-GTAGTCAT ATGCTTG TCTC-3' and NS 24: 5'-AAACC TTGTTACGACTTTTA-3'. The amplification program: a first step of 94°C for 4 min, then 35 cycles consisting of 94°C for 1 min, 52-55°C for 1 min, and 72°C for 1.5 min, and a final step of 72°C for 7 mins. PCR products were purified using Agarose Gel DNA Purification kit ver 2.0 according to instructions (TRKARA Company), 1 µL purification

products were determined in $\rho = 1\%$ Agrose by electrophoresis and sequenced with the above primers by Beijing Sunbiotech Co. Ltd. Sequences of SSU and ITS1-5.8S-ITS2 rDNA regions of this fungus were submitted to GenBank.

Sequence alignment and phylogenetic analysis

Table 2 lists the species used in this molecular study from Genbank. The sequence of the new species was aligned with the related species using ClustalX 1.83 computer programme for multiple sequence alignment and manually corrected. The phylogenetic tree was constructed by neighbor-joining method of MEGA version 3.1 (Kumar *et al.*, 2004). Confidence values for individual branches were determined by bootstrap analysis (1000 replications).

Description of new genus and species

Taxonomy

Taifanglangia Z.Q. Liang, Y.F. Han, H.L. Chu & R.T.V. Fox, **gen. nov.**
MycoBank No: 512803

Etymology: The genus name *Taifanglangia* is dedicated to the late Chinese mycologist Tai, Fanglan.

In agar Czapekii, coloniae albae, griseae, bubalinae, hinnuleae, ochraceae, vel nigricantes, planae. Conidiophora absenita vel simplicia. Phialides singulars, sed interdum in conidiophoris brevibus binate vel ternate aggregatae, e basi inflata subglobosa, ellipsoidea vel cylindrica, in collum distinctum apice inspissato angustatae. Conidia subglobosa, ellipsoidea vel fusiformia.

Species typica: *Taifanglangia hechuanensis* Z.Q. Liang, Y.F. Han, H.L. Chu & R.T.V. Fox.

Colonies on Czapek agar white, grey, straw yellow, hazel, brown to black, flat, loose villiform. Vegetative hyphae hyaline, smooth-walled or slightly rough. *Conidiophores* absent or simple. *Phialides* solitary, consisting of a cylindrical or ellipsoidal swollen basal portion, tapering into a thin neck, directly arising on vegetative hyphae or prophialides, sometimes consisting of a whorl of 2 to 3 phialides on simple conidiophores. *Conidia* one-celled, hyaline, smooth-walled, subglobose, ellipsoidal or fusiform, having or no the connective. Thermotolerant.

Taifanglangia hechuanensis Z.Q. Liang, Y.F. Han, H.L. Chu & R.T.V. Fox, **sp. nov.** (Fig. 1)
MycoBank No: 512804

GenBank No: EU053286; DQ185070

In agar Czapekii, coloniae 56-63 mm diam, 7 diebus ad 40° C, planae humiles. Hyphis septatis, hyalinis, 1.7-3.8 μ m crassis. Conidiophora simplicia, (3.1-) 5-8.7 (-11) \times 2-4 (-5.8) μ m. Phialides singulares, (3.1-) 3.9-19 (-22.1) \times (2.2-) 2.5-4.7 (-5.8) μ m, e basi inflata ellipsoidea vel cylindrica, in collum distinctum apice inspissato angustatae. Conidia ellipsoidea vel fusiformia, (3.1-) 3.9-8.7 \times (1.7-) 2.1-4.7 (-5.1) μ m.

Typus GZUIFR-H08-1 isolatus, e solo, Chongqing, X, 2003, Chu H. L. Liang Z. Q.; in Guizhou Univ., conservatur. Colonia exsiccata et cultura viva, GZUIFR-H08-2.

Colonies on Czapek agar, attaining a diameter of 56 to 63 mm within 7 days at 40 °C, thermotolerant, flat, loose villiform, pale yellow to grey-yellow, with indistinct zones and sectors. Reverse off-white. *Vegetative hyphae* hyaline, smooth-walled, short septate, 1.7-3.8 μ m wide. *Conidiophores* simple, inconspicuous and branched (3.1-) 5-8.7 (-11) \times 2-4 (-5.8) μ m. *Phialides* solitary, (3.1-) 3.9-19 (-22.1) \times (2.2-) 2.5-4.7 (-5.8) μ m, consisting of cylindrical or ellipsoidal swollen basal portions, tapering into thin necks, 2.1-12.7 μ m long, directly arising on vegetative hyphae or pro-phialides, or consisting of a whorl of 2 to 3 phialides on simple conidiophores. *Conidia* 1-celled, hyaline, smooth-walled, ellipsoidal or fusiform, connective, (3.1-) 3.9-8.7 \times (1.7-) 2.1-4.7 (-5.1) μ m, forming divergent long chains.

Material examined: GZUIFR-H08-1 isolated by Y. F. Han & Z. Q. Liang from soil on banks of Jialin River, Hechuan, Chongqing City, China, November 2003.

Teleomorph: Unknown.

Habitat: Soil.

Distribution: Chongqing City, China.

Eight monophialidic species of *Paecilomyces* are transferred to *Taifanglangia*:

Taifanglangia inflata (Burnside) Z.Q. Liang, Y.F. Han & H.L. Chu, **comb. nov.** MycoBank No: 512809.

Myceliophthora inflata Burnside, Papers of the Michigan Academy of Science, Arts and Letters 8: 82. 1928.

Paecilomyces inflatus (Burnside) J.W. Carmich., Canadian Journal of Botany 40: 1148. 1962.

Taifanglangia cinerea (Z.Q. Liang, H.L. Chu & Y.F. Han) Z.Q. Liang, Y.F. Han, & H.L. Chu, **comb. nov.** MycoBank No: 512810.

Table 2. Strains used in the molecular study.

Species	SSU GenBank No	ITS GenBank No.
<i>Aphanoascus cinnabarinus</i>	AY526483	AY753349
<i>Byssochlamys fulva</i>	AY526482	AY753341
<i>Byssochlamys nivea</i>	M83256	AY753339
<i>Chaetomium globosum</i>	AF048796	AY429054
<i>Cordyceps gunnii</i>	AF339572	
<i>Cordyceps takaomontana</i>		AY624198
<i>Corynascus verrucosus</i>		AJ224203
<i>Morchella esculenta</i>	AY526464	AJ543741
<i>P. aerugineus</i>	AB023942	AY753346
<i>P. biformis</i>	EU053283	DQ191963
<i>P. careneus</i>	AY526481	
<i>P. cateniannulatus</i>	AY526465	AY624172
<i>P. cateniobliquus</i>	AY526466	AY624173
<i>P. cicadae</i>		AY624175
<i>P. cinereus</i>	EU053285	DQ243694
<i>P. coleopterorum</i>		AY624177
<i>P. curticatenatus</i>	EU053282	EV004811
<i>P. farinosus</i>	AY526474, AB023943	AY624181
<i>P. fumosoroseus</i>		AY624182
<i>P. ghanensis</i>	AY526470	AY624185
<i>P. furcatus</i>		DQ243695
<i>P. inflatus</i>	AB099943	AB099943
<i>P. javanicus</i>	AY526463	AY624186
<i>P. major</i>	EU053284	DQ243696
<i>P. marquandii</i>	AY526472	AY624193
<i>P. lilacinus</i>	AY526475	AY624188
<i>P. niphetodes</i>	AY526471	AY624792
<i>P. tenuipes</i>		AY624195
<i>P. viridis</i>	AB023949	AY624197
<i>P. variotii</i>	AY526477	AY753337
<i>Paecilomyces amoeneroseus</i>	MEU42642	
<i>Taifanglania hechuanensis</i> (This work)	EU053286	DQ185070
<i>Talaromyces leycettanus</i>	AY526487	
<i>Thermoascus crustaceus</i>	AY526486	
<i>Thielavia rapa-nuensis</i>		AJ271580
<i>Thielavia terrestris</i>	TTU43969	
<i>Thielavia terricola</i> var. <i>minor</i>		AJ271582

Paecilomyces cinereus Z.Q. Liang, H.L. Chu & Y.F. Han, Mycotaxon 97: 16. 2006b

Taifanglania furcatus (Z.Q. Liang, H.L. Chu & Y.F. Han) Z.Q. Liang, Y.F. Han & H.L. Chu **comb. nov.** MycoBank No: 512811.

Paecilomyces furcatus Z. Q. Liang, H.L. Chu & Y.F. Han, Mycotaxon 97: 16. 2006b.

Taifanglania curticatenata (Z.Q. Liang & Y.F. Han) Z.Q. Liang, Y.F. Han & H.L. Chu **comb. nov.**, MycoBank No: 512812.

Paecilomyces curticatenatus Z.Q. Liang & Y.F. Han, Mycosystema 26: 14. 2007.

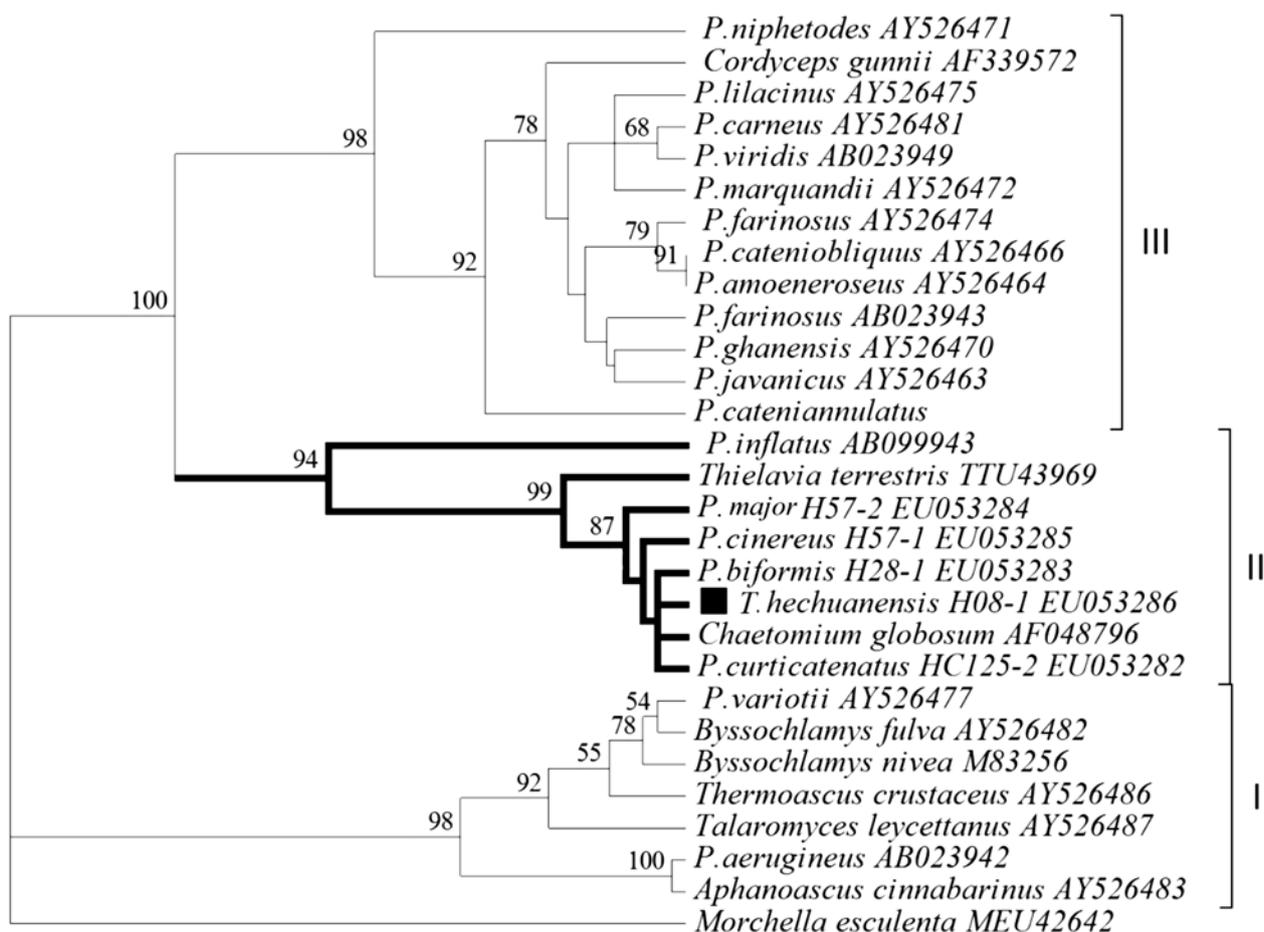


Fig. 2. Phylogenetic tree based on nucleotide sequence of the SSU nrDNA sequence by NJ of MEGA3.1 software. bootstrap values (>50%) from 1000 replicates are included at the internodes. Branch lengths are drawn to scale

Taifanglania major (Z.Q. Liang, H.L. Chu & Y.F. Han) Z.Q. Liang, Y.F. Han & H.L. Chu, **comb. nov.** MycoBank No: 512817.

Paecilomyces inflatus var. *major* Z.Q. Liang, H.L. Chu & Y.F. Han, *Journal of Fungal Research* 2: 43. 2004.

Paecilomyces major (Z.Q. Liang, H.L. Chu & Y.F. Han) Z.Q. Liang, H.L. Chu & Y.F. Han, *Journal of Fungal Research* 4: 47. 2006a.

Taifanglania ampullaris (Matsush.) Z.Q. Liang, Y.F. Han & H.L. Chu, **comb. nov.** MycoBank No: 512813.

Paecilomyces ampullaris Matsush., *Microfungi of the Solomon Islands and Papua-New Guinea*: 42. 1971.

Taifanglania ampulliphora (Matsush.) Z.Q. Liang, Y.F. Han & H.L. Chu, **comb. nov.** MycoBank No: 512814.

Paecilomyces ampulliphorus Matsush., *Icones microfungorum a Matsushima lectorum*: 104. 1975.

Taifanglania bififormis (Z.Q. Liang, H.L. Chu & Y.F. Han) Z.Q. Liang, Y.F. Han & H.L. Chu, **comb. nov.** MycoBank No: 512815.

Paecilomyces bififormis Z.Q. Liang, H.L. Chu & Y.F. Han, *Fungal Diversity* 27: 97. 2007.

Key to the species of *Taifanglania*

1. Sporulating structure of two types, solitary phialide and conidiophore *T. bififormis*
1. Sporulating structures monophialidic only 2
2. Conidia roughened, chains short, consisting of 3~6 conidia..... *T. curticatenata*
2. Without above characters..... 3
3. Phialides with furcate neck *T. furcata*
3. Phialides without furcate neck 4
4. Conidia subglobose or long ellipsoidal 5
4. Conidia fusiform, lemon-shaped or ellipsoidal 7
5. Conidia subglobose, 2.2-3.4 × 2.0-2.6 μm *T. ampullaris*
5. Conidia long ellipsoidal..... 6
6. Conidia 6-8 × 2.5-3 μm..... *T. ampulliphora*
6. Conidia 3-13 × 1.4-5.4 μm..... *T. cinerea*
7. Conidia fusiform to lemon-shaped, 3-4 × 2-3 μm. *T. inflata*
7. Conidia long fusiform 8
8. Conidia fusiform to ellipsoidal, 4.3 -7.3 × 2.1-3.5 μm *T. hechuanensis*
8. Conidia fusiform, larger, 5.2-14.1 × 2.5-5.1 μm *T. major*

SSU and ITS rDNA sequences of *T. hechuanensis* were aligned with those of related species. The species has close affinities

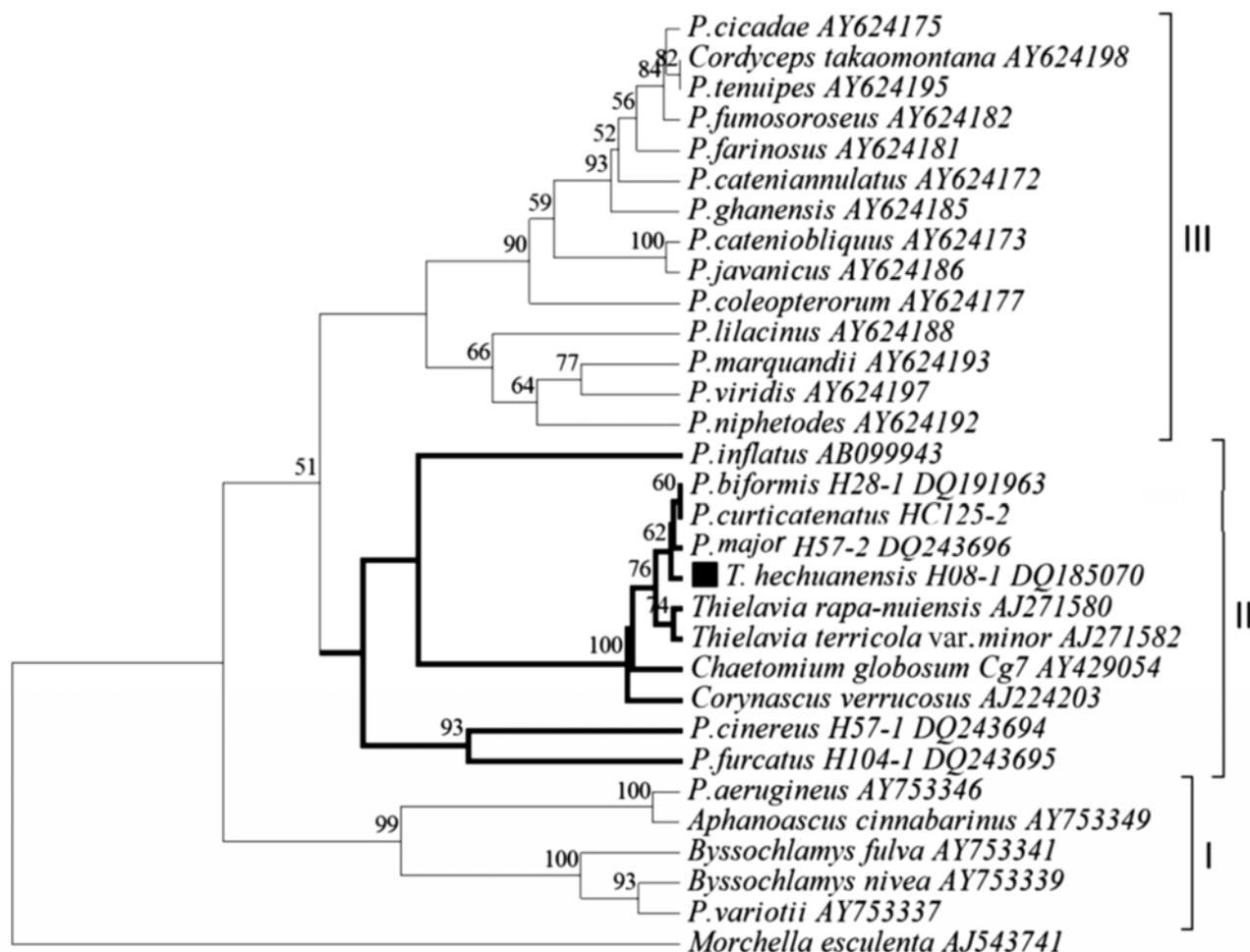


Fig. 3. Phylogenetic tree based on nucleotide sequence of the ITS-5.8S-ITS2 rDNA region by NJ of MEGA3.1 software. Branch lengths are proportional to distance. Bootstrap replication frequencies (1000 replications) are indicated at the internodes.

to other monophialidic species and the genera *Thielavia* and *Chaetomium*, *Sordariales* (Figs 2, 3).

Discussion

Some species of *Botryotrichum* Sacc. & Marchal and *Humicola* Traaen directly produce phialides and conidial chains on the hyphae as in *Taifanglania*. However, these fungi are characterized by simple, short conidiophores and subglobose or globose brown coloured conidia (Barnett and Hunter, 1998). Another genus with a similar conidiogenous structure is *Monocillium* S.B. Saksena, which is distinguished from *Taifanglania* by the inflated or thickened middle part of the phialide (Arx, 1974; Barnett and Hunter, 1998).

Some species of *Acremonium* Link are similar to the monophialidic species in *Taifanglania*. However, the *Acremonium* species

can be distinguished from *Taifanglania* species by their typical awl-shaped phialides (Samson, 1974).

In these monophialidic species, *T. hechuanensis* and *T. major* are two rare species in which conidia are more than 5 μm wide. Moreover, their shapes of phialides, size, surface texture of colonies and reverse color are also basically similar. However, the former species has pale yellow colonies and longer conidia (5.2-14.1 μm) and the later species has off-white colonies, short conidia (3.1-8.7 μm long).

Among the species of *Taifanglania*, the conidia of *T. inflata*, *T. major* and the new species *T. hechuanensis*, are all fusiform. The conidia of *T. inflata* are only 3-4 μm long, distinctly shorter than those of *T. hechuanensis*. The ratio of conidial length: width for *T. major* is greater than for *T. hechuanensis*.

Based on SSU rDNA sequences analyses, the phylogeny tree was split into three mono-

phyletic clades (Fig. 2). Within clade I, are several thermotolerant and thermophilic urotiales species. These species have more complex conidiogenous structures, which are morphologically very different to those in the monophialidic species. *T. hechuanensis* and several monophialidic species including *T. inflata* were grouped in Clade II together with *Chaetomium globosum*, *Thielavia terricola* and *Corynascus verrucosus* within *Chaetomiaceae*, *Sordariales*.

Chaetomium globosum is the most common species of *Chaetomium*. It can produce several bioactive compounds (Wang *et al.*, 2006, Wijeratne, 2006, Fogle *et al.*, 2007), such as chaetoglobosins A and C. These have been shown to be lethal to various tissue culture cell lines at relatively low levels (Fogle *et al.*, 2007). However the relevance of this is not clear. To date, an anamorph has not been formally identified for *C. globosum* (Fogle, 2007). Salar and Aneja (2007) also reported that all thermophilic species of *Chaetomium* did not produce conidia.

Salar and Aneja (2007) reported that the fungus *Acremonium albamensis* was the imperfect state of *Thielavia terricola*.

The anamorph of *Corynascus thermophilus* is *Myceliophthora fergusii* (Arx, 1974) and some anamorphs of *Corynascus* species are also placed in *Myceliophthora* by Salar and Aneja (2007).

Anamorphs of these ascomycetes are members of genera *Sepedonium* Link, *Myceliophthora* Costantin and *Botryotrichum* (Kiffer and Morelet, 1997). They possess awl-shaped phialides, more or less dark-colored hyphae and acrogenous single conidia. The conidiogenous structures of *T. hechuanensis*, are phialides forming divergent long chains of conidia. No species of *Taifanglania* are known to produce a teleomorph. Most of the common entomogenous fungi were located in Clade III, which belong in the families *Clavicipitaceae* and *Hypocreaceae*, *Hypocreales*. Their morphological characters are also different from *Taifanglania*. These entomogenous fungi all produce distinct conidiophores, complex conidiogenous structures and are mesophilic.

Based on ITS sequences analyses (Fig. 3), the phylogeny tree also exhibited as alike phylogenetic tree as SSU. The molecular re-

sults based on the nucleotidic sequences of the SSU and ITS rDNA region support the proposal of *T. hechuanensis* as a new species and *Taifanglania* as a new genus.

References

- Arx, J.A. von (1974). *The Genera of Fungi Sporulating in Pure Culture*. AR Gantner, Germany.
- Barnett, H.L. and Hunter B.B. (1998). *Illustrated Genera of Imperfect Fungi*. Fourth edition, APS Press, USA.
- Brown, A.H.S. and Smith, G. (1957). The genus *Paecilomyces* Bainier and its perfect stage *Byssochlamys* Westling. Transactions of the British Mycological Society 40: 17-89.
- Chu, H.L., Liang, Z.Q. and Han, Y.F. (2004). A thermotolerant *Paecilomyces inflatus* var. *major* Liang Z.Q., Chu H.L., Han Y.F. var. nov. which produces laccase. Journal of Fungal Research 2: 43-46. (in Chinese).
- Fogle, M. (2007). *Growth and mycotoxin production by Chaetomium globosum*. A Ph.D. dissertation in medical microbiology, The Graduate Faculty of Texas Tech University Health Sciences Center.
- Fogle, M., Douglas, D., Jumper, C. and Straus, D. (2007). Growth and mycotoxin production by *Chaetomium globosum*. Mycopathologia 164: 49-56
- Gams, W. (1971). *Cephalosporium-artige Schimmelpilze (Hyphomycetes)*. Gustav Fischer. Stuttgart, 38-130.
- Han, Y.F., Liang, Z.Q. and Chu, H.L. (2007). A new thermophilic species of *Paecilomyces*, *Paecilomyces curticatenuatus*. Mycosystema 26: 13-16. (in Chinese).
- Han, Y.F., Liang, Z.Q. and Chu, H.L. (2005a). Studies on the genus *Paecilomyces* in China II. *Paecilomyces* spp. from Guizhou. Mycotaxon 91: 361-364.
- Han, Y.F., Liang, Z.Q. and Chu, H.L. (2005b). *Paecilomyces parvosporus*, a new species and its allies from Yunnan, China. Mycotaxon 94: 357-363.
- Han, Y.F., Chu, H.L. and Liang, Z.Q. (2005c). Two new species of the genus *Paecilomyces* in China. Mycotaxon 92: 311-316.
- Huang, W.Y., Cai, Y.Z., Hyde, K.D., Corke, H. and Sun, M. (2008). Biodiversity of endophytic fungi associated with 29 traditional Chinese medicinal plants. Fungal Diversity 33: 61-75.
- Hyde, K.D. and Soytong, K. (2008). The fungal endophyte dilemma. Fungal Diversity 33: 163-173.
- Kiffer, E. and Morelet, M. (1997). *The Deuteromycetes Mitosporic Fungi Classification and Generic Keys*. Science Publishers, INC., Enfield, NH. USA.
- Kumar, S., Tamura, K. and Nei, M. (2004). MEGA3: Integrated software for molecular evolutionary genetics analysis and sequence alignment. Briefings in Bioinformatics 5: 150-163.

- Li, Z., Han, Y.F. and Liang, Z.Q. (2006). A new species *Paecilomyces verticillatus* sp. nov. from soil in China. *Mycotaxon* 95: 133-136.
- Liang, Z.Q., Han, Y.F., Chu, H.L. and Liu, A.Y. (2005). Studies on the genus *Paecilomyces* in China I. *Fungal Diversity* 20: 83-101.
- Liang, Z.Q., Han, Y. F. and Chu, H.L. (2006a). Three prospectively applicable species of *Paecilomyces* from soils in China. *Journal of Fungal Research* 4: 45-48. (in Chinese).
- Liang, Z.Q., Han, Y.F. and Chu, H.L. (2006b). Studies on the genus *Paecilomyces* in China. IV. Two new species of *Paecilomyces* with monophialides. *Mycotaxon* 97: 13-20.
- Liang, Z.Q., Han, Y.F. and Chu, H.L. (2007). A new thermotolerant *Paecilomyces* species which produces laccase and a bifiform sporogenous structure. *Fungal Diversity* 27: 95-102.
- Luangsa-ard, J.J., Hywel-Jones, N.L., Manoch, L. and Samson, R.A. (2005). On the relationships of *Paecilomyces* sect. *Isarioidea* species. *Mycological Research* 109: 581-589.
- Luangsa-ard, J.J., Hywel-Jones, N.L. and Samson, R.A. (2004). The polyphyletic nature of *Paecilomyces sensu lato* based on 18S-generated rDNA phylogeny. *Mycologia* 96: 773-780.
- Matushima, T. (1971). *Microfungi of the Solomon Islands and Papua-New Guinea*. Published by the Author, Kobe: 42.
- Matushima, T. (1975). *Icones Microfungorum a Matushima Lectorum*, Published by the Author, Kobe: 104.
- Obornik, M., Jirku, M. and Dolezel, D. (2001). Phylogeny of mitosporic entomopathogenic fungi: Is the genus *Paecilomyces* polyphyletic? *Canadian Journal of Microbiology* 47: 813-819.
- Onions, A.H.S. and Barron, G.L. (1967). Monophialidic species of *Paecilomyces*. *Mycological Paper* 107: 1-25.
- Rungjindamai, N., Pinruan, U., Choeyklin, R., Hattori, T. and Jones, E.B.G. (2008). Molecular characterization of basidiomycetous endophytes isolated from leaves, rachis and petioles of the oil palm, *Elaeis guineensis*, in Thailand. *Fungal Diversity* 33: 130-161.
- Salar, R.K. and Aneja, K.R. (2007) Thermophilic fungi: taxonomy and biogeography. *Journal of Agricultural Technology* 3: 77-107.
- Samson, R.A. (1974). *Paecilomyces* and some allied hyphomycetes. *Studies in Mycology* 6: 1-119.
- Song, W.S., Jun, D.Y., Kim, J.S., Park, H.S., Kim, J.G., Seu, Y.B., Bae, Y.S., Yang, C.H., Woo, M.H. and Kim, Y.H. (2007). Suppressive effect of ethyl acetate extract of *Paecilomyces japonica* on cell cycle progression of human acute leukemia Jurkat T cell clone overexpressing Bcl-2. *Food Chemistry* 100: 99-107.
- Subramanian, C.V. (1972). Conidial chains, their nature and significance in the taxonomy of Hyphomycetes. *Current Science* 41: 43-49
- Wang, L., Zhang, W.M., Hu, B., Chen, Y.Q. and Qu, L.H. (2008). Genetic variation of *Cordyceps militaris* and its allies based on phylogenetic analysis of rDNA ITS sequence data. *Fungal Diversity* 31: 147-155.
- Wang, S., Li, X.M., Teuscher, F., Li, D.L., Diesel, A., Ebel, R., Proksch, P., Wang B.G. (2006). Chaetopyranin, a benzaldehyde derivative, and other related metabolites from *Chaetomium globosum*, an endophytic fungus derived from the marine red alga *Polysiphonia urceolata*. *Journal of Natural Products* 69: 1622-1625.
- Wijeratne, E.M., Turbyville, T.J., Fritz, A., Whitesell, L. and Gunatilaka, A.A. (2006). A new dihydroxanthone from a plant-associated strain of the fungus *Chaetomium globosum* demonstrates anti-cancer activity. *Bioorganic & Medicinal Chemistry* 14: 7917-7923.