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ORIGINAL ARTICLE

The genus *Fusariella*

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Abstract The genus *Fusariella*, typified by *F. atrovirens*, is characterised by semi- to macronematous, mononematous conidiophores, with cylindrical, subulate or lageniform phialidic conidiogenous cells that produce catenate, septate, curved to straight, subhyaline to brown conidia. During a survey of hyaline-spored hyphomycetes from karst areas in Thailand, we collected a new species of *Fusariella* with curved conidia and introduce it in this paper as *Fusariella curvata* sp. nov. In addition, all hitherto described species of *Fusariella* are reviewed. The result of phylogenetic analyses, based on combined SSU, LSU, TEF and RPB2 sequence data, indicates that the genus belongs in the family Bionectriaceae (Hypocreales, Sordariomycetes).

Keywords Bionectriaceae · *Fusariella* · Karst · New species · Phylogeny

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Introduction

The family Bionectriaceae (Hypocreales, Sordariomycetes) was established by Rossman et al. (1999) and consolidated in recent studies by Maharachchikumbura et al. (2015, 2016), who accepted 38 genera in the family. The sexual morphs of Bionectriaceae are characterised by uniloculate perithecial, rarely cleistothecial ascomata that are white, yellow, orange to tan or brown, do not change colour in KOH or lactic acid, and are generally superficial, lacking a stroma, or immersed in the substratum (Rossman et al. 1999; Maharachchikumbura et al. 2016). The asexual morphs in Bionectriaceae are hyphomycetous, acremonium- or gliocladium-like. The conidiogenous cells are phialidic and produce unicellular to multi-septate, ellipsoidal, fusiform to subfusiform, hyaline to greenish hyaline or bright-coloured conidia (Rossman et al. 1999; Maharachchikumbura et al. 2016).

The genus *Fusariella* Sacc. was established by Saccardo (1884) to accommodate *Fusariella atrovirens* (Berk.) Sacc., and is characterised by semi-macronematous, mononematous, unbranched or variously branched conidiophores, with curved, cylindrical, subulate or lageniform, hyaline to pale brown phialides that produce catenate, acrogenous, straight or slightly curved, fusiform, cylindrical, clavate or obclavate, subhyaline to brown conidia (Hughes 1949; Chabelska-Frydman 1964; Roy and Rai 1968; Ellis 1971, 1976; Seifert et al. 2011). Nineteen species epithets for *Fusariella* are listed in Index Fungorum (2016) and MycoBank (2016; http://www.mycobank.org/). In this study, all species are revisited and a synopsis to the species of *Fusariella* is provided.

Although the genus *Fusariella* has been known for more than 130 years since it was established by Saccardo (1884), its natural classification is still uncertain because of the lack of molecular data and a comprehensive taxonomic treatment (Index Fungorum 2016). In this study, we propose taxa at

the ranks of family, order and class based on phylogenetic analysis and morphology.

During a survey of hyphomycetes in karst areas of Thailand, one hitherto unknown *Fusariella* species was found that is described here. The classification of *Fusariella* is determined taking into account morphology and phylogenetic analyses of ITS, SSU, LSU, RPB2 and TEF1 sequence data.

Materials and methods

Collection and isolation of fungi

Dead materials (stems, wood and leaves) from a variety of plants were randomly collected during May to August 2015 from karst areas at Ang Kep Nam Wat Tham Khao Hin Phayanak (Wat Tham Sao Hin Payanak) (20°19′16.58 - 30.12″N, 99°51′40.72 - 54.50″E), Mae Sai District, Chiang Rai Province in Thailand. Samples were taken to the laboratory in zip-lock plastic bags for examination. The specimens were incubated in sterile moist chambers and examined using a Motic SMZ-168 series microscope. Fungi were removed with a needle and placed in a drop of distilled water on a slide for morphological study. Photographs of fungal structures were captured using a Nikon Eclipse 80i compound microscope with a Canon 450D digital camera. All measurements were made by the Tarosoft® Image FrameWork program. Photo plates were made with Adobe Photoshop CS6 Extended version 13.0.1 (Adobe Systems, USA). Isolation onto potato dextrose agar (PDA) or malt extract agar (MEA) was performed by the single spore isolation method (Chomnunti et al. 2014). Herbarium material is deposited in the herbarium of Mae Fah Luang University (MFLU), Chiang Rai, Thailand and the Herbarium of the Department of Plant Pathology (HGUP), Agricultural College, Guizhou University, Guiyang, China. Living cultures are deposited at the Mae Fah Luang University Culture Collection (MFLUCC) and the Culture Collection at the Department of Plant Pathology, Agriculture College, Guizhou University, China (GUCC). Faces of Fungi and Index Fungorum numbers are registered (Jayasiri et al. 2015; Index Fungorum 2016).

DNA extraction, PCR amplification and sequencing

Genomic DNA was extracted from fungal mycelium grown on PDA or MEA at room temperature with the Fungal gDNA Kit (BioMIGA, USA), according to the manufacturer's instructions. The internal transcribed spacer region of ribosomal DNA (ITS), small subunit nuclear ribosomal DNA (SSU), large subunit nuclear ribosomal DNA (LSU), RNA polymerase II second largest subunit (*rpb2*) and the translation elongation factor-1 alpha (*tef1*) genes were amplified via polymerase chain reaction (PCR) using the following primers: ITS5 and ITS4 (White et al. 1990) for ITS, NS1 and NSS4 (White et al. 1990) for SSU, LROR and LR5 (Vilgalys and Hester 1990) for LSU, fRPB2-5F and fRPB2-7cF (Liu et al. 1999) for *rpb2*, and EF1-983F and EF1-2218R (Rehner 2001) for *tef1*. The PCR products were sequenced with the same primers.

Phylogenetic analyses

Original sequences were checked using BioEdit version 7.0.5.3 (Hall 1999), and most reference sequences originated from the publications of Maharachchikumbura et al. (2015, 2016). The remaining homogenous sequences were obtained by BLAST searches (Altschul et al. 1990) from GenBank. All sequences used in this study are listed in Table 1. Alignments for each locus were done in MAFFT v7.212 (Katoh and Standley 2013) and manually verified in MEGA 6.06 (Tamura et al. 2013). Conserved blocks were selected from the initial alignments with Gblocks 0.91b (Castresana 2000). The interleaved NEXUS files were formatted with PAUP* 4.0b10 (Swofford 2002) and manually formatted for Bayesian inference (BI) analyses. BI, maximum parsimony (MP) and maximum likelihood (ML) were used in this study for phylogenetic analyses. For BI analysis, the best model of evolution was determined using MrModeltest v2 (Nylander 2004). BI analysis was done with MrBayes v 3.2.5 (Ronquist et al. 2012). MP analysis was performed in PAUP* 4.0b10 (Swofford 2002). ML analysis was performed in raxmlGUI v 1.3.1 (Silvestro and Michalak 2012). Phylogenetic trees were drawn with TreeView 1.6.6 (Page 1996).

Results

Molecular phylogeny

The aligned sequence matrix comprises SSU (1047 bp), LSU (891 bp), EF1-α (1020 bp) and RPB2 (1043 bp) sequence data for 31 taxa and one outgroup taxon for a total of 4001 characters, of which 904 were parsimony informative and 2591 characters were constant. The results of ML analysis based on combined SSU, LSU, EF1-α and RPB2 sequence data are shown in Fig. 1.

In the present study, we found that the strain of *F. curvata* (MFLUCC 15-0844) forms a clade together with the strains of *Hydropisphaera peziza* (G.J.S. 91-101) with 94 % ML bootstrap support and 100 % Bayesian posterior probabilities within the family Bionectriaceae (Hypocreales, Sordariomycetes).

Table 1 GenBank accession numbers of isolates included in this study

Family	Species	Culture accession no.[b]	LSU	SSU	TEF	RPB2	References
Bionectriaceae	*Bionectria ochroleuca*	AFTOL-ID 187	DQ862027	DQ862044	DQ862029	DQ862013	Zhang et al. (2006)
	Fusariella curvata	MFLUCC 15-0844	KX025154	KX025153	KX025155	KX025156	This study
	Hydropisphaera peziza	G.J.S. 92-101 = BPI 802846	AY489730	AY489698	AY489625	–[a]	Castlebury et al. (2004)
	Roumegueriella rufula	G.J.S. 91-164	EF469082	EF469129	EF469070	EF469116	Sung et al. (2007)
	Stephanonectria keithii	G.J.S. 92-133	AY489727	AY489695	AY489622	–	Castlebury et al. (2004)
Clavicipitaceae	*Claviceps purpurea*	AEG 97-2	AF543789	AF543765	AF543778	–	Currie et al. (2003)
	Epichloe typhina	ATCC 56429	ETU17396	ETU32405	AF543777	DQ522440	Currie et al. (2003), Spatafora et al. (2007)
	Hypocrella discoidea	BCC 8237	DQ384937	–	DQ384977	DQ452461	Unknown
	Shimizuomyces paradoxus	EFCC 6279	EF469084	EF469131	–	EF469117	Sung et al. (2007)
Cordycipitaceae	*Ascopolyporus polychrous*	PC546	AY886546	–	DQ118745	DQ127236	Bischoff et al. (2005), Chaverri et al. (2005)
	Cordyceps militaris	OSC 93623	AY184966	AY184977	DQ522332	–	Sung and Spatafora (2004), Spatafora et al. (2007)
	Hyperdermium pulvinatum	PC602	DQ118738	–	–	–	Chaverri et al. (2005)
	Torrubiella wallacei	CBS 101237	AY184967	AY184978	EF469073	EF469119	Sung and Spatafora (2004), Sung et al. (2007)
Hypocreaceae	*Hypocrea americana*	AFTOL-ID 52	AY544649	AY544693	DQ471043	–	Lutzoni et al. (2004)
	Hypocrea rufa	DAOM JBT1003	JN938865	JN939042	–	–	Schoch et al. (2012)
	Sphaerostilbella berkeleyana	CBS 102308 = G.J.S. 82-274	U00756	AF543770	AF543783	DQ522465	Rehner and Samuels (1994), Currie et al. (2003), Spatafora et al. (2007)
	Trichoderma viride	G.J.S. 89-127	AY489726	–	–	–	Castlebury et al. (2004)
Nectriaceae	*Cosmospora coccinea*	A.R. 2741	AY489734	AY489702	AY489629	–	Castlebury et al. (2004)
	Nectria cinnabarina	CBS 114055 = G.J.S. 89-107	NCU00748	NCU32412	AF543785	–	Currie et al. (2003)
	Neonectria ramulariae	CBS 151.29	HM042436	HQ840414	–	DQ789792	Zhao et al. (2011)
	Viridispora diparietispora	ATCC MYA 627	AY489735	AY489703	AY489630	–	Castlebury et al. (2004)
Niessliaceae	*Niesslia exilis*	CBS 560.74	AY489720	AY489688	AY489614	–	Castlebury et al. (2004)
Ophiocordycipitaceae	*Elaphocordyceps capitata*	OSC 71233	AY489721	AY489689	AY489615	DQ522421	Castlebury et al. (2004), Spatafora et al. (2007)
	Elaphocordyceps japonica	OSC 110991	DQ518761	DQ522547	DQ522330	DQ522428	Spatafora et al. (2007)
	Hymenostilbe aurantiaca	OSC 128578	DQ518770	DQ522556	DQ522345	DQ522445	Spatafora et al. (2007)
	Ophiocordyceps sinensis	YN 09-64	JX968033	JX968028	–	JX968013	Zhang et al. (2013)
Stachybotriaceae	*Parasarcopodium ceratocaryi*	CBS 110664	AY425026	–	–	–	Mel'nik et al. (2004)
	Peethambara spirostriata	CBS 110115	AY489724	AY489692	AY489619	–	Castlebury et al. (2004)
	Myrothecium roridum	ATCC 16297	AY489708	AY489676	AY489603	–	Castlebury et al. (2004)
	Scopinella solani	CBS 770.84	AY015632	AY015621	–	–	Zhang and Blackwell (2002)
	Stachybotrys chlorohalonata	UAMH 6417	AY489712	AY489680	AY489607	–	Castlebury et al. (2004)
Outgroup	*Verticillium dahliae*	ATCC 16535	AY489737	AY489705	AY489632	DQ522468	Castlebury et al. (2004), Spatafora et al. (2007)

[a] No data in GenBank

[b] *AEG*, H.G. Sung and J.W. Spatafora; *AFTOL*, Assembling the Fungal Tree of Life; *A.R.*, Amy Y. Rossman, USDA-ARS MD USA; *ATCC*, American Type Culture Collection, Manassas, United States; *BCC*, BIOTEC Culture Collection, Thailand; *BPI*, U.S. National Fungus Collections, USDA-ARS MD USA; *CBS*, Centraalbureau voor Schimmelcultures, Utrecht, The Netherlands; *DAOM*, Canadian Collection of Fungal Cultures, Agriculture and Agri-Food Canada, Ottawa, Canada; *EFCC*, Entomopathogenic Fungal Culture Collection, USA; *G.J.S.*, Gary J. Samuels; USDA-ARS MD USA; *MFLUCC*, Mae Fah Luang University Culture Collection, Chiang Rai, Thailand; *OSC*, Oregon State University Herbarium, USA; *UAMH*, University of Alberta Microfungus Collection and Herbarium, Edmonton, Canada

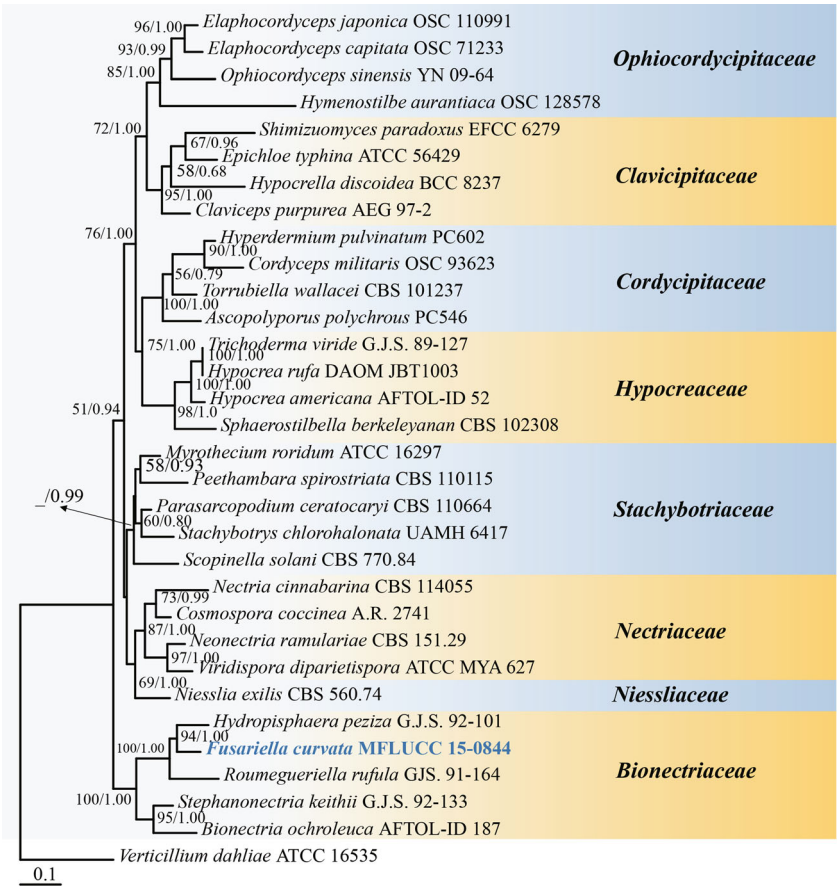

Fig. 1 Phylogenetic tree generated from maximum likelihood (ML) analysis based on combined SSU, LSU, TEF and RPB2 sequence data for the order Hypocreales. Bootstrap support values for ML greater than 50 % and Bayesian posterior probabilities greater than 0.5 are indicated above or below the nodes as MLBS/PP. The new isolate is in *bold and blue*. The tree is rooted with *Verticillium dahliae* ATCC 16535

Taxonomy

Generic description

Fusariella Sacc., Atti Inst. Veneto Sci. lett., ed Arti, Sér. 6 2: 463 (1884)

= *Kurssanovia* Pidopl., Mykrobiol. Zh. 9(2–3): 57 (1948)

= *Tylomyces* Cortini, Atti R. Acad. Lincei, Rendiconti Cl. Sci. Fis., sér. 5 30: 63 (1921)

Type species: *Fusariella atrovirens* (Berk.) Sacc., Fung. 2: 463 (1884)

Description — See Ellis (1971)

Notes: In total, 17 species of the genus *Fusariella* are accepted in this study, including our new species, *Fusariella curvata*. We also confirmed that *F. cladosporioides*, *F. polysciadis* and *F. populi* are factually unfaithful. Phylogenetic analysis of SSU, LSU, EF1-α and RPB2 sequence data indicates that this genus belongs in the family Bionectriaceae and this treatment is supported by morphology.

Species descriptions

Fusariella curvata C.G. Lin, Yong Wang bis & K.D. Hyde, sp. nov. (Fig. 2)

Index Fungorum number: IF552354; *Facesoffungi number*: FoF 02514

Etymology: In reference to the tip of each conidium being curved laterally

Holotype: MFLU 15-3268

Asexual morph *Colonies* on natural substrate effuse, greyish green. *Mycelium* partly superficial and partly immersed. *Conidiophores* macronematous, mononematous, erect, branched, straight or flexuous, smooth, 1–3-septate, hyaline, up to 70 μm long, up to 4.5 μm wide. *Conidiogenous cells* monophialidic, integrated, terminal or laterally intercalary, straight or flexuous, subulate, smooth, hyaline, 19.5–31.5 μm ($\bar{x}$ = 23.9 μm, n = 20) long, 2.0–3.0 μm ($\bar{x}$ = 2.4 μm, n = 20) wide at the base, tapering slightly to the apex to 1.0–2.0 μm ($\bar{x}$ = 1.6 μm, n = 20) wide. *Conidia* catenate, acrogenous, usually straight but sometimes curved, fusiform, obclavate, rounded at the base and pointed at the apex, mostly the apical cell of each conidium curved laterally, 1–3-septate (mostly 3-septate), slightly constricted at the septa, smooth, hyaline when young, pale olivaceous when mature, 18–24 μm ($\bar{x}$ = 20.5 μm, n = 50) long, 3.0–4.5 μm ($\bar{x}$ = 3.8 μm, n = 50) wide at the widest point. **Sexual morph** Undetermined.

Culture characteristics: Conidia germinating on PDA within 24 h. Colonies on MEA effuse, in concentric rings with

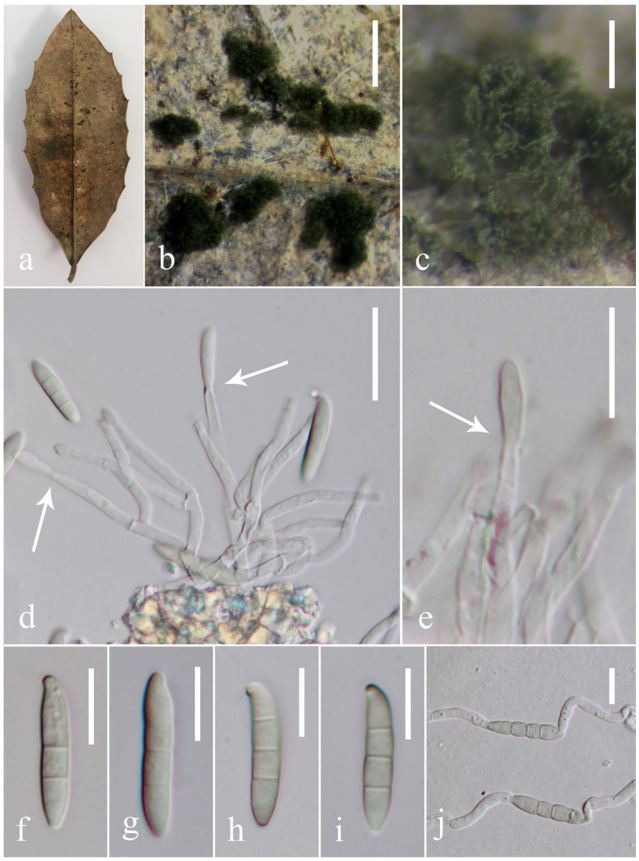

Fig. 2 *Fusariella curvata* (holotype MFLU 15-3268). **a** Host leaf. **b**, **c** Conidiophores on the host surface. **d**, **e** Conidiophores, conidiogenous cells and conidia. **f**–**i** Conidia. **j** Germinating conidia. Scale bars: **b** = 1000 μm, **c** = 200 μm, **d** = 20 μm, **e**–**j** = 10 μm

radial wrinkles in the centre, white from above, light yellow from below, reaching a diam. of 2–3 cm in 20 days at 25 °C.

Material examined: THAILAND, Chiang Rai, Mae Sai District, Ang Kep Nam Wat Tham Khao Hin Phayanak (Wat Tham Sao Hin Payanak), 20°19′16.58 - 30.12″N, 99°51′40.72 - 54.50″E, on decaying *Quercus* sp. leaf, 19 June 2015, C.-G. Lin, WTSP 10-1 (MFLU 15-3268, holotype; HGUP 8001, isotype), living culture MFLUCC 15-0844 = GUCC 8001.

Notes: The shape of conidium (tip mostly curved laterally) clearly distinguishes this species from all other *Fusariella* species. Conidia of our new species are similar to those of *F. sinensis* H.M. Liu & T.Y. Zhang, but the conidiogenous cells of our new species are smooth and hyaline, while those of *F. sinensis* are distinctly verrucose and coloured. Additionally, conidia of our new species are longer but narrower than those of *F. sinensis* (10–15 × 4.4–5.5 μm, $\bar{x}$ = 13.5 × 5 μm) (Liu and Zhang 2006). *Fusariella concinna* (Syd.) S. Hughes is similar to our new species in conidial shape, sometimes the conidia of *F. concinna* are slightly curved or bent above. However, conidia of *F. concinna* mostly are curved, fusoid but tapering towards the apex, whereas those of our new species are straight, fusiform, obclavate. Additionally, conidia of *F. concinna* are hyaline to slightly coloured with a well-defined basal scar, while those of our new species are hyaline when young, pale olivaceous when mature.

Other species accepted in the genus *Fusariella*

Sixteen known species of *Fusariella* are re-evaluated and recognised:

1. ***Fusariella atrovirens*** (Berk.) Sacc., Fung. 2: 463 (1884) (Fig. 3)
   ≡ *Fusisporium atrovirens* Berk., in Smith, Engl. Fl., Fungi (Edn 2) (London) 5(2): 351 (1836)
   ≡ *Fusarium atrovirens* (Berk.) Mussat, in Saccardo, Syll. fung. (Abellini) 15: 144 (1900)
   Description and illustrations — See Hughes (1949)
   Notes: *Fusariella atrovirens* is the type species of the genus *Fusariella*. The conidia of this species are similar to those of *F. bizzozeriana* but its conidiophores are minutely verruculose, while those of *F. bizzozeriana* are smooth (Hughes 1949). Type material of this species is *Mycotheca veneta*, 1038.

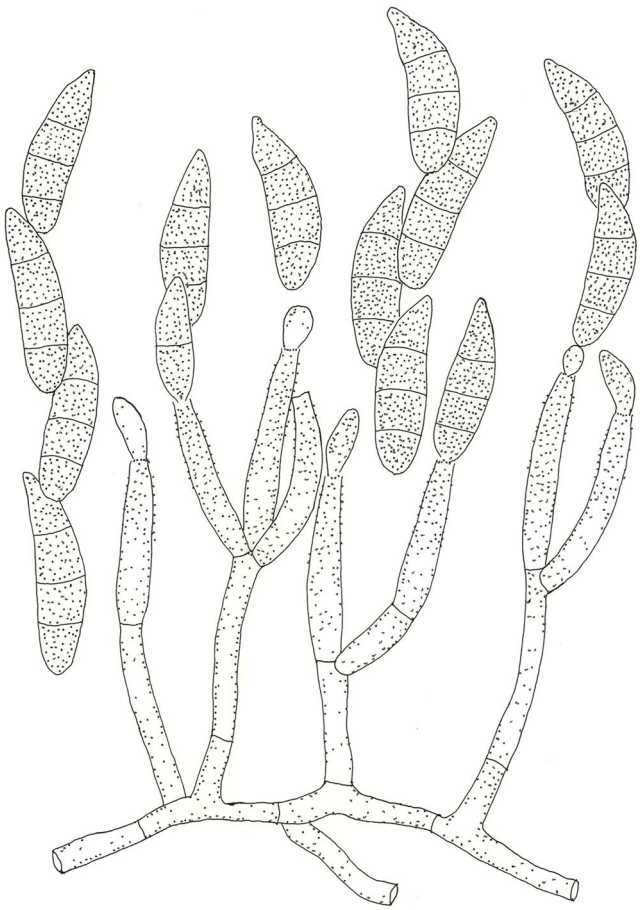

Fig. 3 ***Fusariella atrovirens*** (redrawn from Seifert et al. 2011)

2. ***Fusariella bizzozeriana*** (Sacc.) S. Hughes, Mycol. Pap. 28 (6): 6, 1949 (Fig. 4)

   ≡ *Sporidesmium bizzozerianum* Sacc., Mycotheca veneta: no. 365 (1876)

   ≡ *Clasterosporium bizzozerianum* (Sacc.) Sacc. [as '*Closterosporium*'], Michelia 2(no. 7): 289 (1881)

   Description and illustrations — See Hughes (1949)

   Notes: See notes of *F. atrovirens*. Type material of this species is *Mycotheca veneta*, 365.

3. ***Fusariella candida*** Matsush., Matsush. Mycol. Mem. 7: 51 (1993) (Fig. 5)

   Description and illustrations — See Matsushima (1993)

   Notes: It is a distinct species. The conidia of all *Fusariella* species are coloured when mature, except in *F. candida* and *F. formosana*. *Fusariella candida* has very short conidiophores (6.5–14 μm) (Matsushima 1993). Type material of this species is MFC-0P411 (Matsushima Fungus Collection, Kobe).

4. ***Fusariella concinna*** (Syd.) S. Hughes, Mycol. Pap. 28: 8 (1949) (Fig. 6)

   ≡ *Clasterosporium concinnum* Syd., Annales Mycologici 31 (1–2): 94 (1933)

   Description and illustrations — See Hughes (1949)

   Notes: *Fusariella bizzozeriana* and *F. viridiatra* are similar to *F. concinna* in conidial shape. However, the latter species develops hyaline to slightly coloured conidia, whereas those of *F. bizzozeriana* are olivaceous at the base, the upper parts nearly hyaline and those of *F. viridiatra* are green brown. Type material of this species is Herb. I.M.I. 8669.

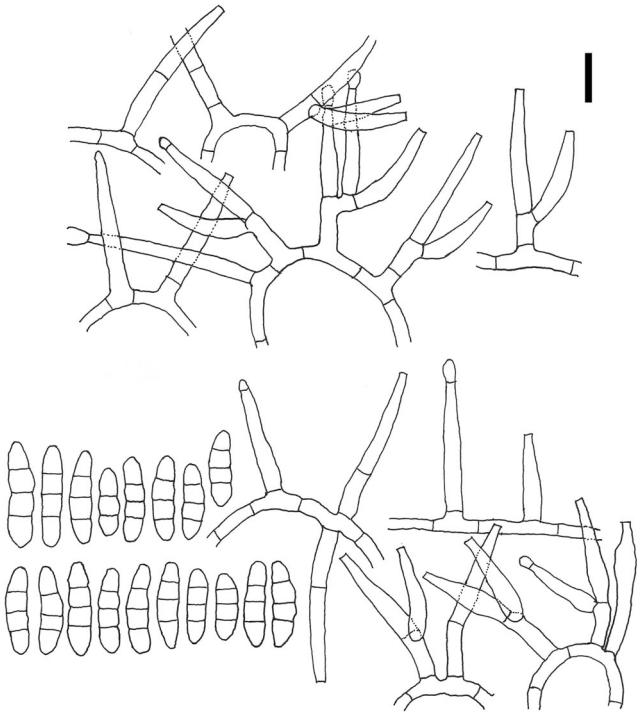

Fig. 5 ***Fusariella candida*** (redrawn from Matsushima 1993) (scale bar = 10 μm)

5. ***Fusariella echinulata*** H.M. Liu & T.Y. Zhang, Mycosystema 25(4): [513] (2006) (Fig. 7)

   Description and illustrations — See Liu and Zhang (2006)

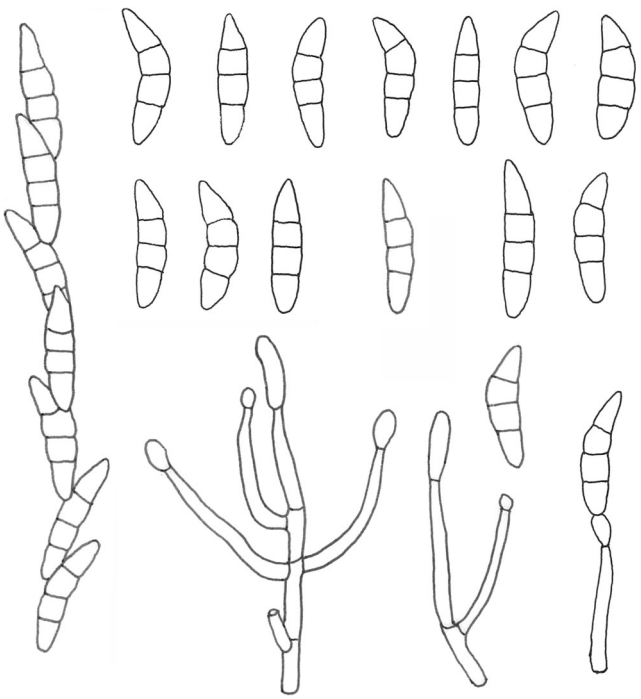

Fig. 4 ***Fusariella bizzozeriana*** (redrawn from Hughes 1949)

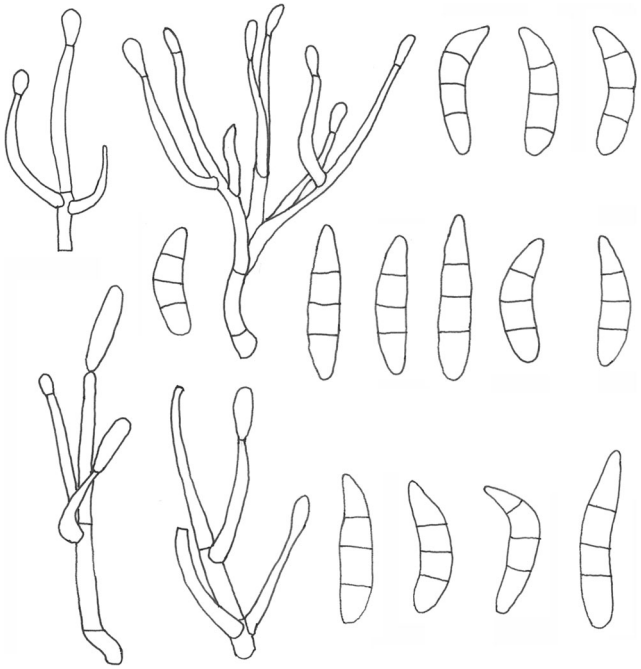

Fig. 6 ***Fusariella concinna*** (redrawn from Hughes 1949)

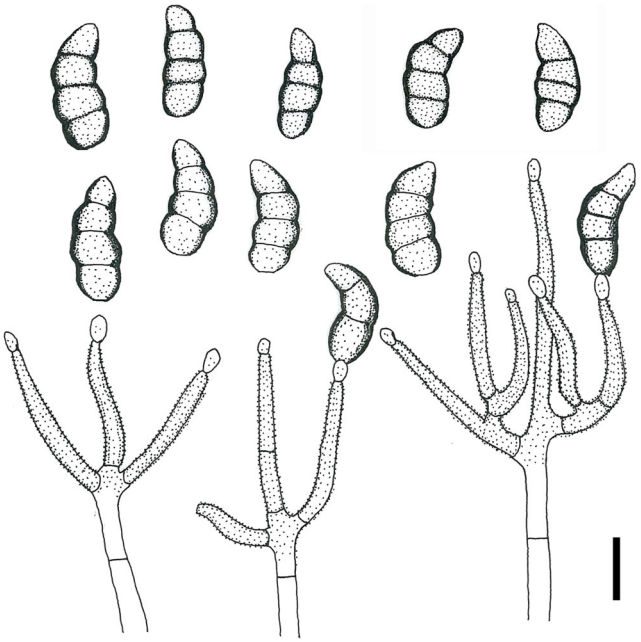

Fig. 7 ***Fusariella echinulata*** (redrawn from Liu and Zhang 2006) (scale bar = 10 μm)

Notes: Liu and Zhang (2006) described this species with obovoid conidia, which are actually obclavate based on their original description "the conidia are rounded at the base, tapered at apex" and the illustration.

Fusariella obstipa is similar to *F. echinulata* in conidial shape. However, the latter species develops pale olivaceous conidia, whereas those of *F. obstipa* are subhyaline. Type material of this species is $HSAUP_{03}1168$.

6. ***Fusariella egyptiaca*** Mouch. [as '*aegyptiacum*'], in Mouchacca & Nicot, Revue Mycol., Paris 37(3): 181 (1973) [1972] (Fig. 8)

Description and illustrations — See Ellis (1976)

Notes: Morphologically, *F. formosana* and *F. hughesii* are similar to *F. egyptiaca* in having subcylindrical to obclavate conidia. However, the conidia of *F. egyptiaca* are dark blackish brown, whereas those of *F. formosana* are hyaline and *F. hughesii* are initially hyaline, at maturity greenish blue to grey when in mass.

7. ***Fusariella formosana*** Matsush., Matsush. Mycol. Mem. 4: 9 (1985) (Fig. 9)

Description and illustrations — See Matsushima (1985)

Notes: *Fusariella formosana* is similar to *F. egyptiaca* and *F. hughesii* in conidial shape, see notes of *F. egyptiaca*. Type material of this species is MFC-10015.

8. ***Fusariella helanshanensis*** Y.M. Wu & T.Y. Zhang, Mycosystema 28(5): 653 (2009) (Fig. 10)

Description and illustrations — See Wu et al. (2009)

Notes: This species is very similar to *F. obstipa* in conidial shape and size, but differs from it by the middle cell of conidia being inflated (Wu et al. 2009). Type material of this species is $HSAUPII_{05}4119$ and ex-type is HMAS 196216.

9. ***Fusariella hughesii*** Chab.-Frydm., Can. J. Bot. 42(11): 1485 (1964) (Fig. 11)

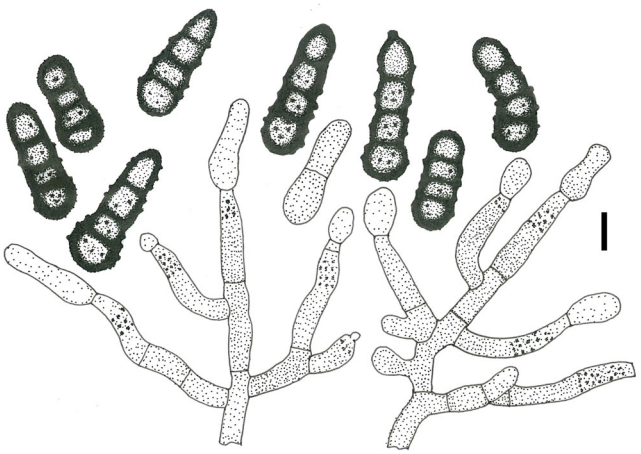

Fig. 8 ***Fusariella egyptiaca*** (redrawn from Ellis 1976) (scale bar = 5 μm)

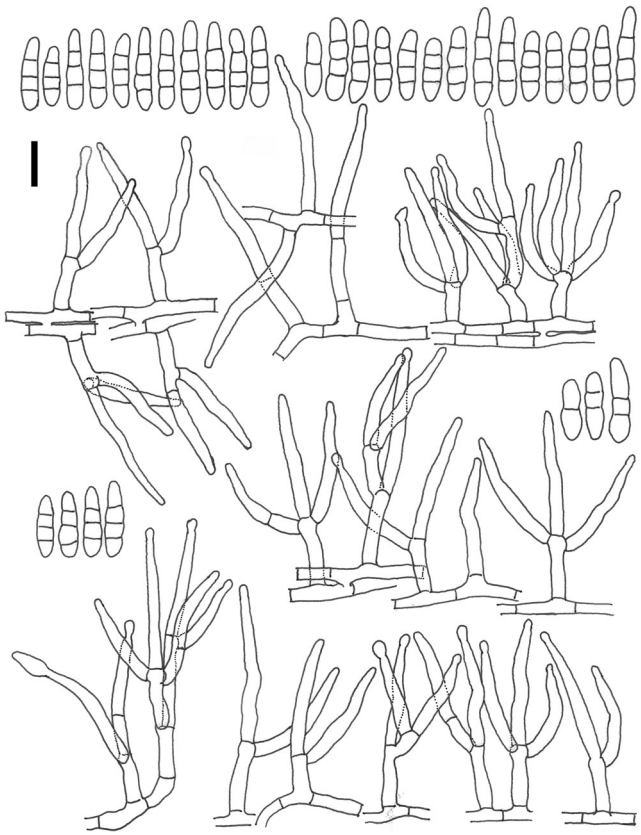

Fig. 9 ***Fusariella formosana*** (redrawn from Matsushima 1985) (scale bar = 10 μm)

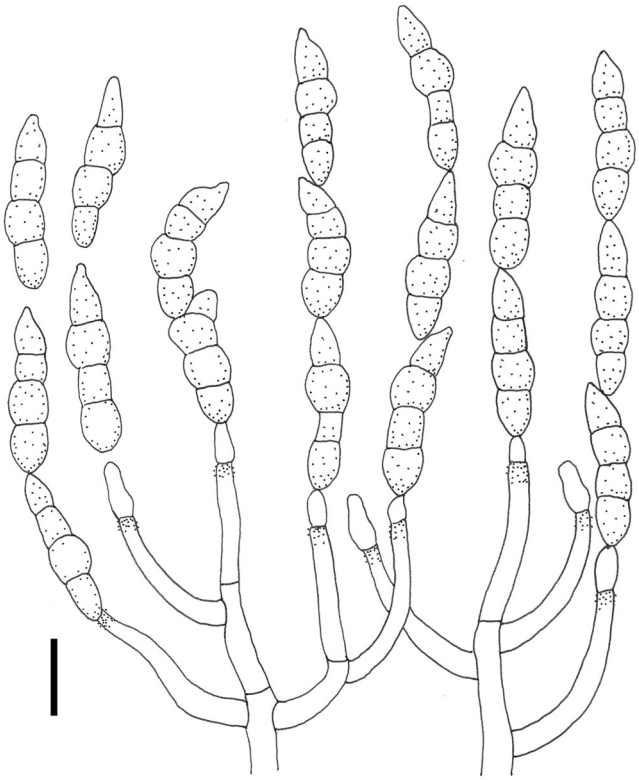

Fig. 10 ***Fusariella helanshanensis*** (redrawn from Wu et al. 2009) (scale bar = 10 μm)

Description and illustrations — See Chabelska-Frydman (1964) and Matsushima (1982)

Notes: It differs from the other *Fusariella* species in its light green conidia (Chabelska-Frydman 1964). Type material is Herb. I.M.I. 82236.

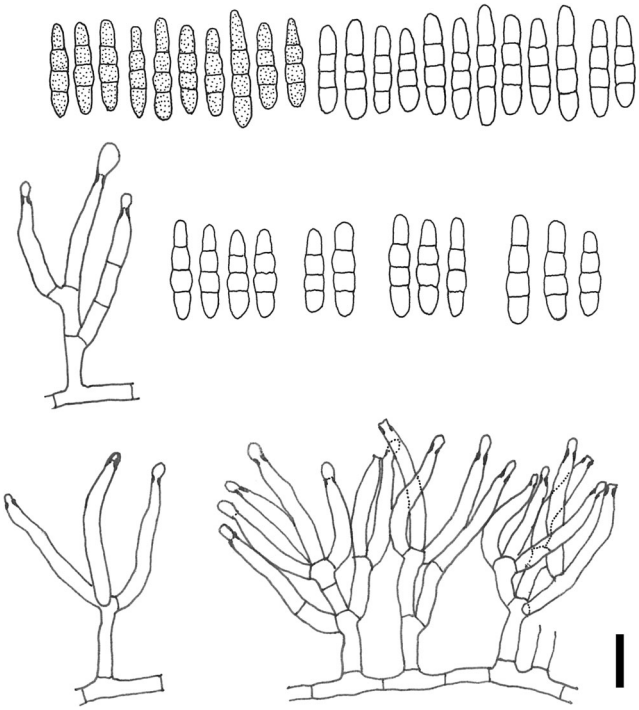

Fig. 11 ***Fusariella hughesii*** (redrawn from Matsushima 1982) (scale bar = 10 μm)

10. ***Fusariella indica*** R.Y. Roy & B. Rai, Trans. Br. Mycol. Soc. 51(2): 333 (1968) (Fig. 12)

Description and illustrations — See Roy and Rai (1968)

Notes: This species differs in producing chains of three kinds of conidia, viz. (i) long obclavate, 1–3-septate, 12–15 × 4.5−5 μm; (ii) short obclavate, 1-septate 8–12 × 4.5−6 μm; (iii) fusiform, 1−3-septate, 12–16 × 4.5−5 μm (Roy and Rai 1968). These three kinds of conidia are hyaline when young, becoming greenish black at maturity. Type material of this species is Herb. I.M.I. 127253.

11. ***Fusariella intermedia*** Mouch. & Nicot, Revue Mycol., Paris 37(3): 181 (1973) [1972] (Fig. 13)

Description and illustrations — See Ellis (1976)

Notes: It is similar to *F. kansensis* in conidial shape, as

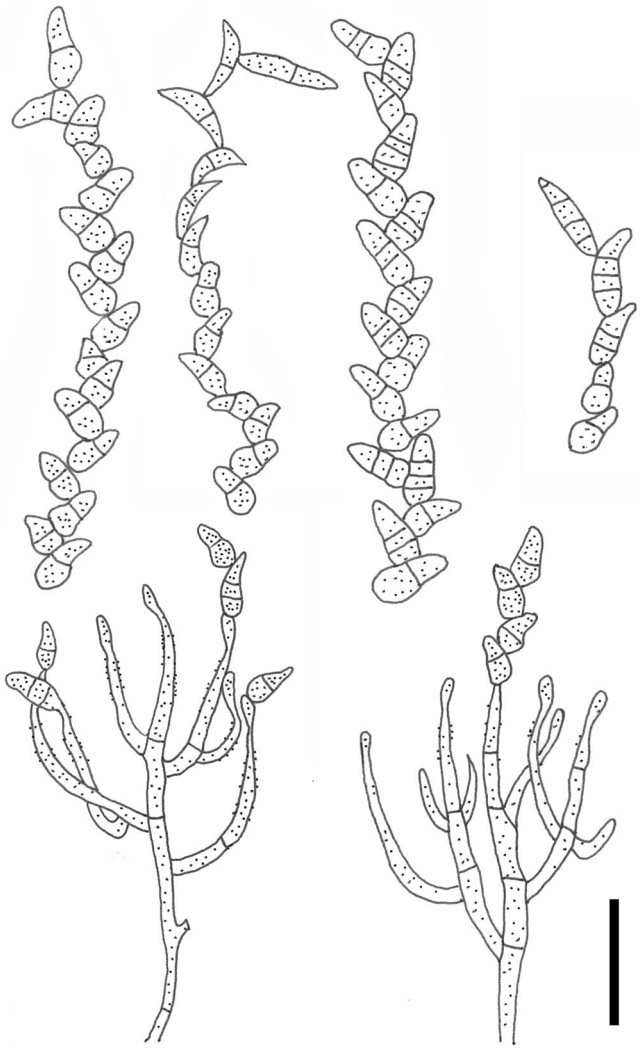

Fig. 12 ***Fusariella indica*** (redrawn from Roy and Rai 1968) (scale bar = 20 μm)

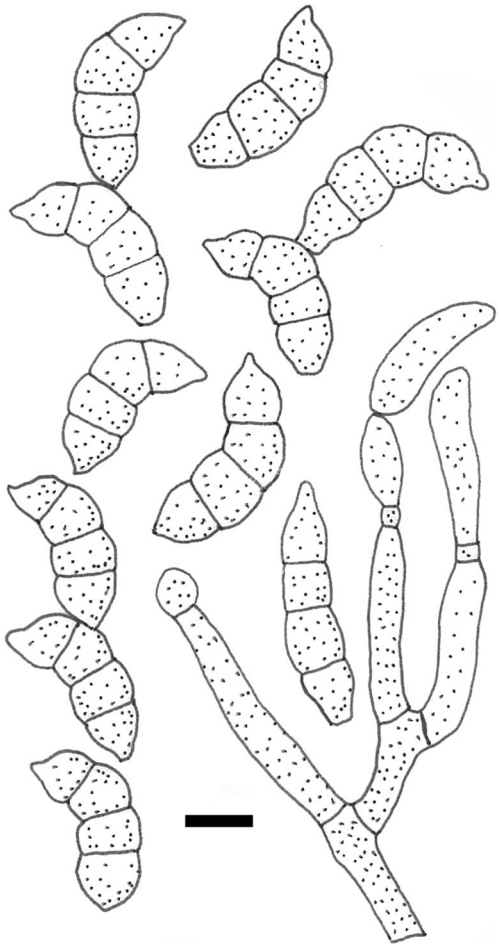

Fig. 13 ***Fusariella intermedia*** (redrawn from Ellis 1976) (scale bar = 5 μm)

both species produce curved and fusiform conidia. However, the conidia of *F. intermedia* are smaller than those of *F. kansensis* (22–27 × 7–9 μm).

12. ***Fusariella kansensis*** (Ellis & Barthol.) M.B. Ellis, More Dematiaceous Hyphomycetes (Kew): 459 (1976) (Fig. 14)

≡ *Clasterosporium kansense* Ellis & Barthol., Erythea 4: 28 (1896)

Description and illustrations — See Ellis (1976)

Notes: Hughes (1958) firstly proposed *Clasterosporium kansense* as a synonym of *F. bizzozeriana*, but the rough-walled phialides and much broader conidia distinguish it from *F. bizzozeriana* (Ellis 1976). Ellis (1976) re-described this species with the following morphological characters: conidia curved, 3-septate, constricted at the septa, smooth-walled, grey, 22–27 × 7–9 μm, conidiophores hyaline to pale olivaceous brown, 15–30 × 3–4 μm, phialides often verruculose, confirming its position in *Fusariella*. *Fusariella kansensis* differs from *F. intermedia* by producing larger conidia; see the notes of *F. intermedia*.

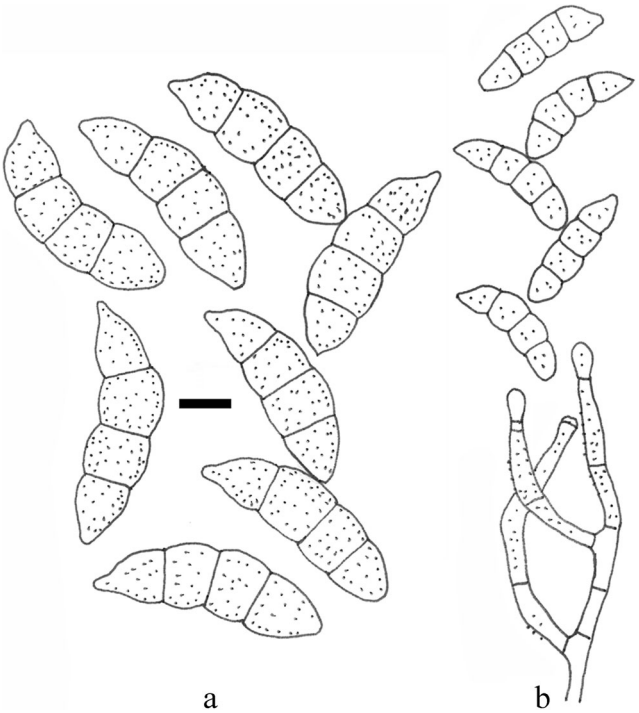

Fig. 14 ***Fusariella kansensis*** (redrawn from Ellis 1976) (**a** scale bar = 5 μm, **b** without scale bar)

13. ***Fusariella obstipa*** (Pollack) S. Hughes, Mycol. Pap. 28: 9 (1949) (Fig. 15)

≡ *Dendryphion obstipum* Pollack, Mycologia 39(5): 617 (1947)

Description and illustrations — See Pollack (1947) and Hughes (1949)

Notes: Amongst the species that produce more or less obclavate conidia, *F. echinulata* is most similar to *F. obstipa*. However, conidia of *F. echinulata* are pale

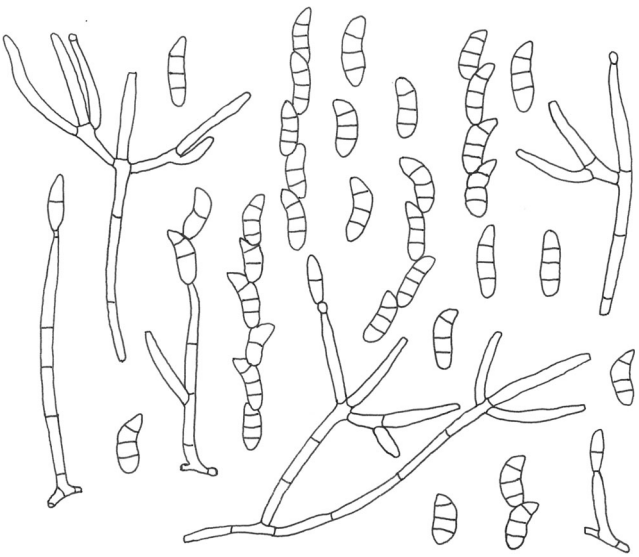

Fig. 15 ***Fusariella obstipa*** (redrawn from Hughes 1949)

olivaceous. Type material of this species is BPI 442857, deposited as *Dendryphion obstipum*.

14. ***Fusariella sarniensis*** M.B. Ellis, More Dematiaceous Hyphomycetes (Kew): 460 (1976) (Fig. 16)
Description and illustrations — See Ellis (1976)
Notes: The conidia are straight, cylindrical, rounded at the apex, truncate at the base, 3-septate, pale to mid-grey, smooth-walled, 15–18 × 5–7 μm (Ellis 1976). The type material of this species is I.M.I. 35730.

15. ***Fusariella sinensis*** H.M. Liu & T.Y. Zhang, Mycosystema 25(4): 514 (2006) (Fig. 17)
Description and illustrations — See Liu and Zhang (2006)
Notes: *Fusariella sinensis* is similar to *F. obstipa* in conidial shape, as both produce obclavate conidia. However, *F. sinensis* differs by having distinctly verrucose and coloured phialides (Liu and Zhang 2006). Type material of this species is $HSAUP_{03}1039$.

16. ***Fusariella viridiatra*** Sacc., Syll. fung. (Abellini) 4: 395 (1886) (Fig. 18)
≡ *Fusisporium atrovirens* Sacc. Fung. Ital., fig. 45 (1881)
Description and illustrations — See Lindau (1910)
Notes: *Fusariella viridiatra* is similar to *F. intermedia* and *F. kansensis* in conidial shape, as all produce fusiform and curved conidia. However, *F. viridiatra* differs by producing green brown conidia.

Species excluded from *Fusariella*

1. ***Fusariella cladosporioides*** P. Karst., Hedwigia 30: 248 (1891)

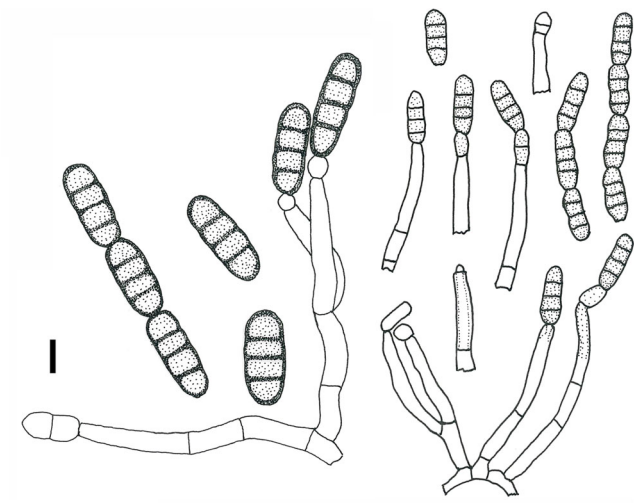

Fig. 16 ***Fusariella sarniensis*** (redrawn from Ellis 1976) (scale bar = 5 μm)

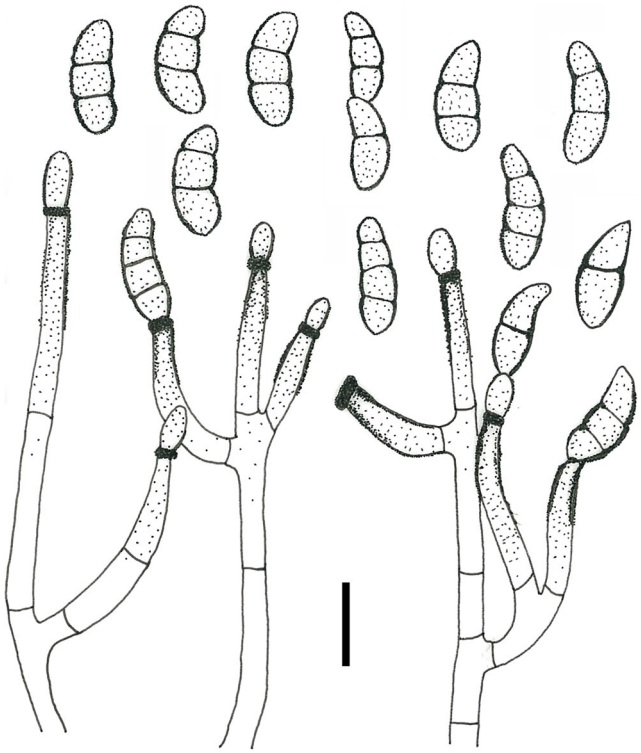

Fig. 17 ***Fusariella sinensis*** (redrawn from Liu and Zhang 2006) (scale bar = 10 μm)

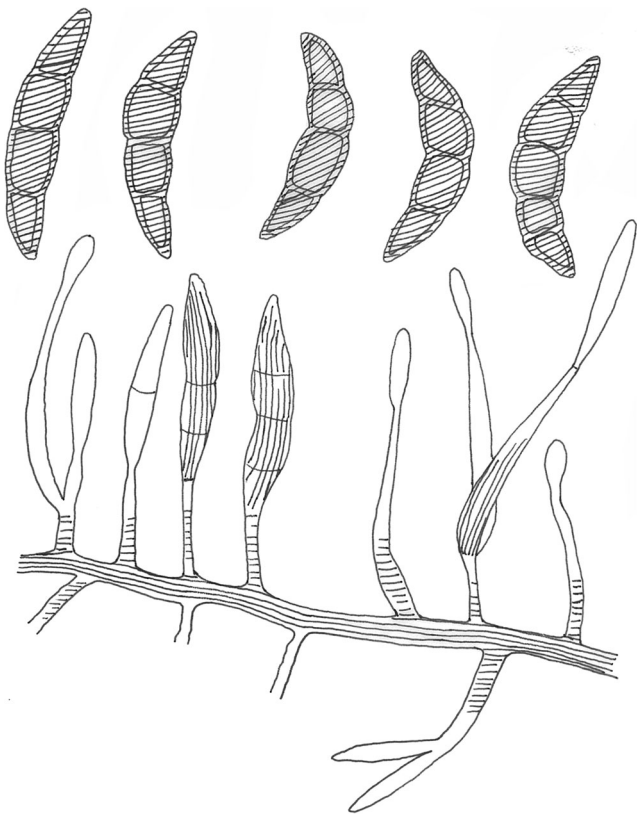

Fig. 18 ***Fusariella viridiatra*** (redrawn from Lindau 1910)

Notes: Karst (1891) briefly described it as "Caespituli effuai, minuti, hypophylli, griseo-olivacei. Hyphae brevissimae, ramosae, articulatae. Conidia bacillaria, apicem versus attenuata, curvata, raro recta, vulgo pauciseptata, fumoso-hyalina vel hyalina (sub lente), 50–100 × 4–6 mmn.", without any illustration (Hughes 1949).

Crous et al. (2013) proposed *F. cladosporioides* as a synonym of *Pseudocercospora myrticola* (Speg.) Deighton, 1976. In this study, we agree with this arrangement.

2. ***Fusariella polysciadis*** (Henn.) Wollenw. [as '*polysciatis*'], Fusaria autographica delineate 1: no. 433 (1916)

≡ *Pionnotes polysciadis* Henn. [as 'polysciatis'], Bot. Jb. 34: 57 (1904)

≡ *Cercosporella polysciadis* (Henn.) Hansf. [as '*polysciatis*'], Proc. Linn. Soc. London 155: 43 (1943) [1942–43]

Notes: This species is not a *Fusariella* because "the conidia are formed in typical *Cercospora* manner on simple or branched geniculate conidiophores" (Hansford 1943).

3. ***Fusariella populi*** Garb., Bull. Soc. Mycol. Fr. 33: 89 (1917)

= ? *Stigmina radiosa* (Lib.) Goid., Annali Bot.: 11 (1938)

Notes: Garbowski (1917) described a new *Fusariella* species as follows: "Caespitulis griseo-olivaceis in macula arida brunneola; conidiophoris subnullis; hyphis sporophoris hyalinis, fliformibus, 2 μ circ. latis; conidiis numerosis, fusoideis, curvulis vel rectis 2-septatis, ad septa leviter constrictis, utrinque rotundatis, guttulatis, olivaceis glabris, 30–35 × 5–7 μm." (Saccardo 1931; Hughes 1949).

Table 2 Synopsis of *Fusariella* species discussed in this study

Species name	Conidia				
	Shape	Colour	Septate	Ornamentation	Size (μm)
F. atrovirens	Fusiform, pointed at the apex, blunt at the base	Olive brown, black in mass	3		20–26 × 6–7
F. bizzozeriana	Fusoid, more tapered at apex than at the base, thick-walled	Olivaceous at the base, upper parts nearly hyaline	3	Smooth	25–31.5 × 5.5–6.5
F. candida	Cylindrical-fusiform	Colourless	(2–)3	Smooth	14–24.5 × 3.2–5.2
F. concinna	Thick-walled when mature, more or less fusoid but tapering towards the apex	Slightly coloured, hyaline to slightly coloured, with a well-defined basal scar	3		16–22(26) × 3.5–4(4.5)
F. curvata	Fusiform, obclavate, rounded at the base and pointed at the apex, mostly the tip of each conidium being curved laterally	Hyaline when young, pale olivaceous when mature	1–3, mostly 3	Smooth	18–24 × 3–4.5
F. egyptiaca	Subcylindrical to obclavate	Dark blackish brown	3	Smooth at first then verruculose	16–24 × 7–9
F. formosana	Cylindrical to obclavate	Hyaline	1–3, usually 3		14–20 × 3.5–5
F. helanshanensis	Clavate, straight, inflated in middle cell	Yellowish brown	2–3	Smooth	20–30 × 5–8
F. hughesii	Nearly cylindrical	Initially hyaline, at maturity greenish blue to grey when in mass	1–3, mostly 3	Smooth	15–19 × 2.5–3.5
F. indica	Long obclavate, short obclavate, fusiform	Hyaline when young, greenish black at maturity	1–3		8–16 × 4.5–6
F. intermedia	Curved, usually truncate and very dark at the base	Grey	3	Mostly smooth	14–22 × 4.5–7
F. kansensis	Curved	Grey	3	Smooth	22–27 × 7–9
F. obstipa	Obclavate with rounded base and pointed apex	Subhyaline when immature, becoming greenish olivaceous with age	1–3, mostly 3		14–20 × 4–6
F. sarniensis	Cylindrical, rounded at the apex, truncate at the base	Pale to mid-grey	3	Smooth	15–18 × 5–7
F. sinensis	Fusoid to short obclavate, pointed at the apex, blunt at the base, the tip of each conidium being deflected laterally	Pale olivaceous brown, olivaceous brown in mass	1–3	Smooth	10–15 × 4.4–5.5
F. viridiatra	Fusiform, curved, pointed at both ends	Green brown	3		25–30 × 6–8

Goidànich (1936) regarded *Fusariella populi* as a synonym of *Stigmina radiosa*, while Hughes (1949) only stated that this species did not belong in *Fusariella*. We concur with their conclusions.

Discussion

In this study, all the earlier described species of *Fusariella* were reviewed and a synopsis of *Fusariella* species is provided Table 2. Seventeen accepted species of the *Fusariella* are included; three species, *F. cladosporioides*, *F. polysciadis* and *F. populi*, are to be excluded.

Prior to this study, the natural classification of the genus *Fusariella* had not been determined. In this study, the phylogeny of the order Hypocreales is inferred from sequence data (SSU, LSU, EF1-α and RPB2) and a phylogenetic tree is provided to infer the phylogenetic position of the genus *Fusariella*. Based on phylogenetic analysis and morphology, the genus *Fusariella* belongs to the family Bionectriaceae.

Maharachchikumbura et al. (2015) accepted 38 genera within the family Bionectriaceae (Hypocreales, Sordariomycetes). The asexual morphs of the family Bionectriaceae are acremonium- or gliocladium-like hyphomycetous, e.g. *Acremonium* Link, *Clonostachys* Corda, *Gliomastix* Guég., *Kutilakesa* Subram., having phialidic conidiogenous cells and hyaline to bright-coloured conidia (Seifert et al. 2011).

In the tree generated from ML analysis based on combined ITS, SSU, LSU, TEF and RPB2 sequence data for the family Bionectriaceae (data not shown), the strain of *F. curvata* (MFLUCC 15-0844) grouped together with *Hydropisphaera arenula* (NRRL 13963) with 59 % ML bootstrap support and sister to the *Hydropisphaera erubescens* (ATCC 36093, ATCC 44545, ATCC 36092, HMAS 91779 and A.R. 2766) clade. The asexual morphs of *Hydropisphaera* were reported as *Acremonium* (Rossman et al. 1999), *Cephalosporiopsis* (Rossman et al. 1999) or *Gliomastix* (Lechat et al. 2010). Morphologically, these genera are similar to *Fusariella* in producing unbranched or branched conidiophores, phialidic conidiogenous cells and unicellular to multi-septate, ellipsoidal, fusiform to subfusiform, hyaline to greenish hyaline or bright-coloured conidia (Seifert et al. 2011; Maharachchikumbura et al. 2015).

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