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Numbers to names – restyling the *Fusarium incarnatum-equiseti* species complex

J.W. Xia[1], M. Sandoval-Denis[2,3], P.W. Crous[2,3,4], X.G. Zhang[1*], L. Lombard[2*]

Key words

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Abstract The *Fusarium incarnatum-equiseti* species complex (FIESC) is a phylogenetically species-rich complex that includes over 30 cryptic phylogenetic species, making identification based on phenotypic characters problematic. Several established *Fusarium* species known to reside in the FIESC lack type material, further complicating the use of Latin binomials for this complex. To overcome this problem, an informal classification system based on a haplotype nomenclature was introduced to improve communication between researchers in various fields. However, some conflicts in the application of this nomenclature system have arisen. To date, 16 phylo-species in the FIESC have been provided with Latin binomials with approximately 18 FIESC phylo-species still lacking Latin binomials, the majority of which reside in the Incarnatum clade. The aim of this study is to introduce Latin binomials for the unnamed FIESC phylo-species based on phylogenetic inference supported by phenotypic characters. The three-gene (calmodulin, RNA polymerase II second largest subunit and translations elongation factor 1-alpha) phylogenetic inference resolved 47 lineages, of which 44 belonged to the FIESC. The *F. camptoceras* species complex (FCAMSC) is introduced here for three lineages that are distinct from the FIESC. Epitypes are designated for *F. compactum*, *F. incarnatum* and *F. scirpi*, and a neotype for *F. camptoceras.* Latin binomials are provided for 20 of these newly resolved phylo-species in the FIESC.

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INTRODUCTION

The *Fusarium incarnatum-equiseti* species complex (FIESC) is a phylogenetically species-rich complex that includes over 30 recognised phylogenetic species (phylo-species) (O'Donnell et al. 2009, 2010, 2012, Villani et al. 2016, Maryani et al. 2019, Santos et al. 2019, Wang et al. 2019). The majority of these phylo-species are considered cryptic, making identification based solely on phenotypic characters problematic (Villani et al. 2016). Additionally, several established *Fusarium* species known to reside in the FIESC lack type material, further complicating the use of Latin binomials for this complex. Therefore, O'Donnell et al. (2009) implemented an informal classification system for FIESC based on the haplotype nomenclature system first introduced by Chang et al. (2006) for clinically important *Neocosmospora* species (formerly the *F. solani* (FSSC) species complex) lacking Latin binomials, depicting the species complex, species and genotype. This haplotype classification system was designed to improve communication between clinicians, veterinarians and agricultural researchers. However, some conflicts in the application of this nomenclature system have arisen in recent studies.

O'Donnell et al. (2009) recognised and classified 28 phylo-species (FIESC 1–28) which were shortly followed by FIESC 29 & 30 (O'Donnell et al. 2012). Villani et al. (2016) introduced FIESC 31 for a clade that included mycotoxin producing equiseti-like strains isolated from cereals. Torbati et al. (2019) also introduced FIESC 29 & 30 for incarnatum-like strains isolated from Basidiomycetes, which Wang et al. (2019) designated as FIESC 32. Similarly, Maryani et al. (2019) resolved six additional phylo-species and designated these as FIESC 29–34, providing Latin binomials for three of these: *F. kotabaruense* (FIESC 31), *F. sulawesiensis* (as *F. sulawense*; FIESC 32) and *F. tanahbumbuense* (FIESC 34). Wang et al. (2019) resolved 33 phylo-species and introduced Latin binomials for nine: *F. arcuatisporum* (FIESC 7), *F. citri* (FIESC 29), *F. guilinense* (FIESC 21), *F. hainanense* (FIESC 26), *F. humuli* (FIESC 33), *F. ipomoeae* (FIESC 1), *F. irregulare* (FIESC 15), *F. luffae* (FIESC 18) and *F. nanum* (FIESC 25). Santos et al. (2019) also resolved 30 phylo-species (FIESC 1–30) in their study on insect associated FIESC strains and were able to induce the sexual morphs of both FIESC 17 and FIESC 20, which they named *F. pernambucanum* and *F. caatingaense*, respectively.

In addition to the 13 phylo-species recently named, only three other phylo-species in the FIESC have been linked to Latin binomials: *F. equiseti* (FIESC 14), *F. lacertarum* (FIESC 4) and *F. scirpi* (FIESC 9) (O'Donnell et al. 2009, Villani et al. 2016). Therefore, approximately 18 FIESC phylo-species currently recognised still lack Latin binomials, with the majority residing in the Incarnatum clade. Thus, the aim of this study was to introduce an epitype for *F. incarnatum*, and provide Latin binomials for unnamed FIESC phylo-species based on a number of FIESC strains accessioned in the Westerdijk Fungal Biodiversity Institute (WI) culture collection.

MATERIALS AND METHODS

Isolates

Fusarium isolates (Table 1), initially identified and treated as members of the FIESC, were obtained from the culture collection

[1] Shandong Provincial Key Laboratory for Biology of Vegetable Diseases and Insect Pests, College of Plant Protection, Shandong Agricultural University, Taian, 271018, China.
[2] Westerdijk Fungal Biodiversity Institute, Uppsalalaan 8, 3584 CT Utrecht, The Netherlands.
[3] Faculty of Natural and Agricultural Sciences, Department of Plant Sciences, University of the Free State, P.O. Box 339, Bloemfontein 9300, South Africa.
[4] Wageningen University and Research Centre (WUR), Laboratory of Phytopathology, Droevendaalsesteeg 1, 6708 PB Wageningen, The Netherlands.
* corresponding authors e-mail:
X.G. Zhang, sdau613@163.com; L. Lombard, l.lombard@wi.knaw.nl.

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Table 1 Details of *Fusarium* strains included in the phylogenetic analyses.

Species	Culture accession[1]	Species complex / Phylogenetic species[2]	Host / substrate	Origin	GenBank accession			Reference
					cmdA	*rpb2*	*tef1*	
Fusarium aberrans	CBS 119866 = MRC 6715	Novel FIESC	Sorghum malt	Niger	MN170310	MN170377	MN170444	Present study
	CBS131385^{T}		*Oryza australiensis*	Australia	MN170311	MN170378	MN170445	Present study
	CBS 131387		*Oryza australiensis*	Australia	MN170312	MN170379	MN170446	Present study
	CBS 131388		*Oryza australiensis*	Australia	MN170313	MN170380	MN170447	Present study
F. arcuatisporum	NRRL 32997	FIESC 7	Unknown	Unknown	GQ505536	GQ505802	GQ505624	O'Donnell et al. (2009)
F. brevicaudatum	NRRL 43638^{T}	FIESC 6	*Trichechus* sp.	USA	GQ505576	GQ505843	GQ505665	O'Donnell et al. (2009)
	NRRL 43694		Human eye	USA	GQ505579	GQ505846	GQ505668	O'Donnell et al. (2009)
	NRRL 45998		Human toe	USA	GQ505584	GQ505851	GQ505673	O'Donnell et al. (2009)
F. bubalinum	CBS 161.25 = NRRL 26857 = NRRL 26918^{T}	Novel FIESC	Unknown	Australia	MN170314	MN170381	MN170448	Present study
F. caatingaense	CBS 976.97	FIESC 20	*Juniper chinensis*	USA	MN170315	MN170382	MN170449	Present study
	NRRL 34003 = CBS 130317		Human sputum	USA	GQ505539	GQ505805	GQ505627	O'Donnell et al. (2009)
F. camptoceras	CBS 193.65 = ATCC 16065 = BBA 9810 = IMI 112500^{ET}	FCAMSC	*Theobroma cacao*	Costa Rica	MN170316	MN170383	MN170450	Present study
F. cateniforme	CBS 150.25 = ATCC 11853^{T}	Novel FIESC	Unknown	Unknown	MN170317	MN170384	MN170451	Present study
F. citri	CBS 621.87	FIESC 29 (O'Donnell et al. 2012)	*Medicago sativa*	Denmark	MN170318	MN170385	MN170452	Present study
	CBS 678.77		Soil	Japan	MN170319	MN170386	MN170453	Present study
	CBS 130905		*Triticum* sp.	Iran	MN170320	MN170387	MN170454	Present study
	CPC 35143 = CCF 1881		*Lactuca sativa*	Czech Republic	MN170321	MN170388	MN170455	Present study
	LC 4879		*Amygdalus triloba*	China	MK289665	MK289768	MK289615	Wang et al. (2019)
	LC 7922		*Capsicum* sp.	China	MK289687	MK289788	MK289634	Wang et al. (2019)
	LC 7937		*Capsicum* sp.	China	MK289693	MK289794	MK289640	Wang et al. (2019)
F. clavum	CBS 394.93 = BBA 64265 = NRRL 25795	FIESC 5	*Disphyma crassifolium*	Germany	GQ505509	GQ505775	GQ505597	O'Donnell et al. (2009)
	CBS 126202^{T}		Soil	Namibia	MN170322	MN170389	MN170456	Present study
	CBS 130395 = NRRL 34032 = UTHSC 98-2172		Human abscess	USA	GQ505547	GQ505813	GQ505635	O'Donnell et al. (2009)
	CBS 119881 = MRC 8412		Unknown	Unknown	MN170323	MN170390	MN170457	Present study
	CBS 131015		*Phalaris minor*	Iran	MN170324	MN170391	MN170458	Present study
	CBS 131448		*Secale montanum*	Iran	MN170325	MN170392	MN170459	Present study
	CBS 131255		*Leucopoa sclerophylla*	Iran	MN170326	MN170393	MN170460	Present study
	CBS 131787		*Triticum* sp.	Iran	MN170327	MN170394	MN170461	Present study
	CBS 140912		*Solanum tuberosum*	Russia	MN170328	MN170395	MN170462	Present study
	NRRL 32871 = FRC R-9561		Human abscess	USA	GQ505531	GQ505797	GQ505619	O'Donnell et al. (2009)
	NRRL 34032		Mandibular abscess	USA	GQ505547	GQ505813	GQ505635	O'Donnell et al. (2009)
	NRRL 34035		Human sinus cavity	USA	GQ505549	GQ505815	GQ505637	O'Donnell et al. (2009)
	NRRL 34037		Human abscess	USA	GQ505550	GQ505816	GQ505638	O'Donnell et al. (2009)
	NRRL 43623		Human sinus cavity	USA	GQ505572	GQ505839	GQ505661	O'Donnell et al. (2009)
	NRRL 45995		Human abscess	USA	GQ505581	GQ505848	GQ505670	O'Donnell et al. (2009)
	NRRL 45997		Human sinus cavity	USA	GQ505583	GQ505850	GQ505672	O'Donnell et al. (2009)
F. coffeatum	CBS 635.76 = BBA 62053 = NRRL 20841^{T}	FIESC 28	*Cynodon lemfuensis*	New Zealand	MN120696	MN120736	MN120755	Lombard et al. (2019)
	NRRL 28577 = CBS 430.81		Grave stone	Romania	MN120697	MN120737	MN120756	Lombard et al. (2019)
F. compactum	CBS 185.31 = NRRL 36318	FIESC 3	Unknown	Unknown	GQ505558	GQ505824	GQ505646	O'Donnell et al. (2009)
	CBS 186.31 = NRRL 36323^{ET}		Cotton yarn	England	GQ505560	GQ505826	GQ505648	O'Donnell et al. (2009)
	NRRL 28029		Human eye	USA	GQ505514	GQ505780	GQ505602	O'Donnell et al. (2009)
F. concolor	NRRL 13459 = ATCC 60096 = CBS 961.87 = FRC M-2405 = IMI 296456^{T}	FCONSC	Plant debris	South Africa	GQ505585	GQ505852	GQ505674	O'Donnell et al. (2009)
F. croceum	CBS 131777^{T}	FIESC 10-a	*Triticum* sp.	Iran	MN170329	MN170396	MN170463	Present study
	CBS 131788		*Triticum* sp.	Iran	MN170330	MN170397	MN170464	Present study
	CPC 35240		Soil	Czech Republic	MN170331	MN170398	MN170465	Present study

Table 1 (cont.)

Species	Culture accession[1]	Species complex / Phylogenetic species[2]	Host / substrate	Origin	GenBank accession			Reference
					cmdA	*rpb2*	*tef1*	
F. croceum (cont.)	NRRL 3020 = FRC R-6053 = MRC 2231		Unknown	Unknown	GQ505498	GQ505764	GQ505586	O'Donnell et al. (2009)
	NRRL 3214 = FRC R-6054 = MRC 2232		Unknown	Unknown	GQ505499	GQ505765	GQ505587	O'Donnell et al. (2009)
F. duofalcatisporum	CBS 264.50 = NRRL 36401	FIESC 2	*Gossypium hirsutum*	Mozambique	GQ505563	GQ505829	GQ505651	O'Donnell et al. (2009)
	CBS 384.92 = NRRL 36448[T]		*Phaseolus vulgaris*	Sudan	GQ505564	GQ505830	GQ505652	O'Donnell et al. (2009)
F. equiseti	CBS 107.07 = IMI 091982 = NRRL 36136	FIESC 14-a	Unknown	Unknown	GQ505556	GQ505822	GQ505644	O'Donnell et al. (2009)
	CBS 185.34		Soil	Netherlands	MN170332	MN170399	MN170466	Present study
	CBS 414.86 = FRC R-8508 = IMI 309348		Potato peel	Denmark	MN170333	MN170400	MN170467	Present study
	CBS 119663		Maize husk	Switzerland	MN170334	MN170401	MN170468	Present study
	CPC 35123		*Hordeum vulgare*	Czech Republic	MN170335	MN170402	MN170469	Present study
	CPC 35134 = DSM 62203		*Daphne mezereum*	Germany	MN170336	MN170403	MN170470	Present study
	CPC 35220		Sediment	Czech Republic	MN170337	MN170404	MN170471	Present study
	CPC 35262		Human toenail	Czech Republic	MN170338	MN170405	MN170472	Present study
	NRRL 20697 = CBS 245.61		*Beta vulgaris*	Chile	GQ505506	GQ505772	GQ505594	O'Donnell et al. (2009)
	NRRL 26419 = BBA 68556 = CBS 307.94[ET]		Soil	Germany	GQ505511	GQ505777	GQ505599	O'Donnell et al. (2009)
F. fasciculatum	CBS 131382[T]	Novel FIESC	*Oryza australiensis*	Australia	MN170339	MN170406	MN170473	Present study
	CBS 131383		*Oryza australiensis*	Australia	MN170340	MN170407	MN170474	Present study
	CBS 131384		*Oryza australiensis*	Australia	MN170341	MN170408	MN170475	Present study
F. flagelliforme	CBS 162.57 = NRRL 36269[T]	FIESC 12	*Pinus nigra*	Croatia	GQ505557	GQ505823	GQ505645	O'Donnell et al. (2009)
	CBS 259.54 = NRRL 36392		Unknown seedling	Germany	GQ505562	GQ505828	GQ505650	O'Donnell et al. (2009)
	NRRL 6548 = IMI 112503		*Hordeum vulgare*	Germany	GQ505501	GQ505767	GQ505589	O'Donnell et al. (2009)
	NRRL 26921 = CBS 731.87		*Triticum* sp.	Germany	GQ505512	GQ505778	GQ505600	O'Donnell et al. (2009)
	NRRL 31011 = BBA 69079		*Thuja* sp.	Germany	GQ505518	GQ505784	GQ505606	O'Donnell et al. (2009)
F. gracilipes	NRRL 43635[T]	FIESC 13	Horse	USA	GQ505573	GQ505840	GQ505662	O'Donnell et al. (2009)
F. guilinense	NRRL 13335 = FRC R-2138	FIESC 21	Alfalfa	Australia	GQ505502	GQ505768	GQ505590	O'Donnell et al. (2009)
	NRRL 32865 = FRC R-8480		Human endocarditis	Brazil	GQ505526	GQ505792	GQ505614	O'Donnell et al. (2009)
F. hainanense	CBS 131386	FIESC 26	*Oryza australiensis*	Australia	MN170376	MN170443	MN170510	Present study
	Indo 161		*Musa acuminata*	Indonesia	LS479428	LS479857	–	Maryani et al. (2019)
	NRRL 26417 = CBS 544.96		Leaf litter	Cuba	GQ505510	GQ505776	GQ505598	O'Donnell et al. (2009)
	NRRL 28714 = ATCC 74289		*Acacia* sp.	Costa Rica	GQ505516	GQ505782	GQ505604	O'Donnell et al. (2009)
F. humuli	LC 4490	FIESC 33 (Wang et al. 2019)	*Osmanthus* sp.	China	MK289664	MK289767	MK289614	Wang et al. (2019)
	LC 12158		*Musa nana*	China	MK289645	MK289745	MK289592	Wang et al. (2019)
	LC 12159		*Musa nana*	China	MK289646	MK289746	MK289593	Wang et al. (2019)
F. incarnatum	CBS 132.73 = ATCC 24387 = IMI 128222 = NRRL 25478[NT]	FIESC 23	*Trichosanthes dioica*	Malawi	MN170342	MN170409	MN170476	Present study
	CBS 132907		*Triticum* sp.	Iran	MN170343	MN170410	MN170477	Present study
	NRRL 13379 = FRC R-5198 = BBA 62200		*Oryza sativa*	India	GQ505503	GQ505769	GQ505591	O'Donnell et al. (2009)
	NRRL 32866 = FRC R-8822		Human	USA	GQ505527	GQ505793	GQ505615	O'Donnell et al. (2009)
	NRRL 32867 = FRC R-8837		Human	USA	GQ505528	GQ505794	GQ505616	O'Donnell et al. (2009)
F. ipomoeae	CBS 135762	FIESC 1	*Miscanthus giganteus*	USA	MN170344	MN170411	MN170478	Present study
	CBS 140909		*Solanum lycopersicum*	Russia	MN170345	MN170412	MN170479	Present study
	Indo 174		*Musa* sp.	Indonesia	LS479430	LS479861	–	Maryani et al. (2019)
	NRRL 34034		Human leg	USA	GQ505548	GQ505814	GQ505636	O'Donnell et al. (2009)
	NRRL 34039		Human	USA	GQ505551	GQ505817	GQ505639	O'Donnell et al. (2009)
	NRRL 43637		Dog	USA	GQ505575	GQ505842	GQ505664	O'Donnell et al. (2009)
	NRRL 43640		Dog	USA	GQ505578	GQ505845	GQ505667	O'Donnell et al. (2009)
	NRRL 45996		Human nasal cavity	USA	GQ505582	GQ505849	GQ505671	O'Donnell et al. (2009)

Table 1 (cont.)

Species	Culture accession[1]	Species complex/Phylogenetic species[2]	Host/substrate	Origin	GenBank accession			Reference
					cmdA	*rpb2*	*tef1*	
F. irregulare	CBS 132190	FIESC 15	Human toenail	Thailand	MN170346	MN170413	MN170480	Present study
	NRRL 31160		Human lung	USA	GQ505519	GQ505785	GQ505607	O'Donnell et al. (2009)
	NRRL 32175		Human sputum	USA	GQ505521	GQ505787	GQ505609	O'Donnell et al. (2009)
	NRRL 32181		Human blood	USA	GQ505522	GQ505788	GQ505610	O'Donnell et al. (2009)
	NRRL 32182		Human blood	USA	GQ505523	GQ505789	GQ505611	O'Donnell et al. (2009)
	NRRL 32869 = FRC R-9445		Human	USA	GQ505530	GQ505796	GQ505618	O'Donnell et al. (2009)
	NRRL 32994		Human sinus cavity	USA	GQ505533	GQ505799	GQ505621	O'Donnell et al. (2009)
	NRRL 32995		Human sinus cavity	USA	GQ505534	GQ505800	GQ505622	O'Donnell et al. (2009)
	NRRL 32996		Human leg wound	USA	GQ505535	GQ505801	GQ505623	O'Donnell et al. (2009)
	NRRL 34001		Human foot wound	USA	GQ505533	GQ505799	GQ505621	O'Donnell et al. (2009)
	NRRL 34006		Human eye	USA	GQ505542	GQ505808	GQ505630	O'Donnell et al. (2009)
	NRRL 34007		Human sputum	USA	GQ505543	GQ505809	GQ505631	O'Donnell et al. (2009)
	NRRL 34008		Human lung	USA	GQ505544	GQ505810	GQ505632	O'Donnell et al. (2009)
	NRRL 34010		Human sinus cavity	USA	GQ505545	GQ505811	GQ505633	O'Donnell et al. (2009)
	NRRL 34011		Human sputum	USA	GQ505546	GQ505812	GQ505634	O'Donnell et al. (2009)
	NRRL 43619		Human finger	USA	GQ505570	GQ505837	GQ505659	O'Donnell et al. (2009)
	NRRL 43622		Human lung	USA	GQ505571	GQ505838	GQ505660	O'Donnell et al. (2009)
F. kotabaruense	InaCC F963^{T}	FCAMSC/FIESC 31 (Maryani et al. 2019)	*Musa* sp.	Indonesia	LS479429	LS479859	LS479445	Maryani et al. (2019)
F. lacertarum	NRRL 20423 = ATCC 42771 = CBS 130185 = IMI 300797^{T}	FIESC 4	Lizard skin	India	GQ505505	GQ505771	GQ505593	O'Donnell et al. (2009)
	NRRL 36123 = CBS 102300		Unknown	Unknown	GQ505555	GQ505821	GQ505643	O'Donnell et al. (2009)
F. longicaudatum	CBS 123.73 = ATCC 24370 = IMI 160825 = NRRL 25477^{T}	Novel FIESC	Unknown	Tanzania	MN170347	MN170414	MN170481	Present study
F. longifundum	CBS 235.79 = NRRL 36372^{T}	Novel FIESC	Air	Curaçao	GQ505561	GQ505827	GQ505649	O'Donnell et al. (2009)
F. luffae	CBS 131097	FIESC 18	*Setaria verticilata*	Iran	MN170348	MN170415	MN170482	Present study
	NRRL 31167		Human sputum	USA	GQ505520	GQ505786	GQ505608	O'Donnell et al. (2009)
	NRRL 32522		Human diabetic cellulitis	USA	GQ505524	GQ505790	GQ505612	O'Donnell et al. (2009)
F. monophialidicum	NRRL 54973	Novel FIESC	Rhinoceros eye	USA	MN170349	MN170416	MN170483	Present study
F. mucidum	CBS 102394	FIESC 30 (Maryani et al. 2019)	*Anacardium occidentale*	El Salvador	MN170350	MN170417	MN170484	Present study
	CBS 102395^{T}		*Anacardium occidentale*	El Salvador	MN170351	MN170418	MN170485	Present study
	Indo 175		*Musa acuminata*	Indonesia	LS479431	LS479862	LS479447	Maryani et al. (2019)
F. multiceps	CBS 130386 = NRRL 43639^{T}	FIESC 19	*Trichechus* sp.	USA	GQ505577	GQ505844	GQ505666	O'Donnell et al. (2009)
F. nanum	CBS 119867 = FRC R-4237 = MRC 3228	FIESC 25	*Sorghum* sp.	Unknown	MN170352	MN170419	MN170486	Present study
	CBS 131781		*Triticum* sp.	Iran	MN170353	MN170420	MN170487	Present study
	CPC 35142 = CCF 1744		Soil	Czech Republic	MN170354	MN170421	MN170488	Present study
	NRRL 22244		*Oryza* sp.	China	GQ505508	GQ505774	GQ505596	O'Donnell et al. (2009)
	NRRL 32868 = FRC R-8880		Human blood	USA	GQ505529	GQ505795	GQ505617	O'Donnell et al. (2009)
	NRRL 32993		Human nasal tissue	USA	GQ505532	GQ505798	GQ505620	O'Donnell et al. (2009)
F. neoscirpi	CBS 610.95 = NRRL 26861 = NRRL 26922^{T}	Novel FIESC	Soil	France	GQ505513	GQ505779	GQ505601	O'Donnell et al. (2009)
F. neosemitectum	CBS 189.60^{T}	FCAMSC	*Musa sapientum*	Dem. Rep. Congo	MN170355	MN170422	MN170489	Present study
	CBS 190.60		*Musa sapientum*	Dem. Rep. Congo	MN170356	MN170423	MN170490	Present study
F. pernambucanum	CBS 791.70	FIESC 17	*Musa sampientum*	Unknown	MN170357	MN170424	MN170491	Present study
	CBS 132194		Human finger nail	Thailand	MN170358	MN170425	MN170492	Present study
	CBS 132894		Human toenail	Unknown	MN170359	MN170426	MN170493	Present study
	CBS 133024		Human foot	Thailand	MN170360	MN170427	MN170494	Present study
	NRRL 32864 = CBS 130312 = FRC R-7245		Human	USA	GQ505525	GQ505791	GQ505613	O'Donnell et al. (2009)
	NRRL 34070		Tortoise	USA	GQ505554	GQ505820	GQ505642	O'Donnell et al. (2009)
F. persicinum	CBS 479.83^{T}	FIESC 29/30 (Torbati et al. 2019)	Unknown	Unknown	MN170361	MN170428	MN170495	Present study
	CBS 131780		*Triticum sp.*	Iran	MN170362	MN170429	MN170496	Present study
	CBS 132821		Soil	Iran	MN170363	MN170430	MN170497	Present study

Table 1 (cont.)

Species	Culture accession[1]	Species complex/Phylogenetic species[2]	Host/substrate	Origin	GenBank accession			Reference
					cmdA	*rpb2*	*tef1*	
F. persicinum (cont.)	CBS 143595 = CPC 30847		*Ganoderma* sp.	Iran	LT970731	LT970750	LT970778	Torbati et al. (2019)
	CBS 143596 = CPC 30848		*Stereum hirsutum*	Iran	LT970732	LT970751	LT970779	Torbati et al. (2019)
	CBS 143597 = CPC 30849		Smut	Iran	LT970737	LT970756	LT970784	Torbati et al. (2019)
	CBS 143598 = CPC 30850		Smut	Iran	LT970733	LT970752	LT970780	Torbati et al. (2019)
	CBS 143600 = CPC 30852		Smut	Iran	LT970734	LT970753	LT970781	Torbati et al. (2019)
	CBS 143603 = CPC 30855		Smut	Iran	LT970735	LT970754	LT970782	Torbati et al. (2019)
	CBS 143606 = CPC 30858		Smut	Iran	LT970736	LT970755	LT970783	Torbati et al. (2019)
F. scirpi	CBS 447.84 = FRC R-6252 = NRRL 36478[NT]	FIESC 9	Soil	Australia	GQ505566	GQ505832	GQ505654	O'Donnell et al. (2009)
	CBS 448.84 = FRC R-6253		Soil	Australia	MN170364	MN170431	MN170498	
	NRRL 13402		Soil	Australia	GQ505504	GQ505770	GQ505592	O'Donnell et al. (2009)
F. serpentinum	CBS 119880 = BBA 62209 = MRC 1813	Novel FIESC	Unknown	Unknown	MN170365	MN170432	MN170499	Present study
F. sulawesiense	CBS 131.73 = ATCC 24386 = IMI 160602 = NRRL 20425	FIESC 16	*Musa sampientum* var. *robusta*	Bahamas	MN170366	MN170433	MN170500	Present study
	CBS 163.57		*Sorghum vulgare*	Trinidad and Tobago	MN170367	MN170434	MN170501	Present study
	CBS 193.60		*Gossypium hirsutum*	El Salvador	MN170368	MN170435	MN170502	Present study
	CBS 622.87 = NRRL 26858 = NRRL 26919 = NRRL 28583		*Bixa orellana*	Brazil	MN170369	MN170436	MN170503	Present study
	CBS 122439		Galia melon	Brazil	MN170370	MN170437	MN170504	Present study
	InaCC F940[T]		*Musa acuminata*	Indonesia	LS479422	LS479855	LS479443	Maryani et al. (2019)
	InaCC F941		*Musa acuminata*	Indonesia	LS479423	LS479856	LS479444	Maryani et al. (2019)
	Indo 186		*Musa* sp.	Indonesia	LS479426	LS479864	LS479449	Maryani et al. (2019)
	Indo 188		*Musa* sp.	Indonesia	LS479427	LS479865	LS479450	Maryani et al. (2019)
	NRRL 34004		Human BAL	USA	GQ505540	GQ505806	GQ505628	O'Donnell et al. (2009)
	NRRL 34056		Human bronchial wash	USA	GQ505552	GQ505818	GQ505640	O'Donnell et al. (2009)
	NRRL 34059		Human blood	USA	GQ505553	GQ505819	GQ505641	O'Donnell et al. (2009)
	NRRL 43730		Contact lens	USA	GQ505580	GQ505847	GQ505669	O'Donnell et al. (2009)
F. tanahbumbuense	CBS 145.44 = BBA 4095	FIESC 24	Unknown	Unknown	MN170371	MN170438	MN170505	Present study
	CBS 131009		*Triticum* sp.	Iran	MN170372	MN170439	MN170506	Present study
	InaCC F965[T]		*Musa* sp.	Indonesia	LS479432	LS479863	LS479448	Maryani et al. (2019)
	NRRL 34005		Human eye	USA	GQ505541	GQ505807	GQ505629	O'Donnell et al. (2009)
	NRRL 43297		Unknown	Unknown	GQ505569	GQ505835	GQ505657	O'Donnell et al. (2009)
F. toxicum	CBS 219.63	FIESC 14-b	Soil	Germany	MN170373	MN170440	MN170507	Present study
	CBS 406.86 = FRC R-8507 = IMI 309347 = NRRL 25796[T]		Soil	Germany	MN170374	MN170441	MN170508	Present study
	CBS 130385		Dog	USA	MN170375	MN170442	MN170509	Present study
	NRRL 43636		Dog	USA	GQ505574	GQ505841	GQ505663	O'Donnell et al. (2009)
Fusarium sp.	NRRL 5537 = ATCC 28805	FIESC 8	Fescue hay	USA	GQ505500	GQ505766	GQ505588	O'Donnell et al. (2009)
	NRRL 43498	FIESC 8	Human cornea	USA	–	GQ505836	GQ505658	O'Donnell et al. (2009)
Fusarium sp. (FIESC 22)	NRRL 34002	FIESC 22	Human sinus cavity	USA	GQ505538	GQ505804	GQ505626	O'Donnell et al. (2009)
Fusarium sp. (FIESC 27)	NRRL 20722 = IMI 190455	FIESC 27	*Pyrethrum* sp.	Kenia	GQ505507	GQ505773	GQ505595	O'Donnell et al. (2009)
Fusarium sp. (FIESC 30)	NRRL 52758	FIESC 30 (O'Donnell et al. 2012)			–	JF741159	JF740833	O'Donnell et al. (2012)
Fusarium sp. (FIESC 31)	ITEM 11401 = NRRL 66339	FIESC 31 (Villani et al. 2016)			LN901594	LN901611	LN901578	Villani et al. (2016)
	ITEM 13601	FIESC 31 (Villani et al. 2016)			–	LN901614	–	Villani et al. (2016)
Fusarium sp. (FIESC 32)	InaCC F964	FIESC 32 (Maryani et al. 2019)	*Musa* sp.	Indonesia	LS479425	LS479860	LS479446	Maryani et al. (2019)
	Indo 167	FIESC 32 (Maryani et al. 2019)	*Musa* sp.	Indonesia	LS479424	LS479858	–	Maryani et al. (2019)

[1] ATCC: American Type Culture Collection, USA; BBA: Biologische Bundesanstalt für Land- und Forstwirtschaft, Berlin-Dahlem, Germany; CBS: Westerdijk Fungal Biodiverity Institute (WFBI), Utrecht, The Netherlands; CCF: Culture Collection of Fungi, Prague, Czech Republic; FRC: Fusarium Research Center, Penn State University, Pennsylvania; IMI: International Mycological Institute, CABI-Bioscience, Egham, Bakeham Lane, UK; ITEM: Agri-Food Toxigenic Fungi Culture Collection, Institute of Sciences of Food Production, Bari, Italy; MRC: National Research Institute for Nutritional Diseases, Tygerberg, South Africa; InaCC: Indonesian Culture Collection, Research Center for Biology, Indonesian Institute of Science (LIPI), Cibinong, Indonesia; Indo: working collection of N. Maryani, Research Center for Biology, Indonesian Institute of Science (LIPI), Cibinong, Indonesia; LC: working collection of Lei Cai, State Key Laboratory of Mycology, Institute of Microbiology, Chinese Academy of Sciences, Beijing, P.R. China; NRRL: Agricultural Research Service Culture Collection, USA; RBG: Royal Botanic and Domain Trust, Sydney, Australia. [T] Ex-type culture; [NT]Neotype. [2]Designation according to O'Donnell et al. (2009) unless indicated otherwise; FCAMSC: Fusarium camptoceras species complex, FIESC: Fusarium incarnatum-equiseti species complex, FCONSC: Fusarium concolor species comple.

(CBS) of the WI in Utrecht, The Netherlands. Additional isolates were also obtained from the Agricultural Research Service (NRRL) culture collection, National Center for Agricultural Utilization Research, Peoria, IL, USA.

DNA isolation, PCR and sequencing

Total genomic DNA was extracted from 7-d-old isolates grown at 24 °C on potato dextrose agar (PDA; recipe in Crous et al. 2019) using the Wizard® Genomic DNA purification Kit (Promega Corporation, Madison, WI, USA), according to the manufacturer's instructions. Partial gene sequences were determined for the calmodulin (*cmdA*), RNA polymerase second largest subunit (*rpb2*) and translation elongation factor 1-alpha (*tef1*), using PCR protocols and primer pairs described elsewhere (O'Donnell et al. 1998, 2009, 2010, Lombard et al. 2019). Integrity of the sequences was ensured by sequencing the amplicons in both directions using the same primer pairs as were used for amplification. Consensus sequences for each locus were assembled in Geneious R11 (Kearse et al. 2012). All sequences generated in this study were deposited in GenBank (Table 1).

Phylogenetic analyses

Sequences of relevant FIESC strains representing the various phylo-species were retrieved from NCBI's GenBank (Table 1) and alignments of the individual loci were determined using MAFFT v. 7.110 (Katoh et al. 2017) and manually corrected where necessary. Three independent phylogenetic algorithms, Maximum Parsimony (MP), Maximum Likelihood (ML) and Bayesian Inference (BI), were employed for phylogenetic analyses. Phylogenetic analyses were conducted of the individual loci and then as a multilocus sequence dataset that included partial sequences of the three genes determined here.

For BI and ML, the best evolutionary models for each locus were determined using MrModeltest (Nylander 2004) and incorporated into the analyses. MrBayes v. 3.2.1 (Ronquist & Huelsenbeck 2003) was used for BI to generate phylogenetic trees under optimal criteria for each locus. A Markov Chain Monte Carlo (MCMC) algorithm of four chains was initiated in parallel from a random tree topology with the heating parameter set at 0.3. The MCMC analysis lasted until the average standard deviation of split frequencies was below 0.01 with trees saved every 1 000 generations. The first 25 % of saved trees were discarded as the 'burn-in' phase and posterior probabilities (PP) were determined from the remaining trees.

The ML analyses were performed using RAxML-NG v. 0.6.0 (Kozlov et al. 2018) to obtain another measure of branch support. The robustness of the analysis was evaluated by bootstrap support (BS) with the number of bootstrap replicates automatically determined by the software. For MP, analyses were done using PAUP (Phylogenetic Analysis Using Parsimony, v. 4.0b10; Swofford 2003) with phylogenetic relationships estimated by heuristic searches with 1 000 random addition sequences. Tree-bisection-reconnection was used, with branch swapping option set on 'best trees' only. All characters were weighted equally and alignment gaps treated as fifth state. Measures calculated for parsimony included tree length (TL), consistency index (CI), retention index (RI) and rescaled consistence index (RC). Bootstrap (BS) analyses (Hillis & Bull 1993) were based on 1 000 replications. Alignments and phylogenetic trees derived from this study were uploaded to TreeBASE (S24736; www.treebase.org).

Morphological characterisation

All isolates were characterised following the protocols described by Leslie & Summerell (2006) and Lombard et al. (2019) using PDA, oatmeal agar (OA, recipe in Crous et al. 2019), synthetic nutrient-poor agar (SNA; Nirenberg 1976) and carnation leaf agar (CLA; Fisher et al. 1982). Colony morphology, pigmentation, odour and growth rates were evaluated on PDA after 7 d at 24 °C in the dark. Colour notations was done using the colour charts of Rayner (1970). Micromorphological characters were examined using water as mounting medium on a Nikon Eclipse 80*i* and/or Zeiss Axioskop 2 *plus* with Differential Interference Contrast (DIC) optics and a Nikon AZ100 stereomicroscope, all fitted with Nikon DS-Ri2 high definition colour digital cameras to photo-document fungal structures. Measurements were taken using the Nikon software NIS-elements D v. 4.50 of at least 30 fungal structures and the 95 % confidence levels were determined for the conidial measurements with extremes given in parentheses. For all other fungal structures examined, only the extremes are presented. To facilitate the comparison of relevant micro- and macroconidial features, composite photo plates were assembled from separate photographs using PhotoShop CSS.

RESULTS

Phylogenetic analyses

Approximately 500–650 bases were determined for *cmdA* and *tef1*, and 1 000 bases for *rpb2*. For the BI and ML analyses, a K80 model for *cmdA*, an HKY+G+I model for *rpb2* and an HKY+G for *tef1* were selected and incorporated into the analyses. The ML tree topology confirmed the tree topologies obtained from the BI and MP analyses, and therefore, only the ML tree is presented.

The combined three loci sequence dataset included 180 ingroup taxa with *F. concolor* (NRRL 13459) as outgroup taxon. The dataset consisted of 2 039 characters including gaps. Of these characters, 1 249 were constant, 252 parsimony-uninformative and 538 parsimony-informative. The BI lasted for 60.968M generations, and the consensus tree and posterior probabilities (PP) were calculated from 46 278 trees left after 15 242 were discarded as the 'burn-in' phase. The MP analysis yielded 1 000 trees (TL = 1 919; CI = 0.566; RI = 0.910; RC = 0.515) and a single best ML tree with -InL = -12431.078914 (Fig. 1).

In the phylogenetic tree (Fig. 1), the ingroup taxa resolved into three main clades. The first main clade (indicated as FCAMSC) is fully supported (ML & MP-BS = 100 %; PP = 1.0) and included four strains representing three lineages. Two of these represent unique single strain lineages, one of which is the ex-type of *F. kotabaruense* (InaCC F 963; Maryani et al. 2019), and the other *F. camptoceras* (CBS 193.65; Gerlach & Nirenberg 1982). The third lineage included two strains (CBS 189.60 & CBS 190.60), both of which were initially identified as *F. incarnatum*.

The second main clade is well-supported (ML-BS = 72 %, MP-BS = 76 % & PP = 1.0) representing the Equiseti clade (*F. equiseti* s.lat.; O'Donnell et al. 2009, Villani et al. 2016). This main clade is further divided into 22 fully to well-supported lineages of which eight are unique single strain lineages, representing phylo-species FIESC 1–14 & FIESC 30 (O'Donnell et al. 2009, 2012), FIESC 30 of Maryani et al. (2019) and FIESC 31 (Villani et al. 2016). Two of the eight single strain lineages (CBS 150.25 & CBS 119880, respectively) represent previously unresolved phylo-species.

The third main clade is well-supported (ML-BS = 72 %, MP-BS = 100 % & PP = 0.99) representing the Incarnatum clade (*F. incarnatum* s.lat., O'Donnell et al. 2009, Villani et al. 2016). This main clade is also further divided into 22 fully to well-supported lineages that includes four unique single strain lineages, representing phylo-species FIESC 15–29 (O'Donnell et al. 2009, 2012), FIESC 29 & 30 of Torbati et al. (2019) and

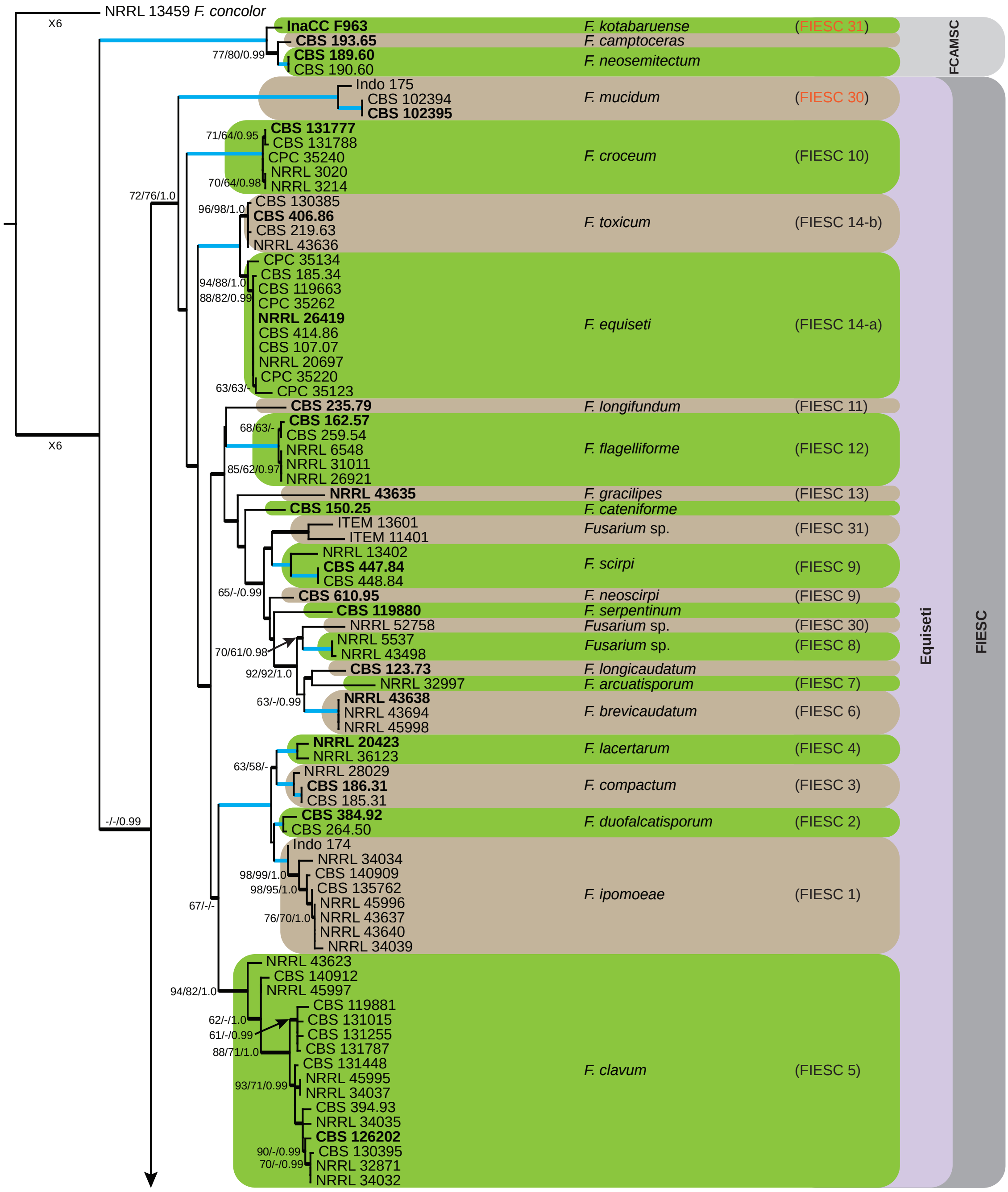


Fig. 1 The ML consensus tree inferred from the combined *cmdA*, *rpb2* and *tef1* sequence alignment. Thickened branches indicate branches present in the ML, MP and Bayesian consensus trees. Blue thickened lines indicate branches with full support (ML & MP-BS = 100 %; PP = 1.0) with support values of other branches indicated at the branches. The tree is rooted to *Fusarium concolor* (NRRL 13459). The scale bar indicates 0.05 expected changes per site. Species complexes, and the Equiseti and Incarnatum clades are indicated on the right. Phylo-species indicated in orange are those of Maryani et al. (2019), dark blue are those of Wang et al. (2019) and yellow those of Torbati et al. (2019). Ex-neotypes, ex-epitypes and ex-types indicated in **bold**.

FIESC 32 of Maryani et al. (2019). Of these, four lineages represent new phylo-species not resolved in previous studies. The phylogenetic relationships between the 44 resolved lineages are further discussed in the notes of the Taxonomy section.

TAXONOMY

In this section, Latin binomials are provided for the majority of phylo-species resolved in this study. For six phylo-species (FIESC 8, 22, 27, 30, 31 and 32; Fig. 1) no Latin binomials are provided as the strains were not available to us at the time of this study. In addition, epitypes are designated for *F. compactum*, *F. incarnatum* and *F. scirpi*, and a neotype for *F. camptoceras*.

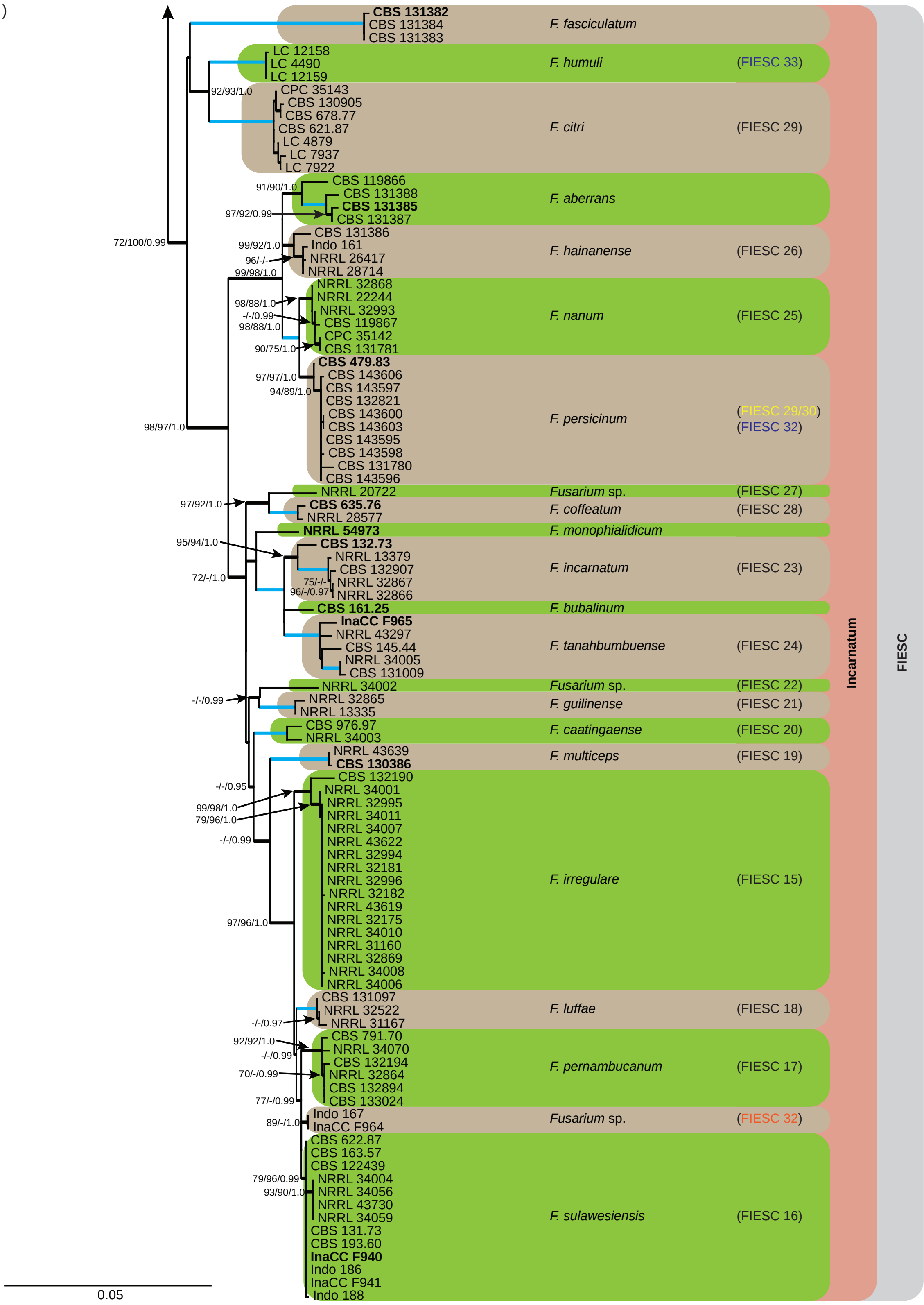
Fusarium aberrans J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831829; Fig. 2

Etymology. Name refers to the abnormal falcate conidia (aerial and sporodochial) produced by this fungus.

Typus. Australia, Northern Territories, Roper River area, from *Oryza australiensis* stem, Apr. 2009, *T. Petrovic* (holotype CBS H-24050 designated here, culture ex-type CBS 131385).

Conidiophores borne on aerial mycelium, 16–110 μm tall, unbranched, sympodial or irregularly branched, bearing terminal or lateral phialides, often reduced to single phialides; *aerial phialides* mono- and polyphialidic, subulate to subcylindrical, sometimes proliferating percurrently, smooth- and thin-walled, 5–30 × 2–4 μm, with inconspicuous periclinal thickening; *aerial conidia* hyaline, falcate, curved dorsiventrally, tapering towards

Fig. 1 (cont.)



both ends, with a blunt and straight to slightly curved apical cell and blunt to barely notched basal cell, smooth- and thin-walled, (1–)3–5-septate; 1-septate conidia: 14–24 × 3–4 µm (av. 21 × 3 µm, *n* = 5); 2-septate conidia: 20–38 × 3–5 µm (av. 27 × 3 µm, *n* = 5); 3-septate conidia: (23–)30–40(–51) × 3–5 µm (av. 35 × 4 µm); 4-septate conidia: (35–)37–43(–45) × 4–5 µm (av. 40 × 4 µm); 5-septate conidia: (37–)39–47(–54) × 4–5 µm (av. 43 × 4 µm). *Sporodochia* saffron to pale brown, formed abundantly on surface of medium. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; sporodochial phialides monophialidic, subulate to subcylindrical, 8–15 × 2–4 µm, smooth, thin-walled, with inconspicuous periclinal thickening; *sporodochial conidia* falcate, slightly curved dorsiventrally to almost straight, tapering towards both ends, with a conical, straight to slightly curved apical cell and a blunt to foot-like basal cell, (1–)3-septate, hyaline, smooth- and thin-walled; 1-septate conidia: 22–26 × 2.5–3.5 µm (av. 24 × 3 µm, *n* = 8); 2-septate conidia: 21–28 × 3–4 µm (av. 25 × 3 µm, *n* = 5); 3-septate conidia: (25–)29–35(–39) × 3–4 µm (av. 32 × 4 µm). *Chlamydospores* not observed.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 7–9

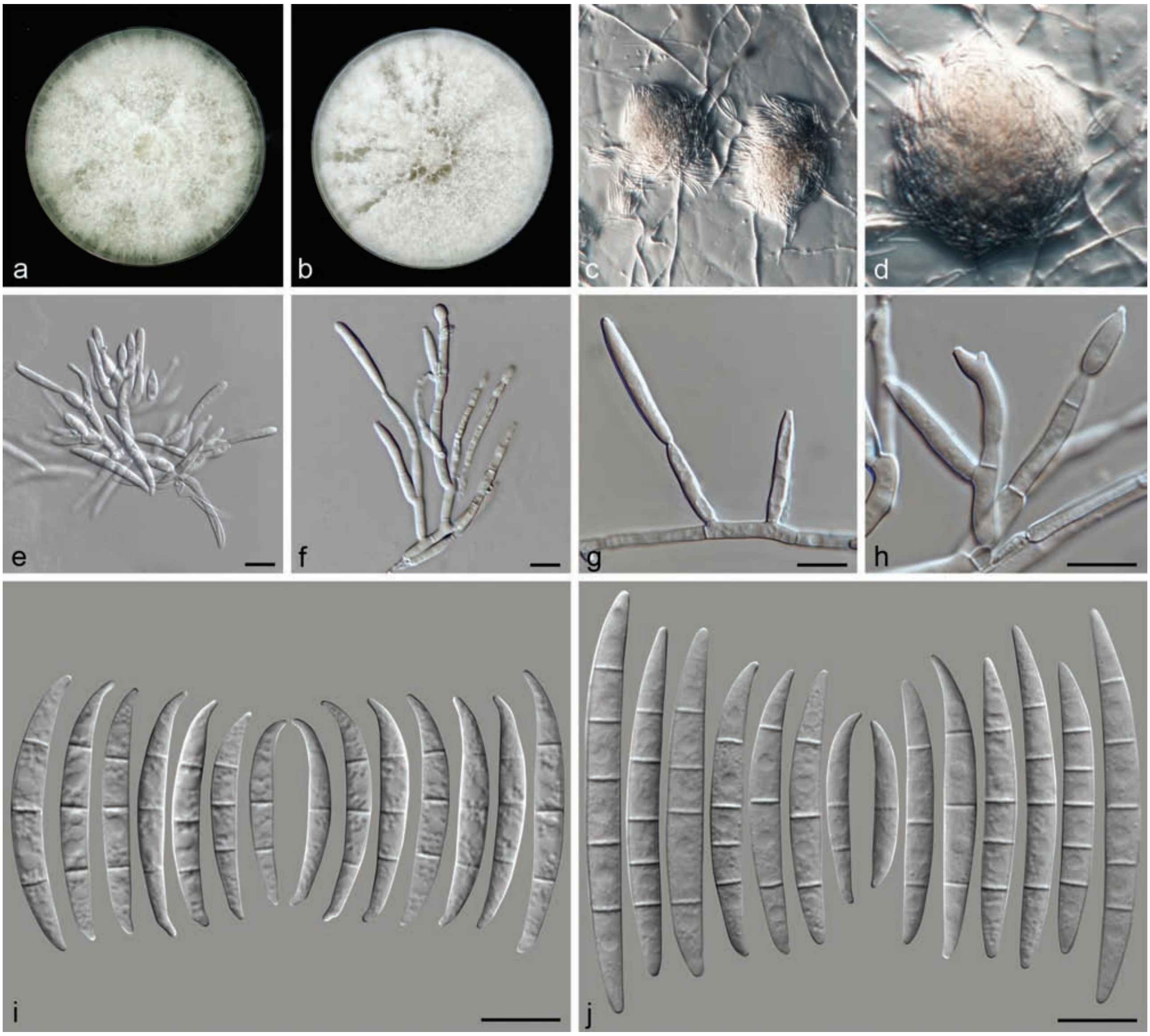


Fig. 2 *Fusarium abberans* (CBS 131385, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on media surface; e. sporodochial conidiophores; f. conidiophores on aerial mycelium; g. lateral monophialides on aerial mycelium; h. mono- and polyphialides on aerial mycelium; i. falcate aerial conidia; j. sporodochial conidia. — Scale bars = 10 µm.

mm/d and occupying an entire 90 mm Petri dish in 7 d; surface white, floccose, radiate, with abundant aerial mycelium, margin irregular, lobate, serrate or filiform. Odour absent. Reverse pale yellow to yellow with yellow diffusible pigments visible in the medium. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface white, floccose, radiate, with abundant aerial mycelium, margin irregular, lobate, serrate or filiform. Reverse straw to pale luteous, without diffusible pigments. On SNA with sparse aerial mycelium, sporulation abundant on the surface of the medium.

Additional materials examined. Australia, Northern Territories, Roper River area, from *Oryza australiensis* stem, Apr. 2009, *T. Petrovic*, CBS 131387; ibid., CBS 131388. – Niger, from sorghum malt, 1992, *A. Lübben*, CBS 119866 = MRC 6715.

Notes — *Fusarium aberrans* represents a well-supported novel lineage (ML-BS = 91 %, MP-BS = 90 %, PP = 1.0) in the Incarnatum clade, closely related to *F. hainanensis*, *F. nanum* and *F. persicinum*. This species readily produces sporodochia in culture distinguishing it from *F. hainanense*, *F. nanum* (Wang et al. 2019) and *F. persicinum*. Furthermore, *F. nanum* produces obovoid aerial conidia in culture (Wang et al. 2019), not seen in *F. aberrans*. All isolates included in this clade appear to be associated with cereals in the Southern Hemisphere.

Fusarium arcuatisporum M.M. Wang et al., Persoonia 43: 78. 2019.

Typus. China, Hubei province, from pollen of *Brassica campestris*, Mar. 2016, *Y.Z. Zhao* (holotype HAMS 248034, culture ex-type CGMCC3.19493 = LC12147).

Descriptions & Illustrations — Wang et al. (2019).

Notes — *Fusarium arcuatisporum* represents phylo-species FIESC 7 in the Equiseti clade (O'Donnell et al. 2009, Wang et al. 2019), resolved as a single strain lineage closely related to *F. brevicaudatum* (FIESC 6) and *F. longicaudatum*. Aerial conidiophores and aerial conidia are absent in these three species (Wang et al. 2019). Wang et al. (2019) only reported 5-septate sporodochial conidia (i.e., macroconidia) produced by *F. arcuatisporum*, whereas those of *F. brevicaudatum* and *F. longicaudatum* are 1–5-septate and (3–)5–6(–7)-septate, respectively. Additionally, the 5-septate sporodochial conidia of *F. arcuatisporum* (29–49.5 × 4–6 µm; Wang et al. 2019) are significantly smaller than those of *F. brevicaudatum* ((31–)43–59(–64) × 4–5 µm) and *F. longicaudatum* ((48–)62–76(–82) × 4–5 µm).

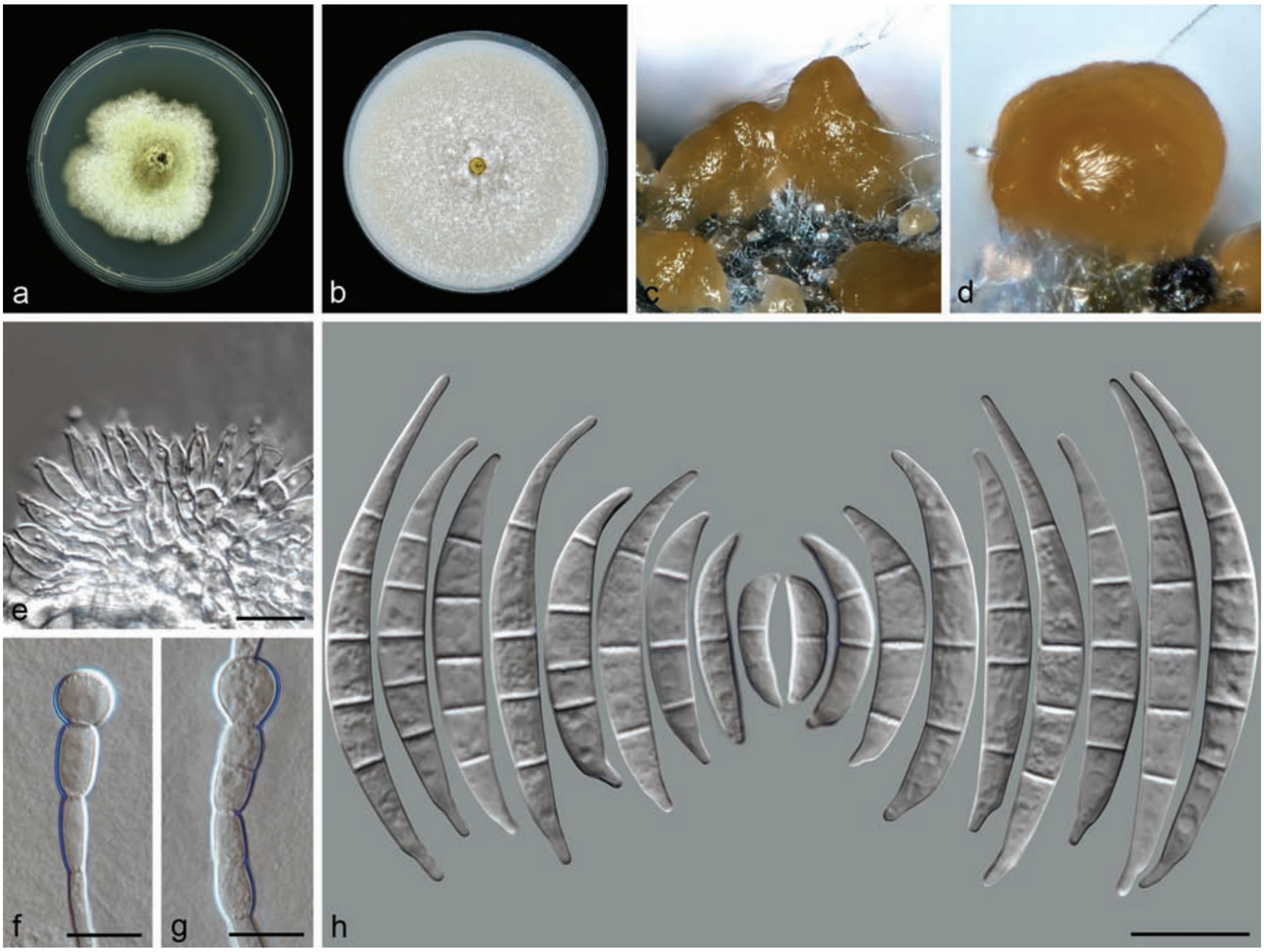


Fig. 3 *Fusarium brevicaudatum* (NRRL 43638, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on carnation leaves; e. sporodochial conidiophores; f–g. chlamydospores; h. sporodochial conidia. — Scale bars = 10 µm.

Fusarium brevicaudatum J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831830; Fig. 3

Etymology. Name refers to the short tail-like apical cells of the sporodochial conidia produced by this fungus.

Typus. USA, Florida, from *Trichechus* sp. (manatee), date and collector unknown (holotype CBS H-24051 designated here, culture ex-type NRRL 43638 = UTHSC R-3500).

Conidiophores and *aerial conidia* borne on aerial mycelium not observed. *Sporodochia* salmon to saffron, formed abundantly on carnation leaves. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, 9–12 × 2–4 µm, smooth, thin-walled, with a short-flared apical collarette. *Sporodochial conidia* falcate, slender, curved dorsiventrally, tapering towards both ends, with a short to slightly elongated or whip-like straight to curved apical cell and a barely notched to prominently extended basal cell, 1–5-septate, hyaline, thin- and smooth-walled;1-septate conidia: (8–)12–16(–21) × 3–4 µm (av. 14 × 4 µm); 2-septate conidia: (12–)13–19(–21) × 3–4 µm (av. 16 × 4 µm, *n* = 15); 3-septate conidia: (19–)25–35(–40) × 4–5 µm (av. 30 × 4 µm); 4-septate conidia: (29–)32–48(–54) × 3–5 µm (av. 40 × 4 µm); 5-septate conidia: (31–)43–59(–64) × 4–5 µm (av. 51 × 4 µm). *Chlamydospores* rare, globose, subglobose to oval, subhyaline, smooth-walled, terminal or intercalary, solitary, in pairs or forming chains, 4–10 µm diam.

Culture characteristics — Colonies on PDA incubated at 25 °C in the dark with an average radial growth rate of 3–7 mm/d and reaching 50–58 mm diam in 7 d; surface white to luteous, flat, felty to velvety, radiate, with aerial mycelium, margin irregular, filiform. Odour mouldy. Reverse salmon to apricot. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface white to salmon, felty to velvety, aerial mycelium floccose, margin irregular, filiform. Reverse pale salmon. On SNA with sparse aerial mycelium.

Additional materials examined. USA, Texas, from human eye, date and collector unknown, NRRL 43694 = CDC 2006743607; from human toe, date and collector unknown, NRRL 45998 = UTHSC 06-2315.

Notes — *Fusarium brevicaudatum* represents phylo-species FIESC 6 in the Equiseti clade as designated by O'Donnell et al. (2009) forming a fully supported clade (ML & MP-BS = 100 %, PP = 1.0) sister to *F. arcuatisporum* and *F. longicaudatum*. This species produced characteristic 1- and 2-septate sporodochial conidia, not seen for *F. arcuatisporum* and *F. longicaudatum*, which are reminiscent of aerial conidia (i.e., microconidia), although no conidiophores or aerial conidia could be found on the aerial mycelium formed on the various media used in this study. This feature could represent an ecological adaptation as all isolates included in this study originated from clinical and veterinarian samples associated with superficial mycoses (O'Donnell et al. 2009). However, this requires further investigation.

Fusarium bubalinum J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank 831831; Fig. 4

Etymology. Name refers to buff-coloured colonies formed on PDA by this fungus.

Typus. Australia, unknown substrate and date, *H.W. Wollenweber* (holotype CBS H-24052 designated here, culture ex-type CBS 161.25 = NRRL 26857 = NRRL 26918).

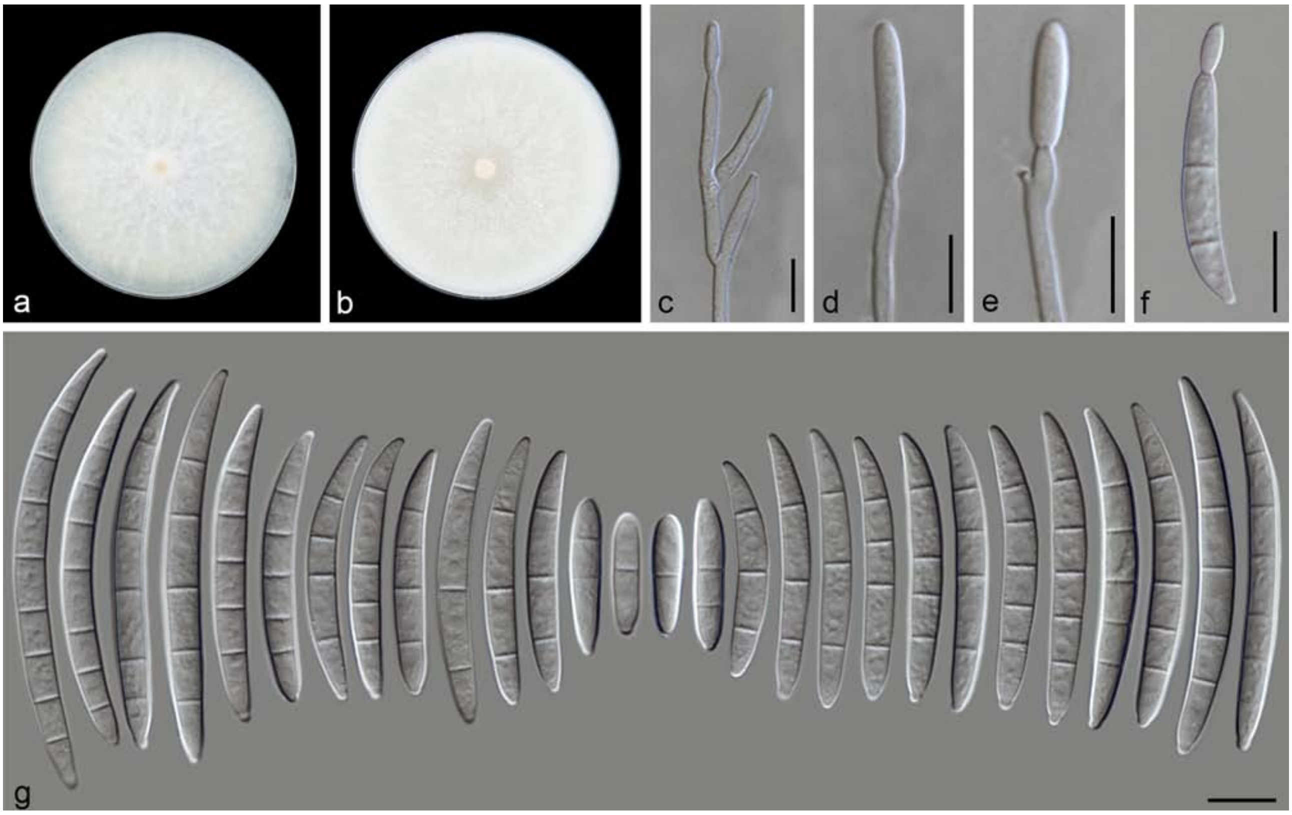


Fig. 4 *Fusarium bubalinum* (CBS 161.25, ex-type culture). a. Colony on PDA; b. colony on OA; c. conidiophore on aerial mycelium; d. monophialide; e. polyphialide; f. microcyclic conidiation; g. ellipsoidal to falcate aerial conidia. — Scale bars = 10 μm.

Conidiophores borne on aerial mycelium, 50–90 μm tall, unbranched, sympodial or irregularly branched, bearing terminal or lateral phialides, often reduced to single phialides; *phialides* mono- and polyphialidic, subulate to subcylindrical, proliferating percurrently, smooth- and thin-walled, 3–31 × 2–4 μm, with inconspicuous periclinal thickening; *aerial conidia* hyaline, rarely ellipsoidal to falcate, slender, curved dorsiventrally and more pronounced on the apical half, tapering towards both ends, with a blunt to conical and straight to slightly curved apical cell and a blunt to papillate basal cell, (1–)3–5(–8)-septate, microcyclic conidiogenesis commonly observed; 1-septate conidia: (16–)18–22(–25) × 3–5 μm (av. 20 × 4 μm, *n* = 16); 2-septate conidia: 22–26(–29) × 3–5 μm (av. 24 × 4 μm, *n* = 11); 3-septate conidia: (24–)32–42(–51) × 4–5 μm (av. 37 × 4 μm); 4-septate conidia: (36–)38–44(–48) × 4–6 μm (av. 41 × 5 μm); 5-septate conidia: (38–)43–53(–58) × 4–6 μm (av. 48 × 5 μm); 6-septate conidia: (47–)48–62(–71) × 4–5 μm (av. 55 × 5 μm, *n* = 7); 7-septate conidia: (54–)60–76 × 4–5 μm (av. 68 × 5 μm, *n* = 5); 8-septate conidia: 61–67 × 4–5 μm (*n* = 2). *Sporodochia* and *chlamydospores* not observed.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 6–10 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface white to buff, floccose, radiate, with moderate aerial mycelium, margin irregular, filiform. Odour mouldy. Reverse primrose. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface pale primrose, flat, membranous to dust, aerial mycelium sparse, margin irregular, filiform. Reverse pale primrose, without diffusible pigments. On SNA with sparse aerial mycelium and abundant sporulation on the surface of the medium.

Notes — *Fusarium bubalinum* represents a new single strain lineage resolved in the Incarnatum clade, closely related to *F. incarnatum*, *F. monophialidicum* and *F. tanahbumbuense*. This species can be distinguished from the latter three by the commonly observed microcyclic conidiogenesis and the formation of (1–)3–5(–8)-septate falcate aerial conidia compared to the (1–)3–5(–7)-septate falcate aerial conidia of *F. incarnatum*, (1–)3–5-septate falcate aerial conidia of *F. monophialidicum* and 3–5-septate falcate aerial conidia of *F. tanahbumbuense* (Maryani et al. 2019). Furthermore, *F. bubalinum* and *F. monophialidicum* did not produce any sporodochia on carnation leaves, whereas *F. incarnatum* and *F. tanahbumbuense* produce abundant sporodochia on carnation leaves.

Fusarium caatingaense A.C.S. Santos et al., Mycologia 111: 248. 2019

Typus. Brazil, Pernambuco, Ibimirim, from *Dactylopius opuntiae*, July 2011, *P.V. Tiago* (holotype URM 91192, culture ex-type culture MUM 1859 = URM 6779).

Additional materials examined. USA, Hawaii, from *Juniper chinensis* leaf, date unknown, *W.H. Ko*, CBS 976.97; Texas, from human sputum, 1995, *J. Swezey*, CBS 130317 = NRRL 34003 = UTHSC 95-28.

Notes — Santos et al. (2019) introduced the Latin binomial *F. caatingaense* to represent phylo-species FIESC 20, which formed a distinct fully supported clade (ML & MP-BS = 100 %, PP = 1.0) in this study. This species was shown to have a heterothallic mating system, producing typical gibberella-like perithecia exuding viable ascospores. This species is also characterised by the various shapes of aerial conidia (up to four) produced in culture (Santos et al. 2019).

Fusarium camptoceras Wollenw. & Reinking, Phytopathology 15: 158. 1925

Typus. Costa Rica, on cushion gall of *Theobroma cacao*, 1963, *W. Gerlach* (neotype CBS H-24077 designated here, ex-neotype culture CBS 193.65; MBT 387942).

Descriptions & Illustrations — Wollenweber & Reinking (1925), Reinking & Wolleweber (1927), Gerlach & Nirenberg (1982), Marasas et al. (1998).

Notes — Gerlach & Nirenberg (1982) studied isolate CBS 193.65 and considered it a good representative of *F. camptoceras*, providing illustrations that match the original description provided by Wollenweber & Reinking (1925), and drawings and description from the type isolate (R42; Wollenweber & Reinking 1925) later published in Reinking & Wollenweber (1927). Marasas et al. (1998) also studied isolate CBS 193.65 and provided an emended description of *F. camptoceras* that included the presence of pedicellate sporodochial conidia (i.e., macroconidia) and mesoconidia produced on polyphialides on the aerial mycelium. Therefore, CBS 193.65 is designated as ex-neotype to stabilise the taxonomic position of this species. Phylogenetic inference in this study placed the ex-neotype of *F. camptoceras* in a fully supported clade (ML & MP-BS = 100 %; PP = 1.0), that includes *F. kotabaruense* and *F. neosemitectum*, forming a distinct monophyletic species complex which is designated as the *F. camptoceras* species complex (FCAMSC) here. The falcate aerial conidia of *F. camptoceras* ((0–)3–4(–7)-septate, 15–51 × 4–7 µm overall; Marasas et al. 1998) are slightly larger than those of *F. kotabaruense* ((2–)3–5(–7)-septate, 21–45 × 5–7.5 µm overall; Maryani et al. 2019) and *F. neosemitectum* ((1–)2–4(–5)-septate, 17–41 × 3–6 µm overall). Additionally, *F. camptoceras* also produces ellipsoidal to obovoid aerial conidia and sporodochia (Marasas et al. 1998), neither observed in culture for *F. kotabaruense* (Maryani et al. 2019) nor *F. neosemitectum*.

Fusarium cateniforme J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831832; Fig. 5

Etymology. Name refers to the long chains of chlamydospores formed in culture.

Typus. Unknown locality and substrate, 1925, *H.W. Wollenweber* (holotype CBS H-24053 designated here, culture ex-type CBS 150.25 = ATCC 11853).

Conidiophores and *aerial conidia* borne on aerial mycelium not observed. *Sporodochia* brown to dark brown. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, doliiform, subulate to subcylindrical, 7–11 × 3–5 µm, smooth, thin-walled, with a short-flared apical collarette. *Sporodochial conidia* falcate, sometimes become sinuate, slender, markedly curved dorsiventrally, tapering towards both ends, with a elongate or whip-like, often curved or sinuate apical cell and an elongated foot-like basal cell, 3–6(–8)-septate, hyaline,

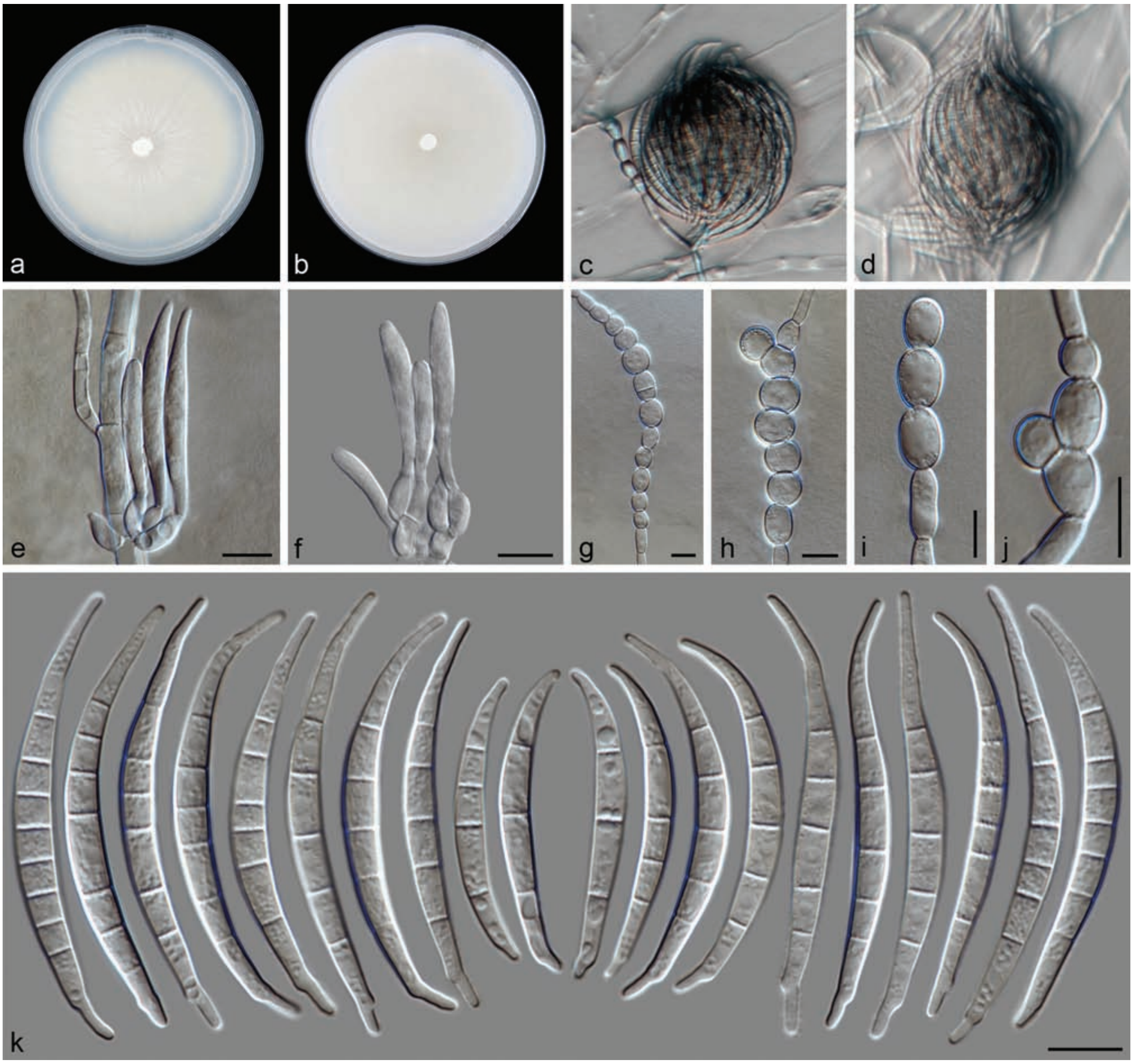


Fig. 5 *Fusarium cateniforme* (CBS 150.25, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on media surface; e–f. sporodochial conidiophores; g–j. chlamydospores; k. sporodochial conidia. — Scale bars = 10 µm.

thin- and smooth-walled; 3-septate conidia: (29–)35–43(–47) × 3–5 µm (av. 39 × 4 µm); 4-septate conidia: (39–)41–47(–52) × 4–5 µm (av. 44 × 4 µm); 5-septate conidia: (42–)50–60(–67) × 4–5 µm (av. 55 × 5 µm); 6-septate conidia: (54–)59–65(–66) × 4–5 µm (av. 62 × 5 µm); 7-septate conidia: 60–62 × 5–6 µm (av. 62 × 5 µm, *n* = 3); 8-septate conidia: 65 × 5 µm (*n* = 1). *Chlamydospores* abundant, globose, subglobose to oval, subhyaline, smooth-walled, terminal or intercalary, solitary, in pairs or forming long chains, 5–13 µm diam.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 6–9 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface pale salmon, flat, radiate, aerial mycelium sparse, margin irregular, filiform. Odour mouldy. Reverse pale straw. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface pale primrose, flat, membranous, aerial mycelium scant or absent, margin irregular, filiform. Reverse pale primrose, without diffusible pigments. On SNA with sparse aerial mycelium.

Notes — *Fusarium cateniforme* represents a novel single strain lineage resolved in this study. This species is characterised by the formation of abundant long chains of chlamydospores in culture. Also, characteristic is the lack of conidiophores and conidia formed on the aerial mycelium in culture, a feature shared with the phylogenetic close relatives *F. flagelliforme*, *F. gracilipes* and *F. longifundum*. The sporodochial conidia of *F. cateniforme* (3–6(–8)-septate, 29–67 × 3–5 µm overall) are smaller than those of *F. flagelliforme* ((3–)4–5(–6)-septate, 37–85 × 3–5 µm overall), *F. gracilipes* ((3–)5(–6)-septate, 40–84 × 4–5 µm overall) and *F. longifundum* ((3–)5(–6)-septate, 21–76 × 3–5 µm overall).

Fusarium citri M.M. Wang et al., Persoonia 43: 79. 2019

Typus. China, Hunan province, from leaf of *Citrus reticulata*, Sept. 2015, *X. Zhou* (holotype HAMS 248036, culture ex-type CGMCC3.19467 = LC6896).

Description & Illustration — Wang et al. (2019).

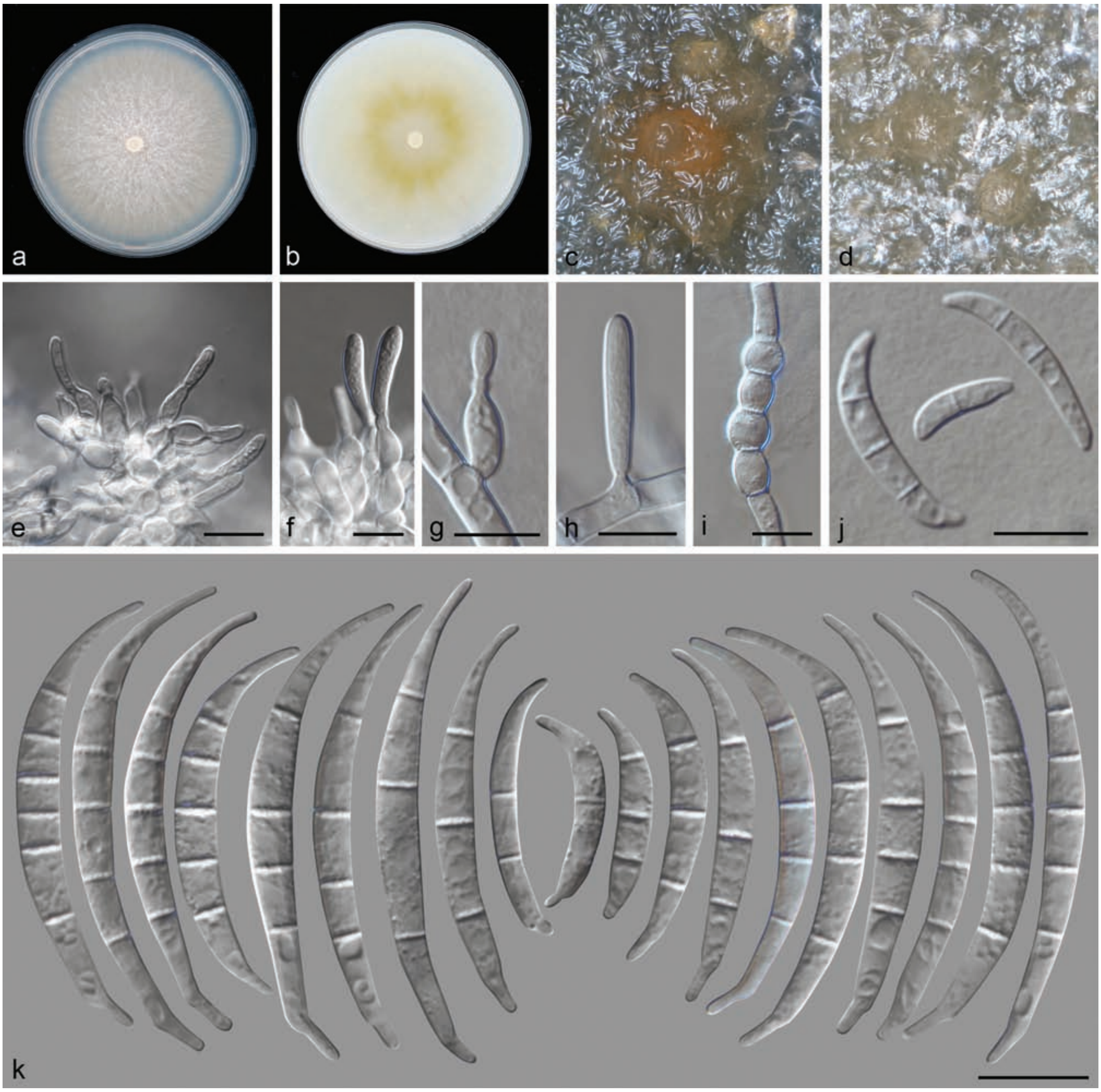


Fig. 6 *Fusarium clavum* (CBS 126202, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on media surface; e–f. sporodochial conidiophores; g. lateral monophialides on aerial mycelium; h. lateral phialidic peg on aerial mycelium; i. chlamydospores; j. falcate aerial conidia; k. sporodochial conidia. — Scale bars = 10 µm.

Additional materials examined. Czech Republic, Olomouc, from *Lactuca sativa*, 1983, *J. Rod*, CPC 35143 = CCF 1881. – Denmark, from *Medicago sativa*, 6 Mar. 1986, *K. Hermansen*, CBS 621.87. – Iran, Babak, Bilesovar, from *Triticum* sp., Apr. 2010, *M. Davari*, CBS 130905. – Japan, Mie, Tsu City, from cultivated soil, Oct. 1964, *T. Matsushima*, CBS 678.77.

Notes — *Fusarium citri* represents phylo-species FIESC 29 (O'Donnell et al. 2012), resolved here as a fully supported clade (ML & MP-BS = 100 %; PP = 1.0). This species is closely related to *F. fasciculatum* and *F. humuli* (see notes under *F. fasciculatum* and Wang et al. 2019 for morphological differences).

Fusarium clavum J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831833; Fig. 6

Etymology. Name refers to the lateral phialidic pegs borne on the aerial mycelium by this fungus.

Typus. Namibia, northern Karoo, 30 km west of Maltahohe, from desert soil, Apr. 2001, *M. Christensen* (holotype CBS H-24054 designated here, culture ex-type CBS 126202).

Conidiophores borne on aerial mycelium rarely seen, 6–13 µm tall, unbranched, reduced to lateral phialidic pegs or single lateral monophialides, obpyriform to lageniform, smooth- and thin-walled, with inconspicuous periclinal thickening; *aerial conidia* hyaline, smooth- and thin-walled, falcate, gently dorsiventrally curved with a blunt apical cell and barely notched basal cell, 1–2(–3)-septate; 1-septate conidia: 13–26(–31) × 3–4 µm (av. 19 × 3 µm, *n* = 6); 2-septate conidia: (19–)21–29(–30) × 3–4 µm (av. 25 × 3 µm, *n* = 5); 3-septate conidia: 25 × 4 µm (*n* = 1). *Sporodochia* salmon to orange, formed abundantly on carnation leaves. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, sometimes proliferating percurrently, 6–9 × 3–5 µm, smooth, thin-walled, with a short-flared apical collarette. *Sporodochial conidia* falcate, slender, curved dorsiventrally, tapering towards both ends, with elongated or whip-like curved apical cells and a barely notched to prominently extended basal cells, 3–5(–6)-septate, hyaline, thin- and smooth-walled; 3-septate conidia: (20–)29–39(–47) × 3–4 µm (av. 34 × 4 µm); 4-septate conidia: (33–)38–46(–53) × 3–5 µm (av. 42 × 4 µm); 5-septate conidia: (38–)42–50(–56) × 4–5 µm (av. 46 × 4 µm); 6-septate conidia: 45–50 × 4–5 µm (*n* = 2). *Chlamydospores* abundant, globose, subglobose to oval, subhyaline, smooth-walled, terminal or intercalary, solitary, in pairs or forming chains, 4–11 µm diam.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 7–10 mm/d and occupying an entire 90 mm Petri dish in 6 d; surface salmon to saffron, flat, felty to velvety, radiate, with aerial mycelium, margin irregular, filiform. Odour mouldy. Reverse pale salmon. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface sulphur yellow to straw with yellow ring near the centre, flat, membranous, aerial mycelium scant or absent, margin entire. Reverse sulphur yellow to saffron, with saffron pigments form ring near the centre. On SNA with sparse aerial mycelium, sporulation moderate on the surface of the medium.

Additional materials examined. Germany, from *Disphyma crassifolium* seed, 1982, *H. Nirenberg*, CBS 394.93 = BBA 64265 = NRRL 25795. – Iran, Aziz abad, Bilesovar, from *Phalaris minor*, date unknown, *M. Davari*, CBS 131015; Gonbad, Golestan, from *Triticum* sp., date unknown, *M. Davari*, CBS 131787; Paragheshlagh, Parsabad, from *Leucopoa sclerophylla*, date unknown, *M. Davari*, CBS 131255; from *Secale montanum*, date unknown, *M. Davari*, CBS 131448. – Russia, Adygea, from potato leaf, 2008, *T.Yu. Gagkaeva*, CBS 140912. – Unknown locality, substrate and date, *W.F.O. Marasas*, CBS 119881 = MRC 8412. – USA, Texas, from human abscess, date unknown, *J. Swezey*, CBS 130395 = NRRL 34032 = UTHSC 98-2172.

Notes — *Fusarium clavum* represents phylo-species FIESC 5 (O'Donnell et al. 2009) resolved as a well-supported clade (ML-BS = 94 %, MP-BS = 82 %, PP = 1.0) in the Equiseti clade, closely related to *F. compactum*, *F. duofalcatisporum*, *F. ipomoeae* and *F. lacertarum*. All five of these species produce only falcate aerial conidia (Gerlach & Nirenberg 1982, Subrahmanyam 1983, Leslie & Summerbell 2006, Wang et al. 2019), a feature apparently unique to this phylogenetic group. *Fusarium clavum* forms abundant lateral phialidic pegs on the aerial mycelia, a characteristic shared with *F. duofalcatisporum*, but not known for *F. compactum*, *F. ipomoeae* and *F. lacertarum* (Gerlach & Nirenberg 1982, Subrahmanyam 1983, Leslie & Summerbell 2006, Wang et al. 2019). However, the falcate aerial conidia of *F. clavum* (1–2(–3)-septate; 13–30 × 3–4 µm overall) are smaller than those of *F. duofalcatisporum* (1–3(–4)-septate; 13–40 × 2–5 µm overall). Isolates of *F. clavum* included in this study were obtained from environmental, plant and human samples collected in Africa, Asia, Europe and North America, indicative of a broad distribution.

Fusarium coffeatum L. Lombard & Crous, Fungal Syst. Evol. 5: 191. 2019 — Fig. 7

Synonym. *Fusarium chlamydosporum* var. *fuscum* Gerlach, Phytopathol. Z. 90: 41. 1977.

Typus. New Zealand, Palmerston North, from *Cynodon lemfuensis* imported from South Africa, Nov. 1973, *C.A.F. Jaques* (isotype CBS H-631, culture ex-type CBS 635.76 = BBA 62053).

Descriptions & Illustrations — Gerlach (1977), Gerlach & Nirenberg (1982).

Additional materials examined. Romania, Mangalia, from grave stone, date unknown, *O. Constantinescu*, CBS 430.81 = NRRL 28577.

Notes — *Fusarium coffeatum* was elevated to species level and linked to phylo-species FIESC 28 based on phylogenetic inference by Lombard et al. (2019). Gerlach (1977) and Gerlach & Nirenberg (1982) initially treated this species as a variety of *F. chlamydosporum* based on morphological similarities, but distinguished them based on colony pigmentation. The ex-type strain (CBS 635.76) of *F. coffeatum* clustered within a fully supported subclade (ML & MP-BS = 100 %; PP = 1.0) in the Incarnatum clade. Unfortunately, the ex-type strain has become degenerate over time (Fig. 11) and no longer produces the beige to coffee-brown pigments in culture, and no sporodochia were observed on CLA.

Fusarium compactum (Wollenw.) Raillo, Fungi of the genus Fusarium: 180. 1950

Basionym. *Fusarium scirpi* var. *compactum* Wollenw., Fus. Autogr. Del. 3: no. 924. 1930.

Synonym. *Fusarium compactum* (Wollenw.) W.L. Gordon, Canad. J. Bot. 30: 224. 1952.

Typus. England, Kew, from cotton yarn, Aug. 1926, *S.J. Ashby* (Wollenweber (1916–1935), lectotype of *Fusarium scirpi* var. *compactum* designated here, MBT387945, as illustration in Wollenweber's Fusaria Autographice Delineata 3: no. 924. 1930). – England, Kew, from cotton yarn, 1926, deposited by *H.W. Wollenweber* (epitype of *Fusarium scirpi* var. *compactum* designated here, specimen and culture CBS 186.31, maintained as metabolically inactive; MBT387946).

Descriptions & Illustrations — Wollenweber (1916–1935, no. 924), Gerlach & Nirenberg (1982), Leslie & Summerell (2006).

Additional material examined. Unknown locality, substrate, date and collector, CBS 185.31.

Notes — Based on phylogenetic inference in this study, *F. compactum* represents phylo-species FIESC 3 (O'Donnell et al. 2009), forming a fully supported clade (ML & MP-BS =

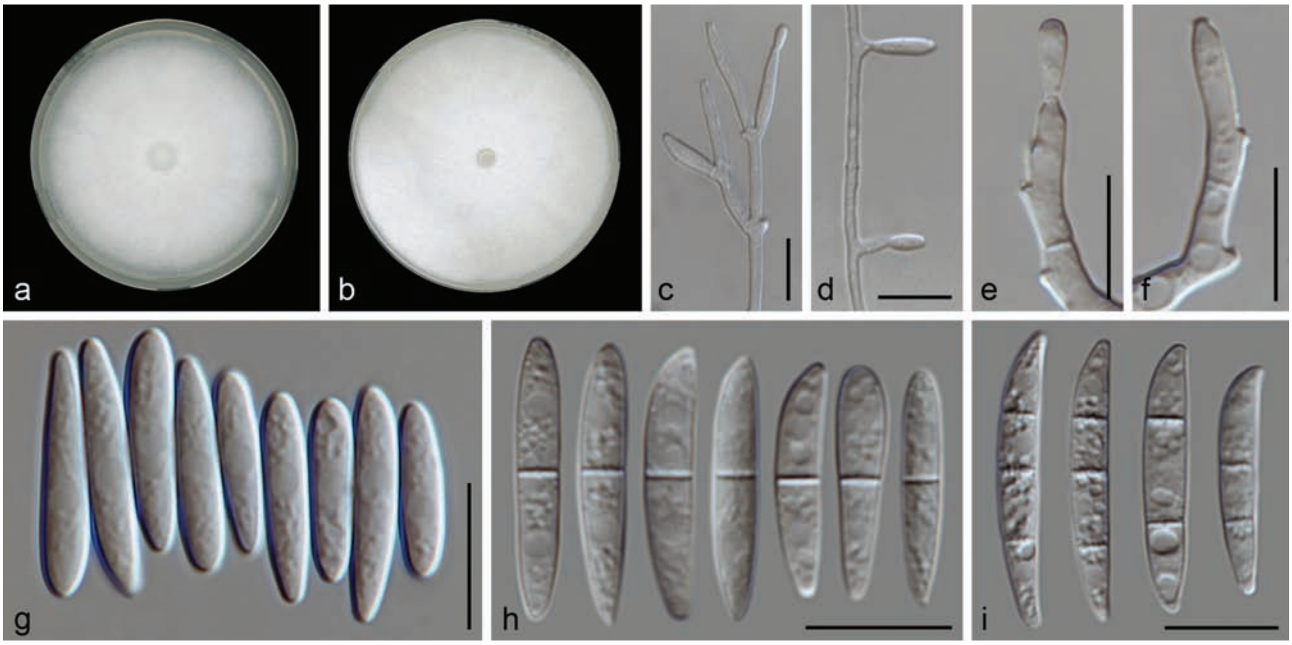


Fig. 7 *Fusarium coffeatum* (CBS 635.76, ex-type culture). a. Colony on PDA; b. colony on OA; c. conidiophore on aerial mycelium with monophialides; d. lateral phialidic pegs on aerial mycelium; e–f. polyphialidic phialides; g–i. aerial conidia. — Scale bars = 10 μm.

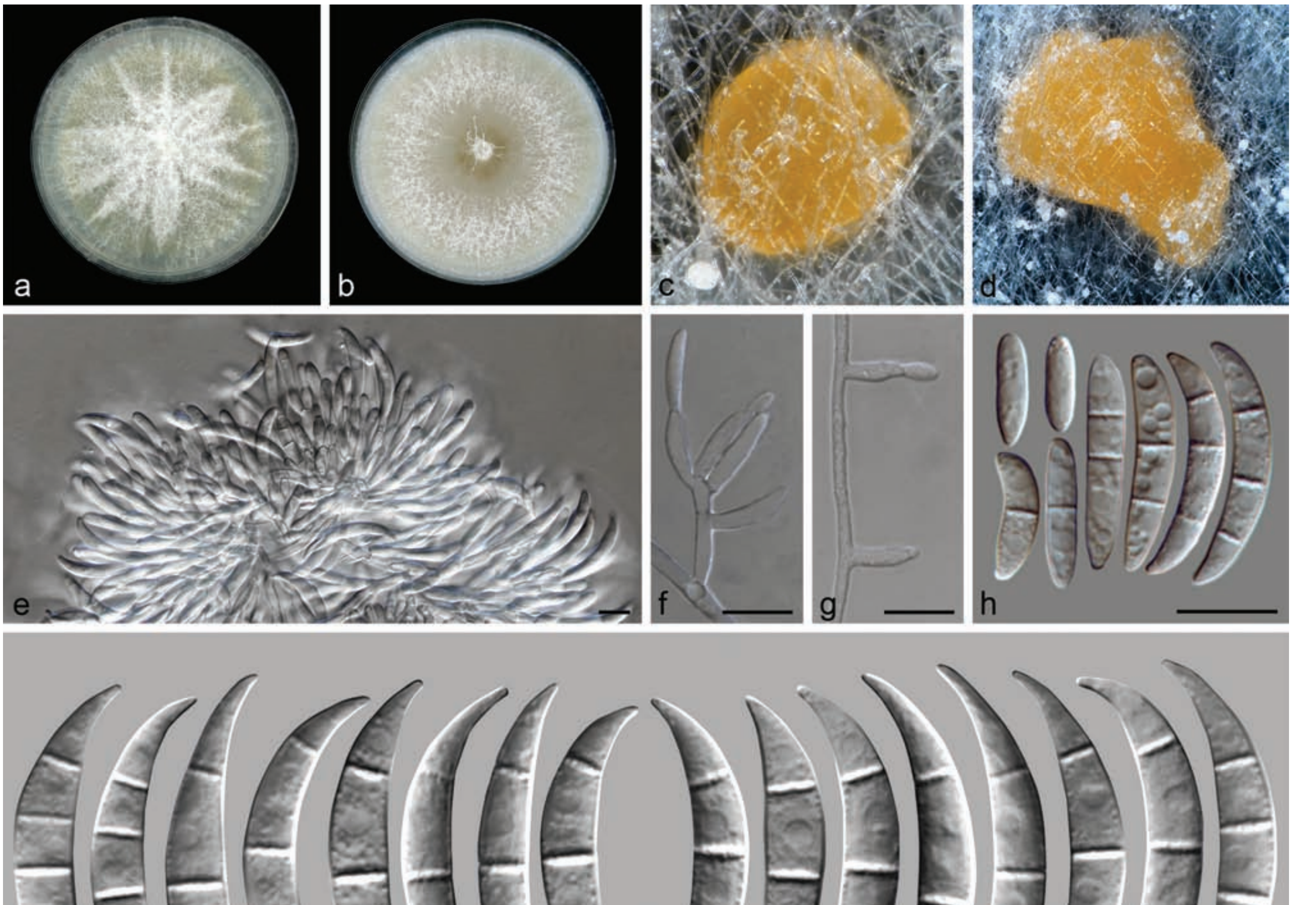


Fig. 8 *Fusarium croceum* (CBS 131777, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on carnation leaves; e. sporodochial conidiophores; f. conidiophore on aerial mycelium; g. lateral monophialides on aerial mycelium; h. aerial conidia; i. sporodochial conidia. — Scale bars = 10 μm.

100 %; PP = 1.0), closely related to *F. clavum*, *F. duofalcatisporum*, *F. ipomoeae* and *F. lacertarum*. To stabilise the species concept of *F. compactum*, we epitypify this species based on isolate (CBS 186.31 = NRRL 36323) that has the same locality, substrate and date of collection as indicated in Wollenweber's Fusaria Autographice Delineata 3: no. 924 (1930). Although CBS 186.31 might represent the true ex-type of *F. compactum*, no definite record could be located to confirm this. Wang et al. (2019) also considered NRRL 36323 (= CBS 186.31) as good representative strain of *F. compactum*.

Fusarium croceum J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831834; Fig. 8

Etymology. Name refers to the orange-coloured sporodochia produced by this fungus.

Typus. Iran, Golestan, Gonbad, from *Triticum* sp., 2013, *M. Davari* (holotype CBS H-24055 designated here, culture ex-type CBS 131777).

Conidiophores borne on aerial mycelium, 30–60 μm tall, unbranched, sympodial or irregularly branched, bearing terminal or lateral phialides, mostly reduced to single lateral phialides borne on aerial mycelium; *aerial phialides* monophialidic, rarely polyphialidic, subulate to subcylindrical, proliferating percurrently, smooth- and thin-walled, 6–24 × 2–4 μm, with inconspicuous periclinal thickening; *aerial conidia* hyaline, smooth- and thin-walled, of two types: (a) ellipsoidal to fusiform, 0–1-septate; 0-septate conidia: (7–)8–12(–14) × 2–3 μm (av. 10 × 3 μm); 1-septate conidia: (10–)12–16(–17) × 3–4 μm (av. 14 × 3 μm); (b) falcate, gently dorsiventrally curved with a blunt apical cell and barely notched basal cell, 1–3-septate; 1-septate conidia: (11–)14–20(–24) × 3–4 μm (av. 17 × 3 μm); 2-septate conidia: (16–)17–21(–22) × 3–4 μm (av. 19 × 3 μm); 3-septate conidia: (18–)22–28(–30) × 3–4 μm (av. 25 × 3 μm). *Sporodochia* orange, formed abundantly on carnation leaves. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, 8–13 × 3–4 μm, smooth, thin-walled, with inconspicuous periclinal thickening; *sporodochial conidia* falcate, curved dorsiventrally, tapering towards both ends, with a conical and curved apical cell and a blunt to foot-like basal cell, (1–)3–5-septate, hyaline, smooth- and thin-walled; 1-septate conidia: 15–21(–24) × 3–4 μm (av. 18 × 4 μm; *n* = 9); 2-septate conidia: 16–22 × 3 μm (av. 19 × 3 μm; *n* = 4); 3-septate conidia: (23–)27–33(–37) × 4–5 μm (av. 30 × 4 μm); 4-septate conidia: (28–)30–36(–42) × 4–5 μm (av. 33 × 5 μm); 5-septate conidia: (29–)34–38(–41) × 4–5 μm (av. 36 × 5 μm). *Chlamydospores* not observed.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 7–9 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface white to pale salmon, felty to velvety, radiate, with moderate aerial mycelium, margin irregular, filiform. Odour mouldy. Reverse pale salmon. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface white to pale salmon, felty to velvety, radiate, with sparse aerial mycelium, margin irregular, filiform. Reverse pale salmon to salmon, without diffusible pigments. On SNA with abundant sporulation on the surface of the medium.

Additional materials examined. Czech Republic, NW Bohemia, Střezovská rokle Nature Monument, gorge near Březno u Chomutova, from soil, 2005, *A. Kubátová*, CPC 35240. – Iran, Golestan, Gonbad, from *Triticum* sp., 2013, *M. Davari*, CBS 131788. – Unknown country, host, date and collector, NRRL 3020 = FRC R-6053 = MRC 2231, NRRL 3214 = FRC R-6054 = MRC 2232.

Notes — *Fusarium croceum* represents phylo-species FIESC 10-a as defined by O'Donnell et al. (2009), which formed a fully supported basal clade (ML & MP-BS = 100 %; PP = 1.0) in the Equiseti clade. No collection information is available for the original two isolates (NRRL 3020 & NRRL 3214) used to delimit FIESC 10. However, the ex-type (CBS 131777) and CBS 131788 were isolated from wheat in Western Asia, whereas CPC 35240 was isolated from soil in Central Europe. This species can be distinguished from *F. equiseti* and other species in the FIESC by the shorter and more robust sporodochial conidia. The apical cell of the sporodochial conidia (i.e., macroconidia) of *F. croceum* is much less elongated than those of *F. equiseti*.

Fusarium duofalcatisporum J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831835; Fig. 9

Etymology. Name refers to the two different (aerial and sporodochial) falcate conidia produced by this fungus.

Typus. Sudan, Nile Province, from *Phaseolus vulgaris* seed, date unknown, *M. Eltayeb* (holotype CBS H-24056 designated here, culture ex-type CBS 384.92 = NRRL 36448).

Conidiophores borne on aerial mycelium rarely seen, 9–16 μm tall, unbranched, reduced to lateral phialidic pegs or single lateral monophialides, subulate to subcylindrical, smooth- and thin-walled, with inconspicuous periclinal thickening; *aerial conidia* hyaline, smooth- and thin-walled, falcate, gently dorsiventrally curved with a blunt apical cell and barely notched basal cell, 1–3(–4)-septate; 1-septate conidia: (13–)16–20(–24) × 2–4 μm (av. 18 × 3 μm); 2-septate conidia: (16–)19–25(–26) × 3–4 μm (av. 22 × 3 μm); 3-septate conidia: (21–)24–32(–36) × 3–5 μm (av. 28 × 4 μm); 4-septate conidia: 36–40 × 4–5 μm (*n* = 3). *Sporodochia* salmon to saffron, formed abundantly on carnation leaves. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, 7–19 × 2–4 μm, smooth, thin-walled, with a short-flared apical collarette. *Sporodochial conidia* falcate, sometimes becoming sinuate, slender, curved dorsiventrally, tapering towards both ends, with an elongated or whip-like curved apical cell and a barely notched to prominently extended basal cell, (3–)5–6(–7)-septate, hyaline, thin- and smooth-walled; 3-septate conidia: 36–51(–60) × 3–4 μm (av. 43 × 4 μm, *n* = 16); 4-septate conidia: (42–)43–59(–68) × 3–5 μm (av. 51 × 4 μm, *n* = 13); 5-septate conidia: (48–)62–76(–80) × 3–5 μm (av. 69 × 4 μm); 6-septate conidia: (43–)61–75(–79) × 4–5 μm (av. 68 × 4 μm); 7-septate conidia: (65–)68–76(–79) × 4–5 μm (av. 72 × 4 μm, *n* = 15). *Chlamydospores* rarely formed, globose, subglobose to oval, subhyaline, smooth-walled, terminal or intercalary, solitary, in pairs or forming chains, 5–9 μm diam.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 4–7 mm/d and reaching 75–82 mm diam in 7 d; surface peach with salmon margins, flat, felty to velvety, radiate, with aerial mycelium, margin entire. Odour mouldy. Reverse pale peach to peach. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface sulphur yellow to straw, flat, membranous to dusty, aerial mycelium scant or absent, margin irregular, filiform. Reverse sulphur yellow to straw, without diffusible pigments. On SNA with sparse aerial mycelium, sporulation abundant on the surface of the medium.

Additional material examined. Mozambique, Maputo, from *Gossypium hirsutum*, date unknown, CBS 264.50 = NRRL 36401.

Notes — *Fusarium duofalcatisporum* represents phylo-species FIESC 2 (O'Donnell et al. 2009), a fully supported clade (ML & MP-BS = 100 %; PP = 1.0), closely related to *F. clavum*, *F. compactum*, *F. ipomoeae* and *F. lacertarum* in the Equiseti clade. The sporodochial conidia of *F. duofalcatisporum* ((3–)5–6(–7)-septate; 36–80 × 3–5 μm overall) are larger

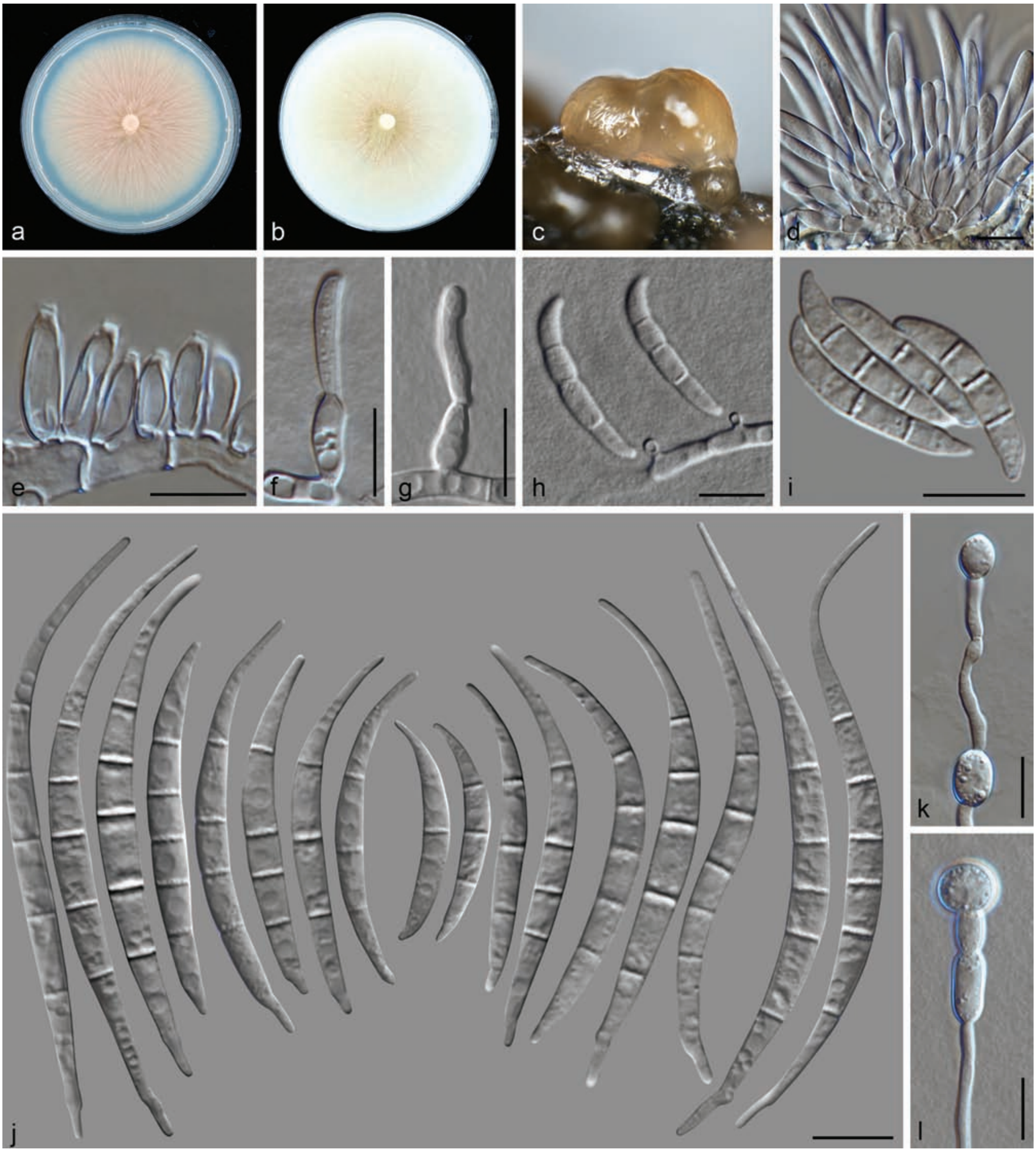


Fig. 9 *Fusarium duofalcatisporum* (CBS 384.92, ex-type culture). a. Colony on PDA; b. colony on OA; c. sporodochia on carnation leaves; d. sporodochial conidiophores; f–g. lateral monophialides on aerial mycelium; h. lateral phialidic peg on aerial mycelium; i. aerial conidia; j. sporodochial conidia; k–l. chlamydospores — Scale bars = 10 µm.

than those of *F. clavum* ((3–)5–6(–7)-septate; 36–80 × 3–5 µm overall), *F. compactum* ((3–)5(–7)-septate; 16–55 × 3.5–6.5 µm overall; Gerlach & Nirenberg 1982) and *F. ipomoeae* (3–5-septate; 26.5–57 × 2.5–5 µm overall; Wang et al. 2019). This species appears to be restricted to North- and South eastern Africa (O'Donnell et al. 2009).

Fusarium equiseti (Corda) Sacc., Syll. Fung. 4: 707. 1886

Basionym. *Selenosporium equiseti* Corda, Icon. Fungorum (Corda) 2: 7, t. IX, Fig. 32. 1838.

Synonyms. *Fusarium gibbosum* Appel & Wollenw., Arbeiten Kaiserl. Biol. Anst. Ld.-u. Forstw. 8: 190. 1910.

Fusarium caudatum Wollenw., J. Agric. Res. 2: 262. 1914.

Gibberella intricans Wollenw., Z. Parasitenk. (Berlin) 3: 332. 1931.

Typus. Germany, Braunschweig, Niedersachsen, from soil, Mar. 1994, *H.I. Nirenberg* (neotype specimen CBS H-5570, culture ex-neotype BBA 68556 = CBS 307.94 = NRRL 26419).

Descriptions & Illustrations — Wollenweber & Reinking (1935), Booth (1971), Gerlach & Nirenberg (1982), Holubová-Jechová et al. (1994), Leslie & Summerell (2006).

Additional materials examined. Czech Republic, Chvaletice, from sediment of abandoned dry sedimentation basin with waste material from Fe-Mn pyrite processing, 1994, *A. Kubátová*, CPC 35220; Praha, toenail of 25-yr-old man, 2008, *M. Skořepová*, CPC 35262. – Denmark, from potato peel, 25 Apr. 1985, *U. Thrane*, CBS 414.86 = FRC R-8508 = IMI 309348. – Germany, from leaf spot of *Daphne mezereum*, 1957, *R. Schneider*, CPC 35134 = DSM 62203. – Netherlands, IJpolder, from soil, date unknown, *J.C. Went*, CBS 185.34. – Switzerland, Hüntwangen, from maize husk, 20 Sept. 2005, *S. Vogelsang*, CBS 119663. – Unknown location and date, *H.W. Wollenweber*, CBS 107.07 = IMI 091982 = NRRL 36136.

Notes — The *F. equiseti* s.str. clade was defined by O'Donnell et al. (2009) as phylo-species FIESC 14-a, which formed a well-supported clade (ML-BS = 94 %, MP-BS = 88 %, PP = 1.0) here. With the exception of isolate CPC 35220, which has a clinical origin, the remaining isolates originated from either plant material or soil/sediment substrates.

Fusarium fasciculatum J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831836; Fig. 10

Etymology. Name refers to the abundant formation of aggregated sporodochia on carnation leaf pieces.

Typus. Australia, Northern Territories, Roper River area, from *Oryza australiensis* stem, Apr. 2009, *T. Petrovic* (holotype CBS H-24057 designated here, culture ex-type CBS 131382).

Conidiophores and *aerial conidia* borne on aerial mycelium not observed. *Sporodochia* salmon to saffron, formed abundantly on carnation leaves or the surface of the medium. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, 7–16 × 2–4 µm, smooth, thin-walled, with a short-flared apical collarette. *Sporodochial conidia* falcate, slender, curved dorsiventrally, tapering towards both ends, with a slightly elongated and conical or short whip-like curved apical cell and a blunt to barely notched to foot-like basal cell, (2–)3–5(–6)-septate, hyaline, thin- and smooth-walled; 2-septate conidia: 34–42 × 3–4 µm (n = 2); 3-septate conidia: (30–)34–42(–45) × 3–5 µm (av. 38 × 4 µm); 4-septate conidia: (37–)39–45(–48) × 3–5 µm (av. 42 × 4 µm); 5-septate conidia: (38–)42–48(–51) × 4–5 µm (av. 45 × 4 µm); 6-septate conidia: 45–57 × 4–5 µm (n = 3). *Chlamydospores* not observed.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 6–9 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface pale orange to orange, flat, felty, radiate, aerial mycelium scant or absent, margin irregular, lobate, serrate or filiform. Odour mouldy. Reverse pale straw to pale orange. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface pale saffron, flat, membranous, aerial mycelium scant or absent, margin irregular, lobate, serrate or filiform. Reverse sulphur yellow to straw, without diffusible pigments. On SNA with sparse aerial mycelium, and sporodochia forming on the surface of the medium.

Additional materials examined. Australia, Northern Territories, Roper River area, from *Oryza australiensis* stem, Apr. 2009, *T. Petrovic*, CBS 131383; ibid., CBS 131384.

Notes — *Fusarium fasciculatum* represents a new lineage in the Incarnatum clade, forming a fully supported clade (ML & MP-BS = 100 %; PP = 1.0), closely related to *F. citri* and *F. humuli* (Wang et al. 2019). The sporodochial conidia (i.e., macroconidia) of *F. fasciculatum* ((2–)3–5(–6)-septate; 30–57 × 3–5 µm overall) are larger than those of *F. citri* (3–5-septate; 25.5–40.5 × 3–5 µm overall; Wang et al. 2019) and *F. humuli* (3–5-septate; 21–35 × 3–5 µm overall; Wang et al. 2019). All three isolates representing *F. fasciculatum* were obtained from a native Australian wild rice species. However, it is not certain whether these are pathogens or endophytes of their respective hosts.

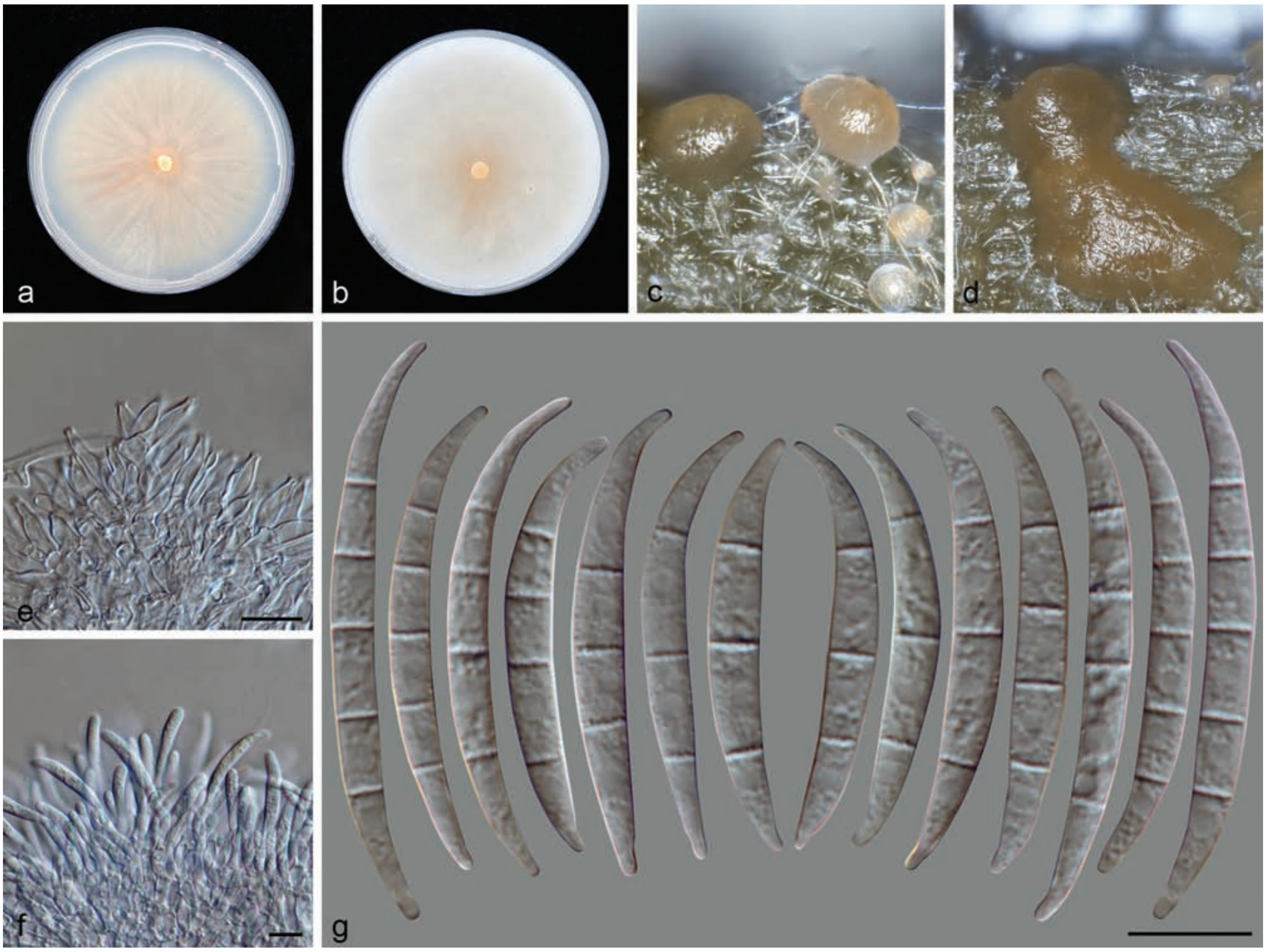


Fig. 10 *Fusarium fasciculatum* (CBS 131382, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on carnation leaves; e–f. sporodochial conidiophores; g. sporodochial conidia. — Scale bars = 10 µm.

Fusarium flagelliforme J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831837; Fig. 11

Etymology. Name refers to the whip-like apical cells of the sporodochial conidia.

Typus. Croatia, Zagreb, from *Pinus nigra* seedling, date and collector unknown (holotype CBS H-24058 designated here, culture ex-type CBS 162.57 = NRRL 36269).

Conidiophores and *aerial conidia* borne on aerial mycelium not observed. *Sporodochia* salmon to saffron, formed abundantly on carnation leaves and on the surface of the medium. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, 7–14 × 3–4 μm, smooth, thin-walled, with a short-flared apical collarette. *Sporodochial conidia* falcate, slender, curved dorsiventrally, tapering towards both ends, with elongated or whip-like, curved apical cell and a barely notched to prominently extended basal cell, (3–)4–5(–6)-septate, hyaline, thin- and smooth-walled; 3-septate conidia: (37–)41–51(–54) × 4–5 μm (av. 46 × 4 μm, *n* = 16); 4-septate conidia: (45–)49–61(–69) × 3–5 μm (av. 55 × 4 μm); 5-septate conidia: (49–)59–75(–85) × 4–5 μm (av. 67 × 4 μm); 6-septate conidia: 59–84 × 4–5 μm (av. 74 × 4 μm, *n* = 4). *Chlamydospores* rarely formed, globose, subglobose to oval, subhyaline, smooth-walled, terminal or intercalary, solitary or in pairs or forming chains, 5–11 μm diam.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 3.5–6 mm/d and reaching 65–70 mm diam in 7d; surface pale luteous to orange red, flat, felty to velvety, radiate, with moderate aerial mycelium, margin irregular, filiform. Odour mouldy. Reverse pale luteous to pale orange-red. Diffusible pigments absent. On OA in the dark reaching 60–70 mm diam in 7 d; surface straw to pale luteous, flat, membranous to dusty, aerial mycelium scant or absent, margin irregular, filiform. Reverse straw to pale luteous, without diffusible pigments. On SNA with sparse aerial mycelium, membranous.

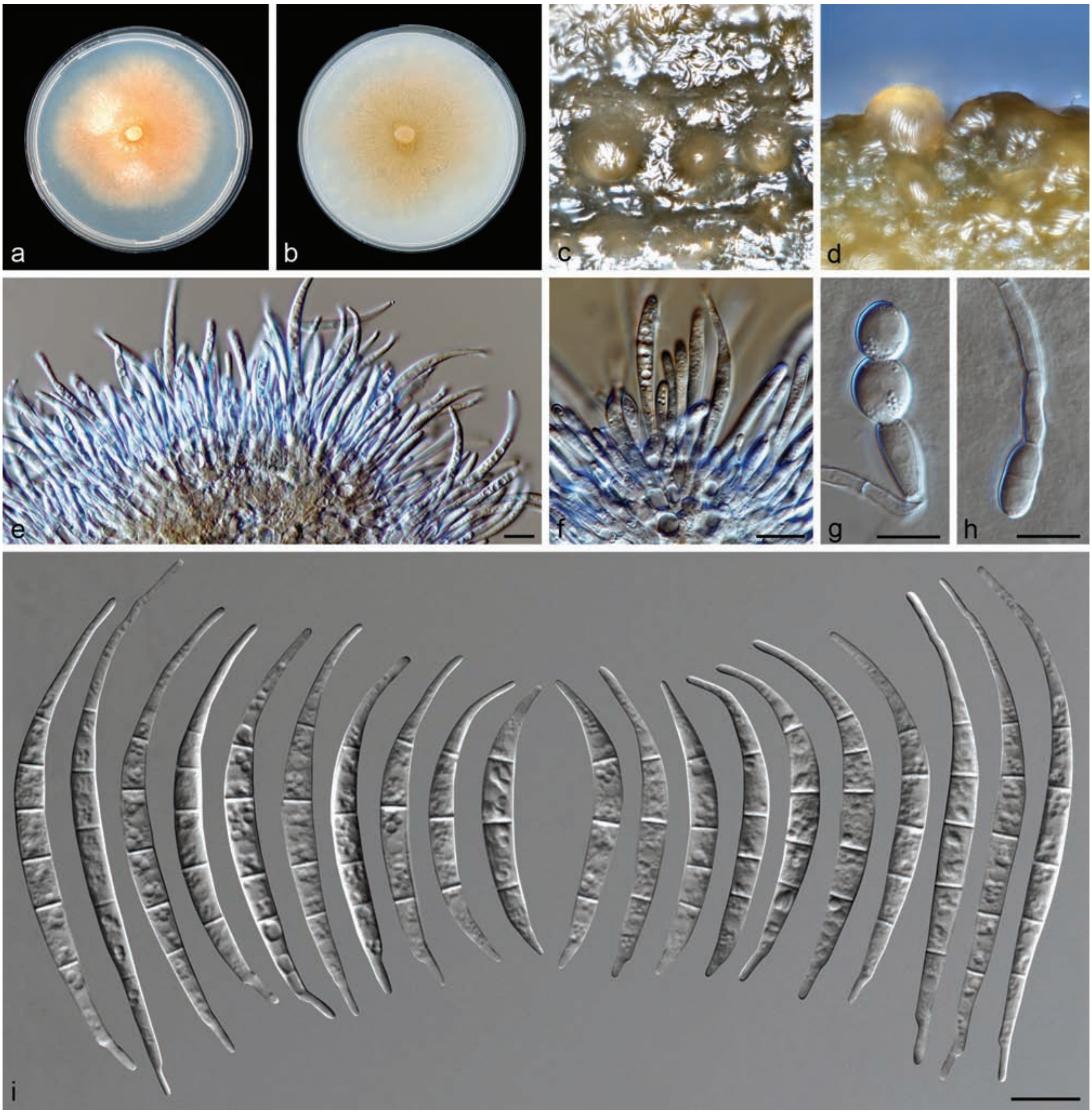


Fig. 11 *Fusarium flagelliforme* (CBS 162.57, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on carnation leaves; e–f. sporodochial conidiophores; g–h. chlamydospores; i. sporodochial conidia. — Scale bars = 10 μm.

Additional materials examined. Germany, from unknown seedling, date and collector unknown, CBS 259.54 = NRRL 36392; from *Triticum* sp., date and collector unknown, CBS 731.87 = NRRL 26921, ibid., NRRL 6548 = IMI 112503; from *Thuja* sp., date and collector unknown, NRRL 31011 = BBA 69079.

Notes — *Fusarium flagelliforme* represents phylo-species FIESC 12 (O'Donnell et al. 2009), a fully supported clade (ML & MP-BS = 100 %; PP = 1.0), closely related to *F. longifundum* in the Equiseti clade. Similar to *F. longifundum*, this species lacks conidiophores and conidia on its aerial mycelia, but does produce abundant sporodochia and sporodochial conidia on the carnation leaf pieces and surrounding medium. The sporodochial conidia of *F. flagelliforme* ((3–)4–5(–6)-septate; 37–85 × 3–5 µm overall) are larger than those of *F. longifundum* ((3–)5(–6)-septate; 21–76 × 3–5 µm overall). This species appears to be restricted to Europe, mostly associated with cereals.

Fusarium gracilipes J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831838; Fig. 12

Etymology. Name refers to the slender foot-shaped basal cells of the sporodochial conidia.

Typus. USA, Nebraska, from a horse, date and collector unknown (holotype CBS H-24059 designated here, culture ex-type NRRL 43635).

Conidiophores and *aerial conidia* borne on aerial mycelium not observed. *Sporodochia* salmon to saffron, formed abundantly on carnation leaves. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, 8–15 × 3–4 µm, smooth, thin-walled, with a short-flared apical collarette. *Sporodochial conidia* falcate, slender, curved dorsiventrally, tapering towards both ends, with elongated or whip-like, somewhat spatulate and curved apical cells and a barely notched to elongated, slender foot-shaped basal cell, (3–)5(–6)-septate, hyaline, thin- and smooth-walled; 3-septate conidia: (40–)44–58(–63) × 4–5 µm (av. 51 × 4 µm, *n* = 13); 4-septate conidia: (48–)51–59(–61) × 4–5 µm (av. 55 × 4 µm, *n* = 23); 5-septate conidia: (55–)58–70(–84) × 4–5 µm (av. 64 × 4 µm); 6-septate conidia: 58–66 × 4–5 µm (av. 63 × 5 µm, *n* = 3). *Chlamydospores* rare, globose, subglobose to oval, subhyaline, smooth-walled, terminal or intercalary, solitary, in pairs or forming chains, 4–11 µm diam.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 6–8.5 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface pale salmon, flat, radiate, aerial mycelium sparse, margin irregular, filiform. Odour mouldy. Reverse pale salmon. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface pale straw, flat, membranous, aerial mycelium scant or absent, margin irregular, filiform. Reverse pale straw, without diffusible pigments. On SNA with sparse aerial mycelium, membranous.

Notes — *Fusarium gracilipes* represents a single strain lineage in the Equiseti clade, previously designated as phylo-species FIESC 13 by O'Donnell et al. (2009). Similar to *F. cateniforme*, *F. flagelliforme* and *F. longifundum*, its closest phylogenetic neighbours, this species does not produce conidiophores or conidia on the aerial mycelium in culture. For morphological differences, see notes under *F. cateniforme*.

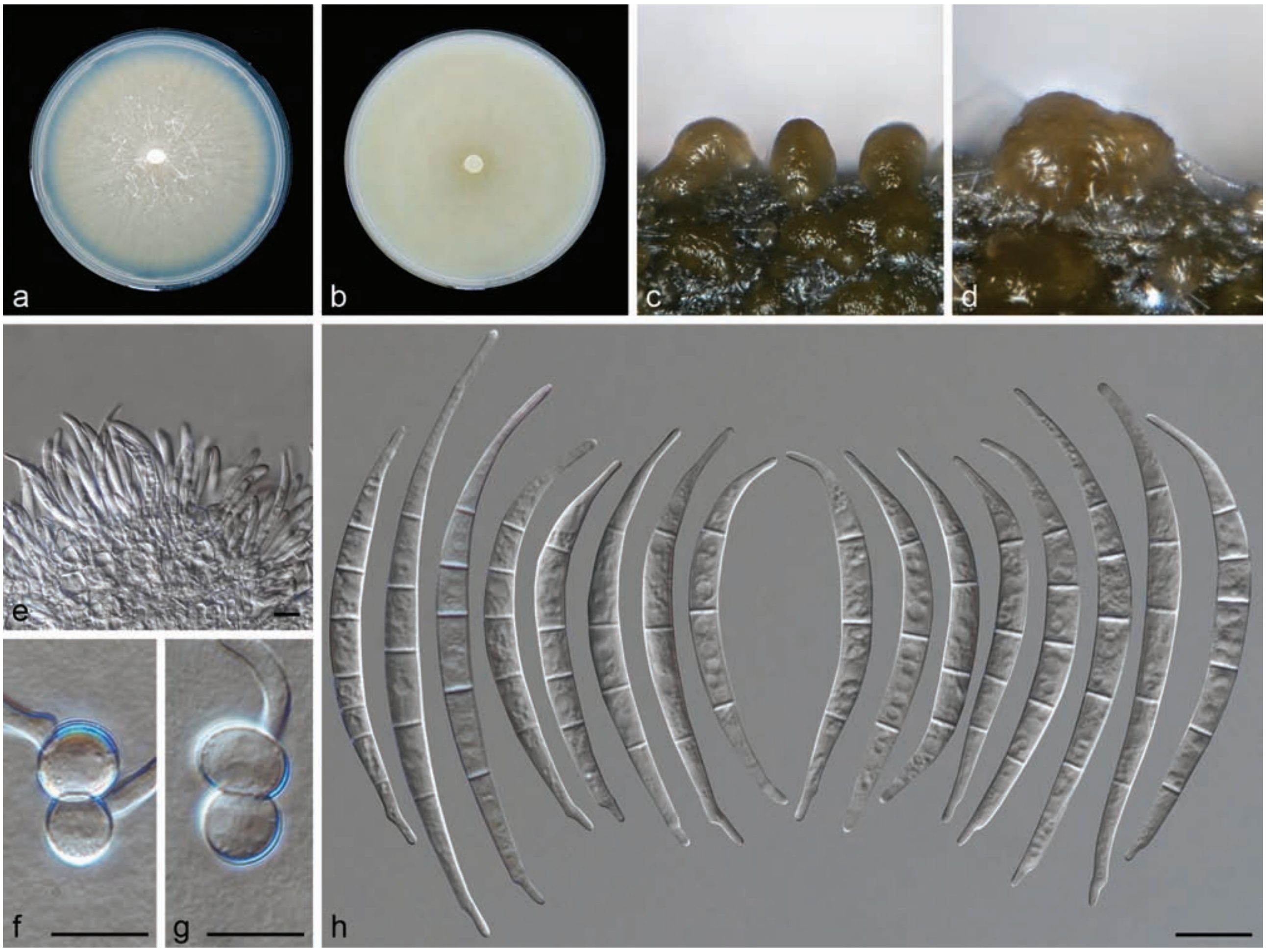


Fig. 12 *Fusarium gracilipes* (NRRL 43635, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on carnation leaves; e. sporodochial conidiophores; f–g. chlamydospores. h. sporodochial conidia. — Scale bars = 10 µm.

Fusarium guilinense M.M. Wang et al., Persoonia 43: 82. 2019

Typus. China, Guangxi province, Guilin, from leaf of *Musa nana*, Sept. 2016, *Y.Z. Diao* (holotype HAMS 248037, culture ex-type CGMCC3.19495 = LC12160).

Notes — *Fusarium guilinense* was introduced by Wang et al. (2019) representing phylo-species FIESC 21 (O'Donnell et al. 2009), a fully supported clade (ML & MP-BS = 100 %; PP = 1.0) in the Incarnatum clade.

Fusarium hainanense M.M. Wang et al., Persoonia 43: 82. 2019

Typus. China, Hainan province, from stem of *Oryza* sp., Mar. 2016, *G.H. Huang* (holotype HAMS 248038, culture ex-type CGMCC3.19478 = LC11638).

Additional material examined. Australia, Northern Territories, Roper River area, from *Oryza australiensis* stem, Apr. 2009, *T. Petrovic*, CBS 131386.

Notes — *Fusarium hainanense* was introduced by Wang et al. (2019) representing phylo-species FIESC 26 (O'Donnell et al. 2009), a well-supported clade (ML-BS = 99 %, MP-BS = 92 %, PP = 1.0) in the Incarnatum clade and closely related to *F. abberans*, *F. nanum* and *F. persicinum*. For morphological comparisons, see notes under *F. abberans* and Wang et al. (2019).

Fusarium humuli M.M. Wang et al., Persoonia 43: 83. 2019

Typus. China, Jiangsu Province, from leaf of *Humulus scandens*, Nov. 2017, *Q. Chen* (holotype HAMS 248039, culture ex-type CGMCC3.19374 = CQ1039).

Description & Illustration — Wang et al. (2019).

Notes — *Fusarium humuli* represents a unique lineage first resolved by Wang et al. (2019), which was also designated as phylo-species FIESC 33 by the authors. This species is closely related to *F. citri* and *F. fasciculatum*, forming a fully supported clade (ML & MP-BS = 100 %; PP = 1.0) in the Incarnatum clade. For morphological differences, see notes under *F. fasciculatum* and Wang et al. (2019).

Fusarium incarnatum (Desm.) Sacc., Syll. Fung. 4: 712. 1886 — Fig. 13

Basionym. *Fusisporium incarnatum* Roberge ex Desm., Ann. Sci. Nat., Bot., sér. 2, 10: 309. 1838.

Synonyms. *Fusarium semitectum* Berk. & Ravenel, Grevillea 3: 98. 1875.
Fusisporium pallidoroseum Cooke, Grevillea 6: 139. 1878.
Fusarium pallidoroseum (Cooke) Sacc., Syll. Fung. 4: 720. 1886.
Fusarium semitectum var. *majus* Wollenw., Fus. Autogr. Del. 3: 907. 1931.

Typus. France, from *Tagetes erecta*, 1848, *M. Roberge* (holotype of *Fusisporium incarnatum* in herb. Desmazières, Plantes Cryptogamiques de France, éd. 2, No. 1303, in PC). – Malawi, from *Trichosanthes dioica*, date unknown, *H.M. Phiri* (epitype of *F. incarnatum* designated here: CBS H-24060, MBT387952, culture ex-epitype CBS 132.73 = ATCC 24387 = IMI 128222 = NRRL 25478).

Conidiophores borne on the aerial mycelium, 45–105 µm tall, unbranched, sympodial or irregularly branched, bearing terminal or lateral phialides, often reduced to single phialides; *phialides* mono- and polyphialidic, subulate to subcylindrical, sometimes proliferating percurrently, smooth- and thin-walled, 5–28 × 2–4 µm, with inconspicuous periclinal thickening; *aerial conidia* hyaline, smooth- and thin-walled, of two types: (a) ellipsoidal to fusiform, (0–)3-septate; 0-septate conidia: 12–21 × 4 µm (n = 2); 1-septate conidia: (14–)15–19(–23) × 3–4 µm (av. 17 × 4 µm, n = 14); 2-septate conidia: 17–21(–22) × 3–4 µm (av. 19 × 4 µm, n = 6); 3-septate conidia: (19–)24–34(–38) × 3–5 µm (av. 29 × 4 µm); (b) falcate, curved dorsiventrally, tapering towards both ends, with blunt apical cell and blunt to barely notched basal cell, (1–)3–5(–7)-septate; 1-septate conidia: 18–25 × 3–4 µm (n = 2); 2-septate conidia: 21–24 × 4 µm (n = 2); 3-septate conidia: (20–)27–39(–45) × 4–5 µm (av. 33 × 4 µm); 4-septate conidia: (33–)34–42(–52) × 4–6 µm (av. 38 × 5 µm); 5-septate conidia: (36–)40–48(–51) × 4–5 µm (av. 44 × 5 µm); 6-septate conidia: (40–)42–58(–66) × 5–6 µm (av. 50 × 5 µm, n = 9); 7-septate conidia: 50–58 × 5 µm (n = 3). *Sporodochia* saffron to pale brown, formed less abundantly on the surface of the medium. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, 8–17 × 3–5 µm, smooth, thin-walled, with inconspicuous periclinal thickening; *sporodochial conidia* falcate, curved dorsiventrally, tapering towards both ends, with slightly papillate, curved apical cell and a notched to foot-like basal cell, (1–)3–5(–6)-septate, hyaline, smooth- and thin-walled; 1-septate conidia: 15–18 × 3–4 µm (n = 3); 2-septate conidia: 16–21 × 3–4 µm (n = 2); 3-septate conidia: (23–)28–36(–42) × 4–5 µm (av. 32 × 4 µm); 4-septate conidia: (31–)34–40(–48) × 4–5 µm (av. 37 × 5 µm); 5-septate conidia: (34–)36–42(–45) × 4–5 µm (av. 39 × 5 µm); 6-septate conidium: 48 × 5 µm (n = 1). *Chlamydospores* abundant, globose, subglobose to oval, subhyaline, smooth-walled, terminal or intercalary, solitary, in pairs or forming chains, 5–11 µm diam.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 8–12 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface white to primrose, floccose, radiate, with abundant aerial mycelium, margin irregular, filiform. Odour mouldy. Reverse pale yellow. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface pale primrose, floccose in the centre, radiate, with less abundant aerial mycelium, margin irregular, filiform. Reverse pale yellow, without diffusible pigments. On SNA with abundant aerial mycelium and sporulation on the aerial mycelium.

Additional materials examined. India, from *Oryza sativa*, date and collector unknown, NRRL 13379 = FRC R-5198 = BBA 62200. – Iran, Golestan, Kalaleh, from *Triticum* sp., date unknown, *M. Davari*, CBS 132907. – USA, Texas, from human, date and collector unknown, NRRL 32866 = FRC R-8822, NRRL 32867 = FRC R-8837.

Notes — Considerable controversy surrounds the application of the epithet '*incarnatum*' within the Incarnatum clade (Booth & Sutton 1984, Nirenberg 1990, Khoa et al. 2004, O'Donnell et al. 2009, Santos et al. 2019). Through their respective taxonomic histories, the names *F. incarnatum*, *F. pallidoroseum* and *F. semitectum* (and their respective varieties) have been linked to each other as either synonyms or as distinct species (Wollenweber & Reinking 1935, Gordon 1952, 1956, Booth 1971, Joffe 1974, Booth & Sutton 1984, Gerlach & Nirenberg 1982, Gams & Nirenberg 1989, Nirenberg 1990). Booth & Sutton (1984) studied the holotypes of *F. semitectum* and *Fusisporium pallidoroseum* (≡ *F. pallidoroseum*) and found that the holotype of *F. semitectum* only contained structures representing *Colletotrichum musae*, and therefore regarded the name *F. semitectum* as misapplied. They proposed a revised nomenclature that synonymised *F. semitectum* var. *majus* under *F. pallidoroseum*. Gams & Nirenberg (1989) accepted this revised nomenclature and recognised *F. pallidoroseum* var. *majus*. However, Nirenberg (1990) compared both the holotypes of *Fusisporium incarnatum* and *Fusisporium pallidoroseum* and found that they were conspecific, unifying both species and their varieties under *F. incarnatum* as the older epithet. As there is no living ex-type material available to serve as phylogenetic anchor for the Incarnatum clade, and therefore preventing the application of names to the various phylo-species recognised in this clade, we designate an epitype for *F. incarnatum*. Although the ex-epitype isolate CBS 132.73 does not conform to the type locality and host substrate of the holotype, Gerlach & Nirenberg

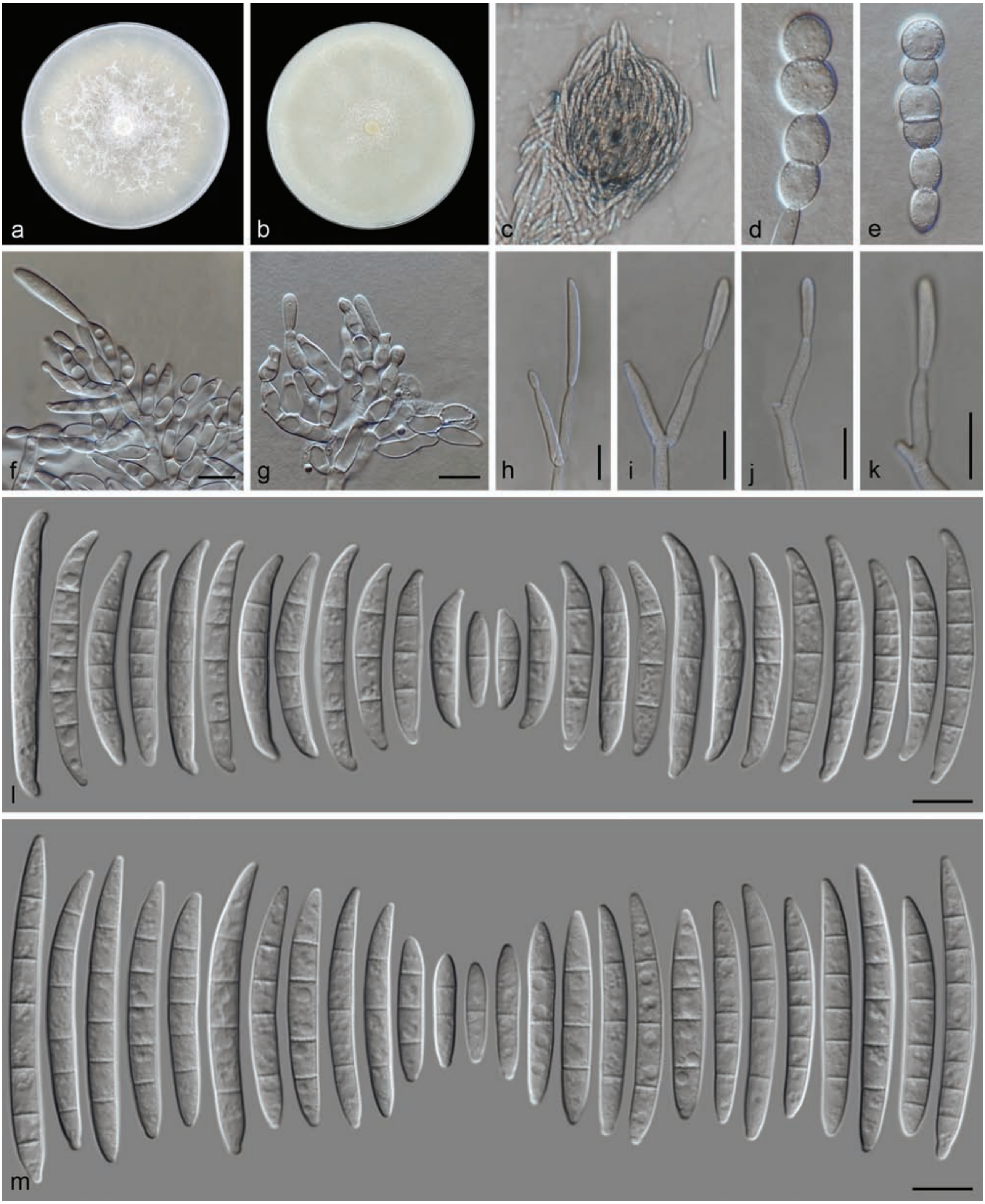


Fig. 13 *Fusarium incarnatum* (CBS 132.73, ex-epitype culture). a. Colony on PDA; b. colony on OA; c. sporodochia on medium surface; d–e. chlamydospores; f–g. sporodochial conidiophores; h–i. monophialides on aerial conidiophores; j–k. polyphialides on aerial conidiophores; l. aerial conidia; m. sporodochial conidia. — Scale bars = 10 μm.

(1982) considered this isolate as a good representative culture of *F. semitectum* var. *majus* (= *F. incarnatum*).

The ex-epitype (CBS 132.73) of *F. incarnatum* clustered within the well-supported clade (ML-BS = 95 %, MP-BS = 94 %, PP = 1.0) representing FIESC 23 (O'Donnell et al. 2009), closely related to *F. bubalinum*, *F. monophialidicum* and *F. tanahbumbuense*. See notes under *F. bubalinum* for morphological differences.

Fusarium ipomoeae M.M. Wang et al., Persoonia 43: 83. 2019

Typus. China, Jiangsu province, from leaf of *Ipomoea aquatica*, Aug. 2016, *L. Cai* (holotype HAMS 248040, culture ex-type CGMCC3.19496 = LC12165).

Description & Illustration — Wang et al. (2019).

Notes — Wang et al. (2019) introduced the Latin binomial *F. ipomoeae* for phylo-species FIESC 1, a fully supported clade (ML & MP-BS = 100 %; PP = 1.0), closely related to *F. compactum*, *F. duofalcatisporum* and *F. lacertarum* in the Equiseti clade.

For morphological differences, see notes under *F. compactum* and *F. duofalcatisporum*, and Wang et al. (2019).

Fusarium irregulare M.M. Wang et al., Persoonia 43: 84. 2019

Typus. China, Guangdong province, from bamboo, July 2016, *L. Cai* (holotype HAMS 248041, culture ex-type CGMCC3.19489 = LC7188).

Description & Illustration — Wang et al. (2019).

Additional material examined. Thailand, Bangkok, Mahidol University, from human toenail, date and collector unknown, CBS 132190.

Notes — *Fusarium irregulare* represents phylo-species FIESC 15 (Wang et al. 2019), a well-supported clade (ML-BS = 99, MP-BS = 98 %, PP = 1.0), closely related to *F. luffae*, *F. pernambucanum*, *F. sulawesiensis* and FIESC 32 (*sensu* Maryani et al. 2019). Similar to *F. luffae*, *F. irregulare* does not produce any sporodochia in culture (Wang et al. 2019), whereas both *F. pernambucanum* (Santos et al. 2019) and *F. sulawesiensis* (Maryani et al. 2019) produce abundant sporodochia in culture. Additionally, *F. pernambucanum* produces a variety (in shape) of non-falcate aerial conidia, not known for *F. irregulare*, *F. luffae* and *F. sulawesiensis* (Maryani et al. 2019, Santos et al. 2019, Wang et al. 2019). The falcate aerial conidia of *F. irregulare* (3-septate; 16–38.5 × 4–5 μm overall; Wang et al. 2019) are smaller than those of *F. luffae* (3–5-septate; 26.5–46 × 4–5 μm overall; Wang et al. 2019), *F. pernambucanum* (3–6(–7)-septate; 17.5–57 × 2.5–5 μm overall; Santos et al. 2019) and *F. sulawesiensis* (3–5(–9)-septate; 20.5–67.5 × 3.5–6 μm overall; Maryani et al. 2019).

Fusarium kotabaruense N. Maryani et al., Persoonia 43: 65. 2019

Typus. Indonesia, Desa Sungai Birah, Kecamatan Pamukan Barat, Kota Baru, Kalimantan Selatan (E115°59'982" S2°22'883"), on infected pseudostem of *Musa* var. Pisang Hawa (ABB), 19 June 2014, *N. Maryani* (holotype specimen and culture, InaCC F963, preserved in metabolically inactive state).

Description & Illustration — Maryani et al. (2019).

Notes — *Fusarium kotabaruense* represents a single strain lineage, designated as phylo-species FIESC 31 by Maryani et al. (2019) and closely related to *F. camptoceras* and *F. neosemitectum* in the newly introduced FCAMSC. The falcate aerial conidia of *F. kotabaruense* ((2–)3–5(–7)-septate; 21–45 × 5–7.5 μm overall; Maryani et al. 2019) are smaller than those of *F. camptoceras* (3–5(–7)-septate; 15–58 × 4–7 μm overall; Gerlach & Nirenberg 1982, Marasas et al. 1998, Leslie & Summerell 2006) but larger than those of *F. neosemitectum* ((1–)2–4(–5)-septate; 17–39 × 3–6 μm overall).

Fusarium lacertarum Subrahm. (as '*laceratum*'), Mykosen 26: 478. 1983

Typus. India, Poona, Pimpri, from skin of a lizard, 1982, *A. Subrahmanyam* (holotype IMI 300797, culture ex-type ATCC 42771 = NRRL 20423 = CBS 130185 = IMI 300797).

Description & Illustration — Subrahmanyam (1983).

Notes — *Fusarium lacertarum* constitutes phylo-species FIESC 4 according to O'Donnell et al. (2009), forming a fully supported clade (ML & MP-BS = 100 %; PP = 1.0) in the Equiseti clade closely related to *F. clavum*, *F. compactum*, *F. duofalcatisporum* and *F. ipomoeae*. Based on the description and illustrations by Subrahmanyam (1983), *F. lacertarum* produces 2–4-septate, falcate aerial conidia on conidiophores borne on the aerial mycelium and no mention is made of sporodochia. The ex-type strain accessioned at CBS (CBS 130185) appears to have degenerated as no sporulation or formation of sporodochia could be induced in this study. Therefore, no morphological comparison could be made with its closest phylogenetic neighbours.

Fusarium longicaudatum J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831839; Fig. 14

Etymology. Name refers to the elongated tail-like apical cells of the sporodochial conidia.

Typus. Tanzania, Tropical Products Research Inst., substrate unknown, 1971, *A.A. Jaffer* (holotype CBS H-24061 designated here, culture ex-type CBS 123.73 = ATCC 24370 = IMI 160825 = NRRL 25477).

Conidiophores and *aerial conidia* borne on aerial mycelium not observed. *Sporodochia* salmon to saffron, formed abundantly on carnation leaves or the surface of the medium. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, 7–15 × 3–4 μm, smooth, thin-walled, with a short-flared apical collarette. *Sporodochial conidia* falcate, slender, curved dorsiventrally, tapering towards both ends, with an elongate or whip-like curved apical cell and a foot-like to notched basal cell, (3–)5–6(–7)-septate, hyaline, thin- and smooth-walled; 3-septate conidia: 45 × 4 μm (*n* = 1); 4-septate conidia: 48–54 × 4–5 μm (*n* = 3); 5-septate conidia: (48–)62–76(–82) × 4–5 μm (av. 69 × 5 μm); 6-septate conidia: (68–)70–76(–81) × 4–5 μm (av. 73 × 5 μm); 7-septate conidia: (68–)71–79(–81) × 5 μm (av. 75 × 5 μm, *n* = 6). *Chlamydospores* abundant, globose, subglobose to oval, subhyaline, smooth-walled, terminal or intercalary, solitary, in pairs or forming chains, 5–11 μm diam.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 7–11 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface primrose to olivaceous buff, radiate, aerial mycelium abundant at the centre, margin irregular, filiform. Odour mouldy. Reverse buff to honey. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface white, flat, membranous, aerial mycelium scant or absent, margin irregular, filiform. Reverse white, without diffusible pigments. On SNA with sparse aerial mycelium sparse.

Notes — *Fusarium longicaudatum* represents a newly resolved single strain lineage in the Equiseti clade. This species is closely related to *F. arcuatisporum* (Wang et al. 2019) which also does not produce any conidiophores and aerial conidia in culture. Wang et al. (2019) only reported 5-septate sporodochial conidia (29–49.5 × 4–5 μm) for *F. arcuatisporum*, whereas *F. longicaudatum* produces (3–)5–6(–7)-septate sporodochial conidia (45–81 × 4–5 μm overall), which are much longer than those of *F. arcuatisporum.*

Fusarium longifundum J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831840; Fig. 15

Etymology. Name refers to the prominently long basal cells of the sporodochial conidia.

Typus. Netherlands Antilles, Curaçao, from air, date and collector unknown (holotype CBS H-24062 designated here, culture ex-type CBS 235.79 = NRRL 36372).

Conidiophores and *aerial conidia* borne on aerial mycelium not observed. *Sporodochia* salmon to saffron, formed abundantly on carnation leaves. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, 7–15 × 2–4 μm, smooth, thin-walled, with a short-flared

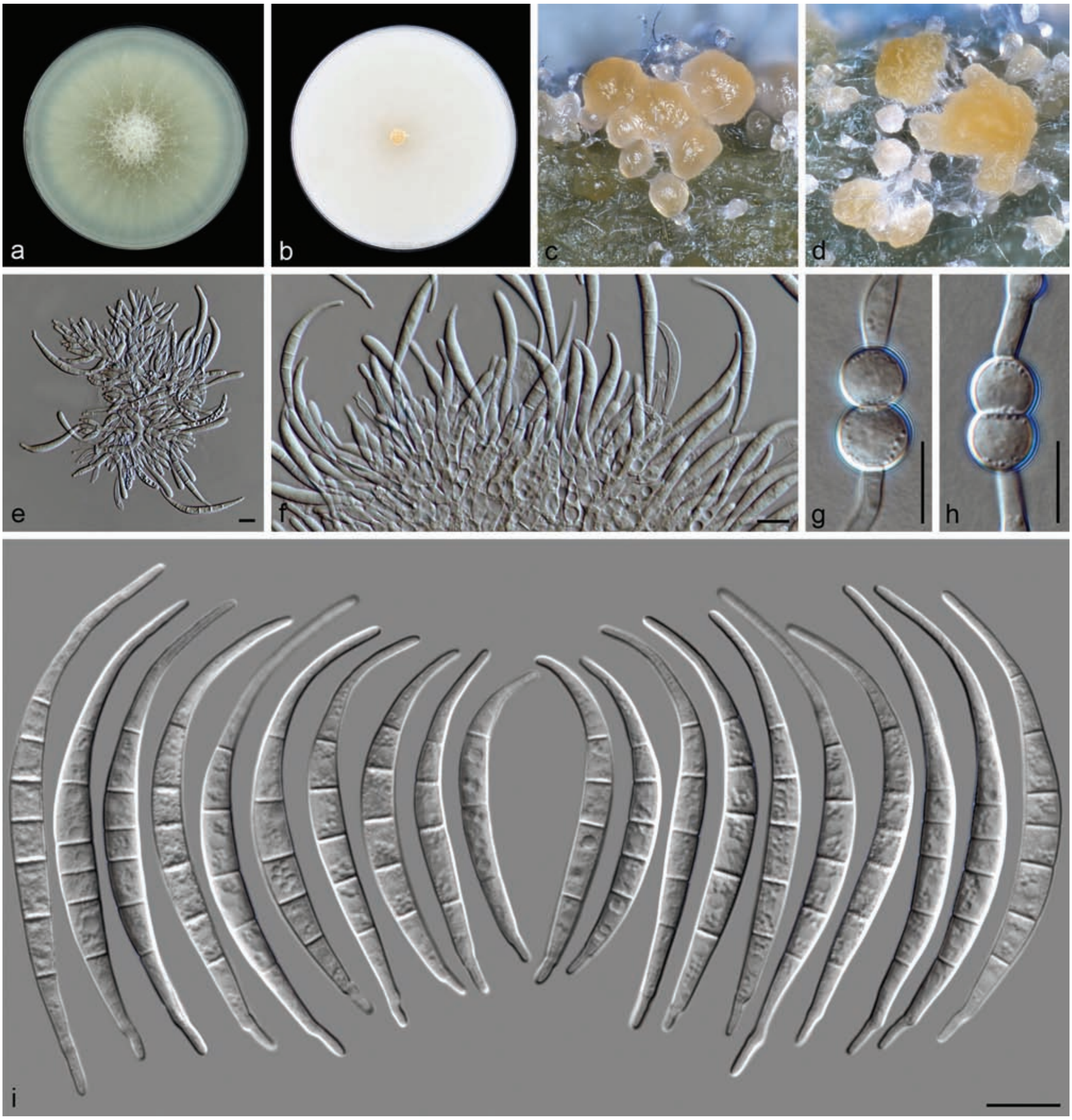


Fig. 14 *Fusarium longicaudatum* (CBS 123.73, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on carnation leaves; e–f. sporodochial conidiophores; g–h. chlamydospores; i. sporodochial conidia. — Scale bars = 10 µm.

apical collarette. *Sporodochial conidia* falcate, slender, curved dorsiventrally, tapering towards both ends, with an elongate or whip-like curved apical cell and a barely notched to prominently extended basal cell, (3–)5(–6)-septate, hyaline, thin- and smooth-walled; 3-septate conidia: (21–)29–41(–46) × 3–5 µm (av. 35 × 4 µm); 4-septate conidia: (34–)39–55(–62) × 3–5 µm (av. 47 × 4 µm); 5-septate conidia: (38–)55–71(–76) × 4–5 µm (av. 63 × 4 µm); 6-septate conidia: 62–72 × 4–5 µm (av. 67 × 5 µm, n = 5). *Chlamydospores* rare, globose, subglobose to oval, subhyaline, smooth-walled, terminal or intercalary, solitary or in pairs forming chains, 4–9 µm diam.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 5–8 mm/d and reaching 76–80 mm diam in 7 d; surface saffron to pale orange, flat, felty to velvety, radiate, with aerial mycelium, margin entire. Odour mouldy. Reverse straw to pale luteous. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface straw to pale luteous, flat, membranous to dusty, aerial mycelium scant or absent, margin entire. Reverse sulphur yellow to straw, without diffusible pigments. On SNA, hyphae hyaline, smooth-walled, aerial mycelium sparse.

Notes — *Fusarium longifundum* formed a single strain lineage sister to *F. flagelliforme* in the Equiseti clade. Like *F. flagelliforme*, this species does not produce conidiophores or conidia on its aerial mycelia. For morphological differences, see notes under *F. flagelliforme.*

Fusarium luffae M.M. Wang et al., Persoonia 43: 85. 2019

Typus. China, Fujian province, from *Luffa aegyptiaca*, Aug. 2016, *L. Cai* (holotype HAMS 248042, culture ex-type CGMCC3.19497 = LC12167).

Descriptions & Illustrations — Wang et al. (2019).

Additional material examined. Iran, Parsabad, Natural Resource site, from *Setaria verticilata*, date unknown, *M. Davari*, CBS 131097.

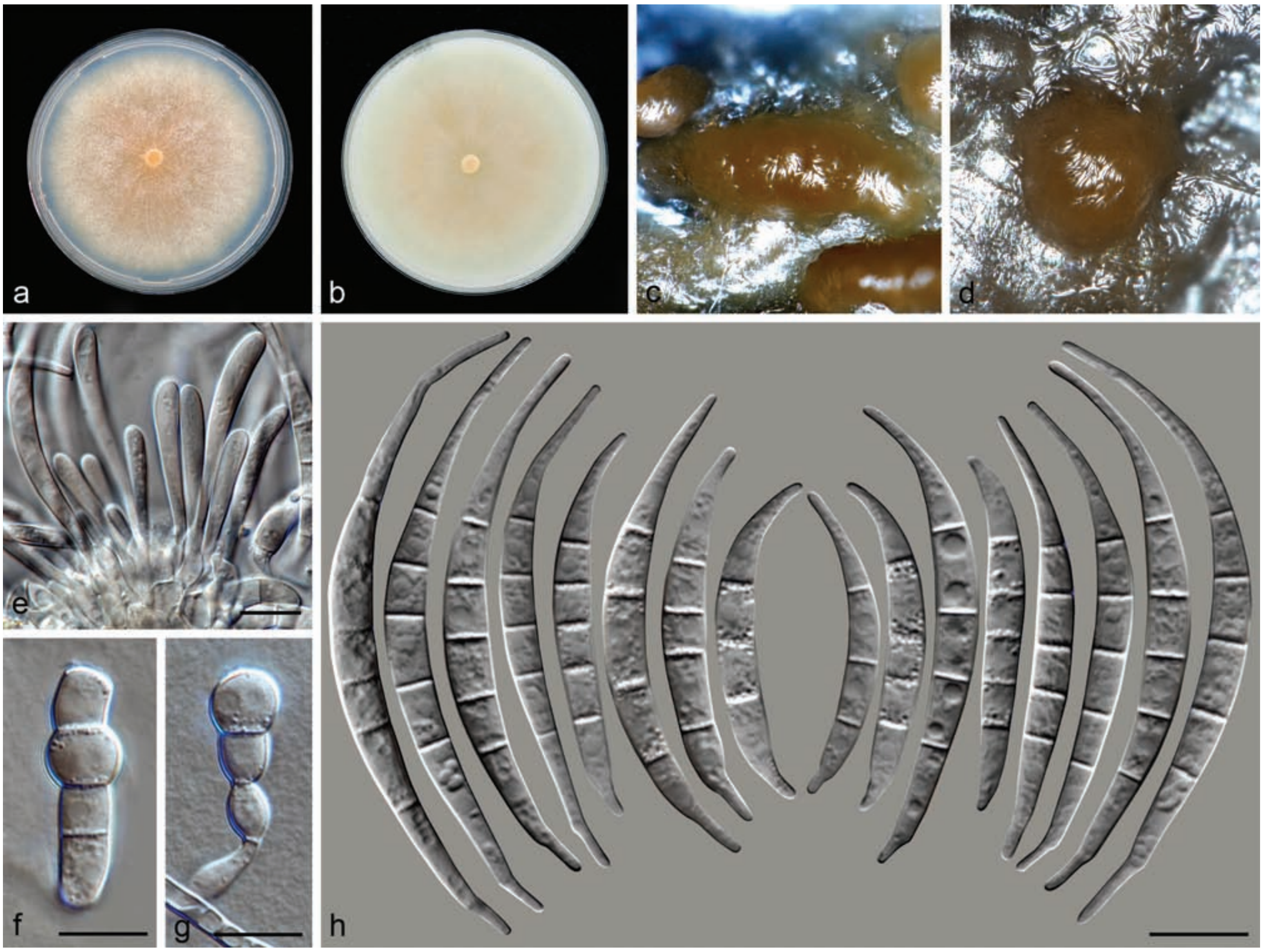


Fig. 15 *Fusarium longifundum* (CBS 235.79, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on carnation leaves; e. sporodochial conidiophores; f–g. chlamydospores; h. sporodochial conidia. — Scale bars = 10 µm.

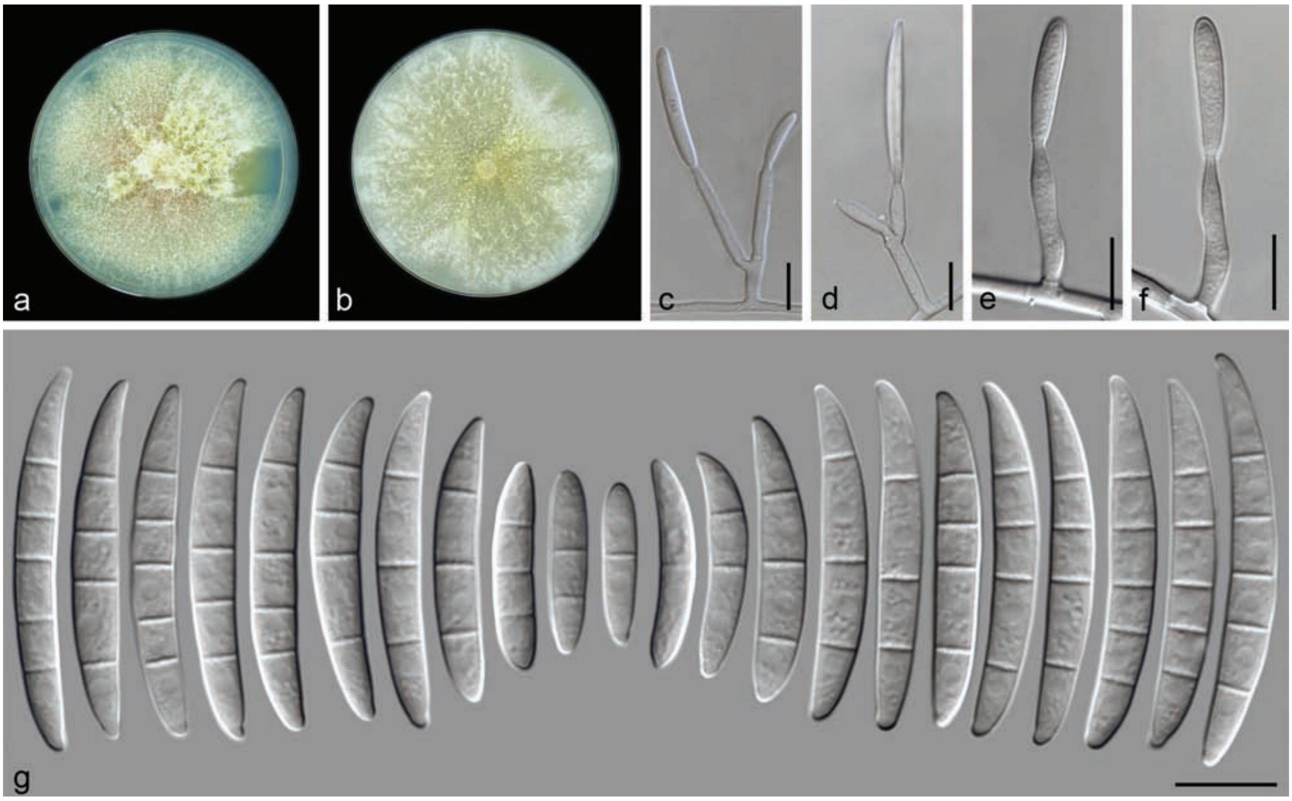


Fig. 16 *Fusarium monophialidicum* (NRRL 54973, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. conidiophores on aerial mycelium; e–f. lateral monophialides on aerial mycelium; g. aerial conidia. — Scale bars = 10 µm.

Notes — *Fusarium luffae* represents phylo-species FIESC 18, a fully supported subclade (ML & MP-BS = 100 %; PP = 1.0) in the Incarnatum clade, closely related to *F. irregulare*, *F. pernambucanum*, *F. sulawesiensis* and FIESC 32 (*sensu* Maryani et al. 2019). For morphological comparisons, see notes under *F. irregulare* and Wang et al. (2019). This species includes strains isolated from both plants and humans (O'Donnell et al. 2009, Wang et al. 2019) in Asia and North America.

Fusarium monophialidicum J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831841; Fig. 16

Etymology. Name refers to the monophialides produced on its aerial mycelium.

Typus. USA, Ohio, Rhinoceros eye, collector and date unknown (holotype CBS H-24063 designated here, culture ex-type NRRL 54973 = UTHSC 06-1473).

Conidiophores borne on the aerial mycelium 25–70 μm tall, unbranched, sympodial or irregularly branched, bearing terminal or lateral phialides, often reduced to single phialides; *phialides* monophialidic, subulate to subcylindrical, smooth- and thin-walled, 10–25 × 3–5 μm, with inconspicuous periclinal thickening; *aerial conidia* hyaline, rarely ellipsoidal to falcate, curved dorsiventrally, tapering towards both ends, with a blunt to conical and slightly curved apical cell and blunt to barely notched basal cell, smooth- and thin-walled, (1–)3–5-septate; 1-septate conidia: 16–29 × 3–4 μm (av. 21 × 4 μm, n = 4); 2-septate conidia: (18–)20–24(–25) × 3–4 μm (av. 22 × 4 μm, n = 10); 3-septate conidia: (19–)24–34(–40) × 4–5 μm (av. 29 × 4 μm); 4-septate conidia: (28–)32–38(–39) × 4–5 μm (av. 35 × 4 μm); 5-septate conidia: (33–)34–40(–46) × 4–5 μm (av. 37 × 4 μm). *Sporodochia* and *chlamydospores* not observed.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 5–9 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface buff to olivaceous buff, floccose, radiate, with abundant aerial mycelium, margin irregular, filiform. Odour mouldy. Reverse pale luteous to luteous. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface white to pale luteous, floccose, radiate, with abundant aerial mycelium, margin irregular, filiform. Reverse pale luteous, without diffusible pigments. On SNA with abundant aerial mycelium and sporulation on the aerial mycelium.

Notes — *Fusarium monophialidicum* formed a new single strain lineage in the Incarnatum clade, closely related to *F. bubalinum*, *F. incarnatum* and *F. tanahbumbuense*. This species can be distinguished from the latter three species by the lack of polyphialides on the aerial mycelia and its inability to form sporodochia in culture. For more morphological differences, see notes under *F. bubalinum* and *F. incarnatum*.

Fusarium mucidum J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831842; Fig. 17

Etymology. Name refers to the mouldy odour this species produces in culture.

Typus. El Salvador, Cooperación Coralama, from *Anacardium occidentale* mouldy nut, July 1999, *M. Reuter* (holotype CBS H-24064 designated here, culture ex-type CBS 102395).

Conidiophores borne on aerial mycelium, 40–110 μm tall, unbranched to sympodial or irregularly branched, bearing terminal or lateral mono- and polyphialides, often reduced to single phialides; *aerial phialides* mono- and polyphialidic, subulate to subcylindrical, sometimes proliferating percurrently,

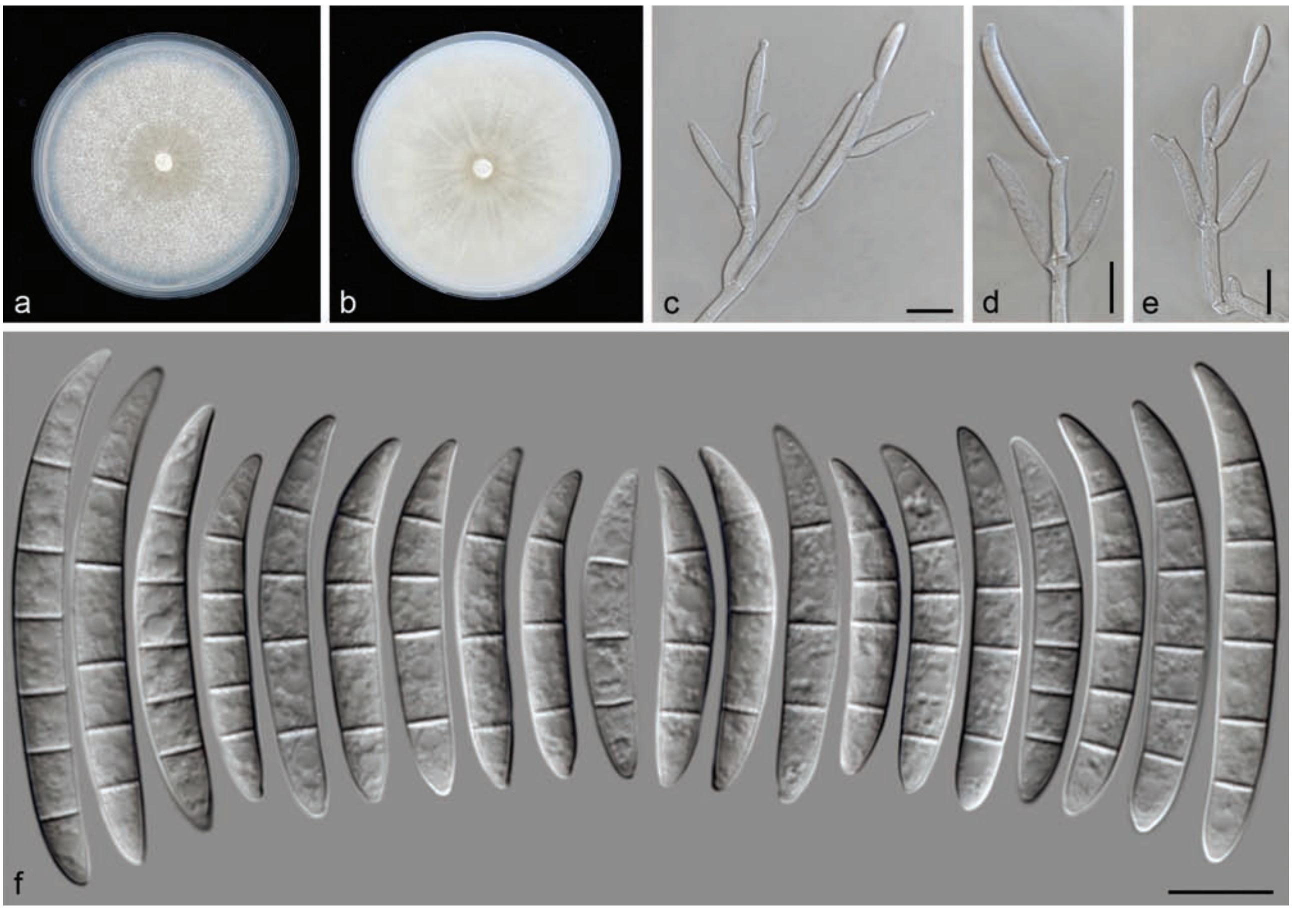


Fig. 17 *Fusarium mucidum* (CBS 102395, ex-type culture). a. Colony on PDA; b. colony on OA; c–e. conidiophores on aerial mycelium with mono- and polyphialides; f. aerial conidia. — Scale bars = 10 μm.

smooth- and thin-walled, 3–37 × 2–4 µm, with inconspicuous periclinal thickening; *aerial conidia* hyaline, falcate, slender, curved dorsiventrally, tapering towards both ends, with a blunt and curved apical cell and a blunt basal cell, 3–5(–7)-septate; 3-septate conidia: (24–)29–33(–39) × 4–5 µm (av. 31 × 5 um); 4-septate conidia: (30–)33–39(–44) × 4–5 µm (av. 36 × 5 um); 5-septate conidia: (33–)37–47(–55) × 4–6 µm (av. 42 × 5 um); 6-septate conidia: 44–54 × 5–6 µm (av. 51 × 5 µm; *n* = 9); 7-septate conidia: 51 × 4 µm (*n* = 1). *Sporodochia* and *chlamydospores* not observed.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 6–10 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface salmon, flat, felty to velvety, radiate, with abundant aerial mycelium, margin irregular, filiform. Reverse straw. Odour mouldy. Diffusible pigments absent in the dark. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface pale salmon, flat, radiate, aerial mycelium sparse, margin irregular, filiform. Reverse pale straw. On SNA with abundant aerial mycelium, sporulating profusely on the aerial mycelium.

Additional material examined. El Salvador, Cooperación Coralama, from *Anacardium occidentale* mouldy nut, July 1999, *M. Reuter*, CBS 102394.

Notes — The clade representing *F. mucidum* formed a fully supported basal lineage (ML & MP-BS = 100 %; PP = 1.0) to the Equiseti clade. The *F. mucidum* clade included two isolates collected from mouldy cashew (*Anacardium occidentale*) nuts in El Salvador and the third from *Musa acuminata* (Indo 175) in Indonesia, which Maryani et al. (2019) designated as phylospecies FIESC 30. Both isolates (CBS 102394 & CBS 102395) studied here did not produce sporodochia in culture, and only produced falcate aerial conidia.

Fusarium multiceps J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831843; Fig. 18

Etymology. Name refers to the multiple conidiogenous loci present on its polyphialides.

Typus. USA, Florida, from *Trichechus* sp., date and collector unknown (holotype CBS H-24065 designated here, culture ex-type CBS 130386 = NRRL 43639 = UTHSC 04-135)

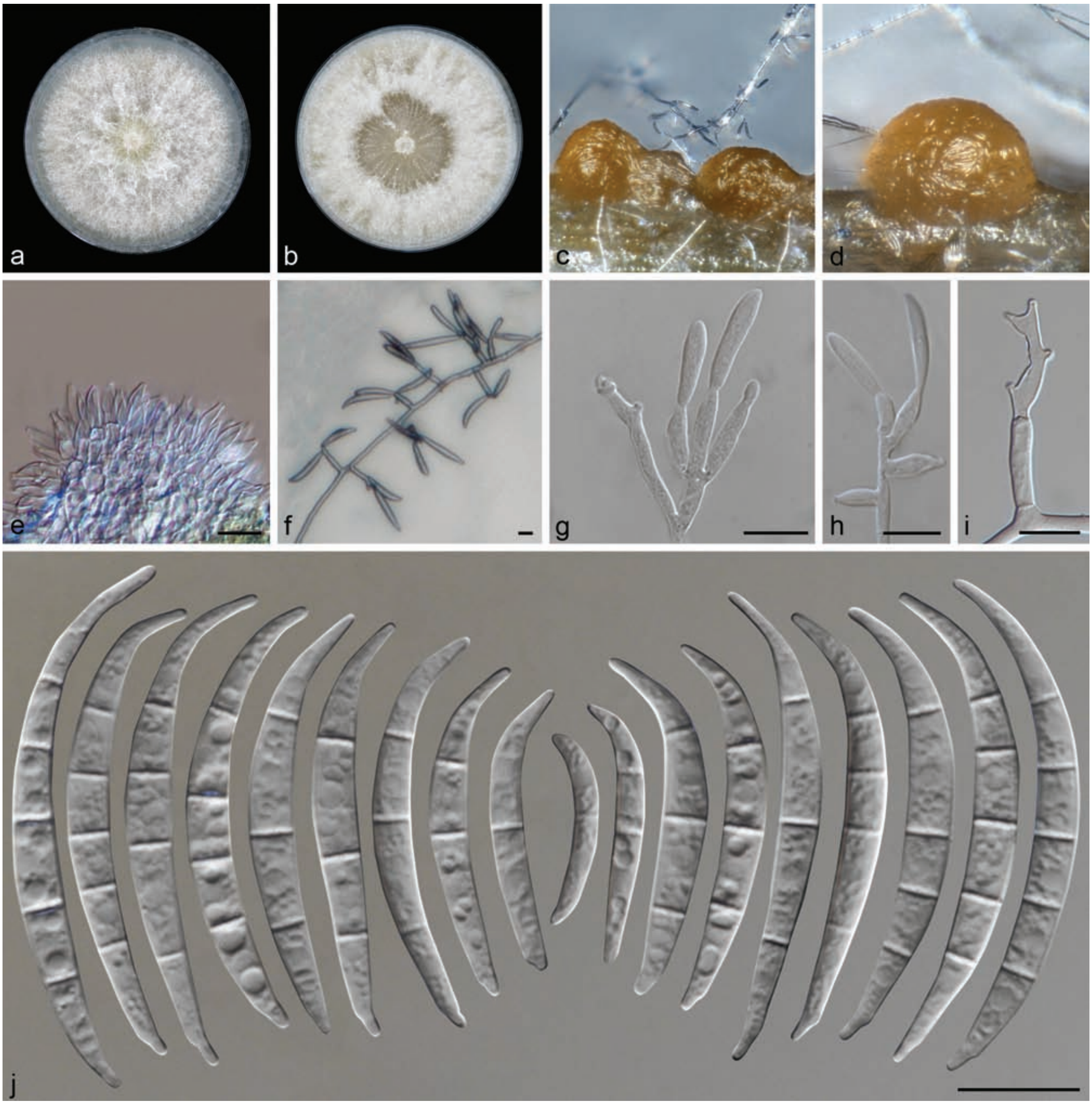


Fig. 18 *Fusarium multiceps* (CBS 130386, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on carnation leaves; e. sporodochial conidiophores; f. conidiophores on aerial mycelium; g–i. mono- and polyphialides; j. aerial conidia. — Scale bars = 10 µm.

Conidiophores borne on aerial mycelium, 20–55 µm tall, unbranched, sympodial or irregularly branched, bearing terminal or lateral phialides, often reduced to single phialides; *phialides* mono- and polyphialidic, subulate to subcylindrical, proliferating percurrently, smooth- and thin-walled, 7–34 × 2–5 µm, with inconspicuous periclinal thickening; *aerial conidia* hyaline, falcate, curved dorsiventrally, with a blunt to slightly papillate apical cell and a notched to foot-like basal cell, smooth- and thin-walled, (1–)3–4(–5)-septate; 1-septate conidia: (16–)19–25(–26) × 3–4 µm (av. 22 × 3 µm; *n* = 8); 2-septate conidia: (19–)21–31 × 3–4 µm (av. 26 × 4 µm, *n* = 6); 3-septate conidia: (26–)31–37(–40) × 3–4 µm (av. 34 × 4 µm); 4-septate conidia: (33–)35–41(–44) × 3–4 µm (av. 38 × 4 µm); 5-septate conidia: (36–)37–41(–42) × 4 µm (av. 39 × 4 µm; *n* = 12). *Sporodochia* salmon to orange, formed abundantly on carnation leaves or the surface of the medium. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, proliferating percurrently, 8–14 × 2–3 µm, smooth, thin-walled, with a short-flared apical collarette. *Sporodochial conidia* falcate, slender, curved dorsiventrally, tapering towards both ends, with a slightly elongated conical or whip-like curved apical cell and a foot-like to notched basal cell, (1–)2–5-septate, hyaline, thin- and smooth-walled; 1-septate conidia: (16–)18–24(–25) × 3–4 µm (av. 21 × 3 µm; *n* = 15); 2-septate conidia: (20–)22–26(–31) × 3–4 µm (av. 24 × 3 µm); 3-septate conidia: (25–)32–38(–42) × 3–4 µm (av. 35 × 4 µm); 4-septate conidia: (35–)37–43(–48) × 3–4 µm (av. 40 × 4 µm); 5-septate conidia: (36–)40–46(–49) × 3–4 µm (av. 43 × 4 µm). *Chlamydospores* not observed.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 7–10 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface white, flat, felty to velvety, radiate, with aerial mycelium, margin irregular, filiform. Odour mouldy. Reverse pale salmon. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface white and aerial mycelium absent in the centre forming a vacant circle, margin irregular, filiform. Reverse pale salmon. On SNA with abundant aerial mycelium and sporulation on the aerial mycelium.

Notes — *Fusarium multiceps* represents phylo-species FIESC 19 (O'Donnell et al. 2009), which formed a unique lineage basal (ML & MP-BS = 100 %; PP = 1.0) to *F. irregulare*, *F. luffae*, *F. pernambucanum* and *F. sulawesiensis* (FIESC 15–18; O'Donnell et al. 2009, Maryani et al. 2019, Santos et al. 2019, Wang et al. 2019). This species can be distinguished from *F. irregulare* based on the polyphialides formed by *F. multiceps*, but not observed for *F. irregulare*, and the 3-septate falcate aerial conidia (i.e., macroconidia) of *F. irregulare* (Wang et al. 2019) compared to the (1–)3–4(–5)-septate falcate aerial conidia of *F. multiceps*. *Fusarium pernambucanum* produces various shapes of aerial conidia (Santos et al. 2019) whereas only falcate aerial conidia were produced by *F. multiceps*. *Fusarium sulawesiensis* produces up to 9-septate falcate aerial conidia (Maryani et al. 2019), not seen for *F. multiceps*.

Fusarium nanum M.M. Wang et al., Persoonia 43: 85. 2019

Typus. China, Guangxi province, Guilin, from leaf of *Musa nana*, Aug. 2016, *Y.Z. Diao* (holotype HAMS 248043, culture ex-type CGMCC3.19498 = LC12168).

Description & Illustration — Wang et al. (2019).

Additional material examined. Australia, from sorghum, date unknown, *W.F.O. Marasas*, CBS 119867 = FRC R-4237 = MRC 3228. – Czech Republic, Semčice, from beet root seedling soil, 1979, *D. Veselý*, CPC 35142. – Iran, Kordkooy, Golestan, from *Triticum* sp., *M. Davari*, CBS 131780.

Notes — *Fusarium nanum* represents phylo-species FIESC 25 (O'Donnell et al. 2009, Wang et al. 2019), a well-supported clade (ML-BS = 98 %, MP-BS = 88 %, PP = 1.0) in the Incarnatum clade and closely related to *F. aberrans*, *F. hainanense* and *F. persicinum*. For morphological differences, see notes under *F. aberrans*. This species includes strains obtained from environmental, human and plant samples collected in Asia, Europe and North America (O'Donnell et al. 2009, Wang et al. 2019).

Fusarium neoscirpi L. Lombard, J.W. Xia, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831844; Fig. 19

Etymology. Name reflects the fact that the ex-type strain of this fungus was initially treated as *F. scirpi*.

Typus. France, from soil, 1995, *V. Edel* (holotype CBS H-24066 designated here, culture ex-type CBS 610.95 = NRRL 26861 = NRRL 26922).

Conidiophores borne on aerial mycelium, 25–50 µm tall, unbranched, rarely irregularly branched, bearing terminal or lateral phialides, often reduced to single phialides; *phialides* monophialidic, subulate to subcylindrical, sometimes proliferating percurrently, smooth- and thin-walled, 9–22 × 2–4 µm, with inconspicuous periclinal thickening; *aerial conidia* hyaline, smooth- and thin-walled, of two types: (a) ampulliform to ellipsoidal to reniform, 0–2(–3)-septate; 0-septate conidia: (9–)11–15(–22) × 3–4 µm (av. 13 × 3 µm, *n* = 17); 1-septate conidia: (11–)15–21(–24) × 3–4 µm (av. 18 × 4 µm); 2-septate conidia: 19–23(–28) × 3–5 µm (av. 21 × 4 µm, *n* = 14); 3-septate conidia: 20–24 × 4–5 µm (*n* = 3); (b) falcate, curved dorsiventrally, tapering towards both ends, with acute apical cell and notched to foot-like basal cell, 3–4-septate; 3-septate conidia: (21–)23–29 × 4–5 µm (av. 26 × 4 µm, *n* = 8); 4-septate conidia: (31–)32–36(–38) × 4 µm (av. 36 × 4 µm, *n* = 7). *Sporodochia* saffron to pale orange, formed abundantly on the carnation leaves and surface of the medium. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–4 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, 10–19 × 3–4 µm, smooth, thin-walled, with inconspicuous periclinal thickening; *sporodochial conidia* falcate, curved dorsiventrally, tapering towards both ends, with elongated and whip-like, curved apical cell and a notched to foot-like basal cell, (1–)3–5-septate, hyaline, smooth- and thin-walled; 1-septate conidia: (16–)19–25(–27) × 3–4 µm (av. 22 × 3 µm, *n* = 12); 2-septate conidia: 19–31(–36) × 3–5 µm (av. 25 × 4 µm, *n* = 7); 3-septate conidia: (28–)32–42(–46) × 4–5 µm (av. 37 × 4 µm); 4-septate conidia: (41–)44–50(–53) × 3–5 µm (av. 47 × 5 µm); 5-septate conidia: (47–)50–58(–64) × 4–6 µm (av. 54 × 5 µm). *Chlamydospores* not observed.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 8–12 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface white to buff, floccose, radiate, with abundant aerial mycelium, margin irregular, filiform. Odour mouldy. Reverse pale yellow. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface white to pale primrose, floccose in the centre, radiate, with less abundant aerial mycelium, margin irregular, filiform. Reverse pale yellow, without diffusible pigments. On SNA with sparse aerial mycelium and abundant sporulation on medium surface.

Notes — *Fusarium neoscirpi* formed a unique single strain lineage, closely related to *F. arcuatisporum*, *F. brevicaudatum*, *F. longicaudatum* and *F. serpentinum*. The ex-type of this novel species was initially resolved in the FIESC 9 (*F. scirpi*) clade by O'Donnell et al. (2009), forming a basal lineage in that clade and therefore designated as haplotype FIESC 9c. *Fusarium neoscirpi* can be distinguished from the latter four species

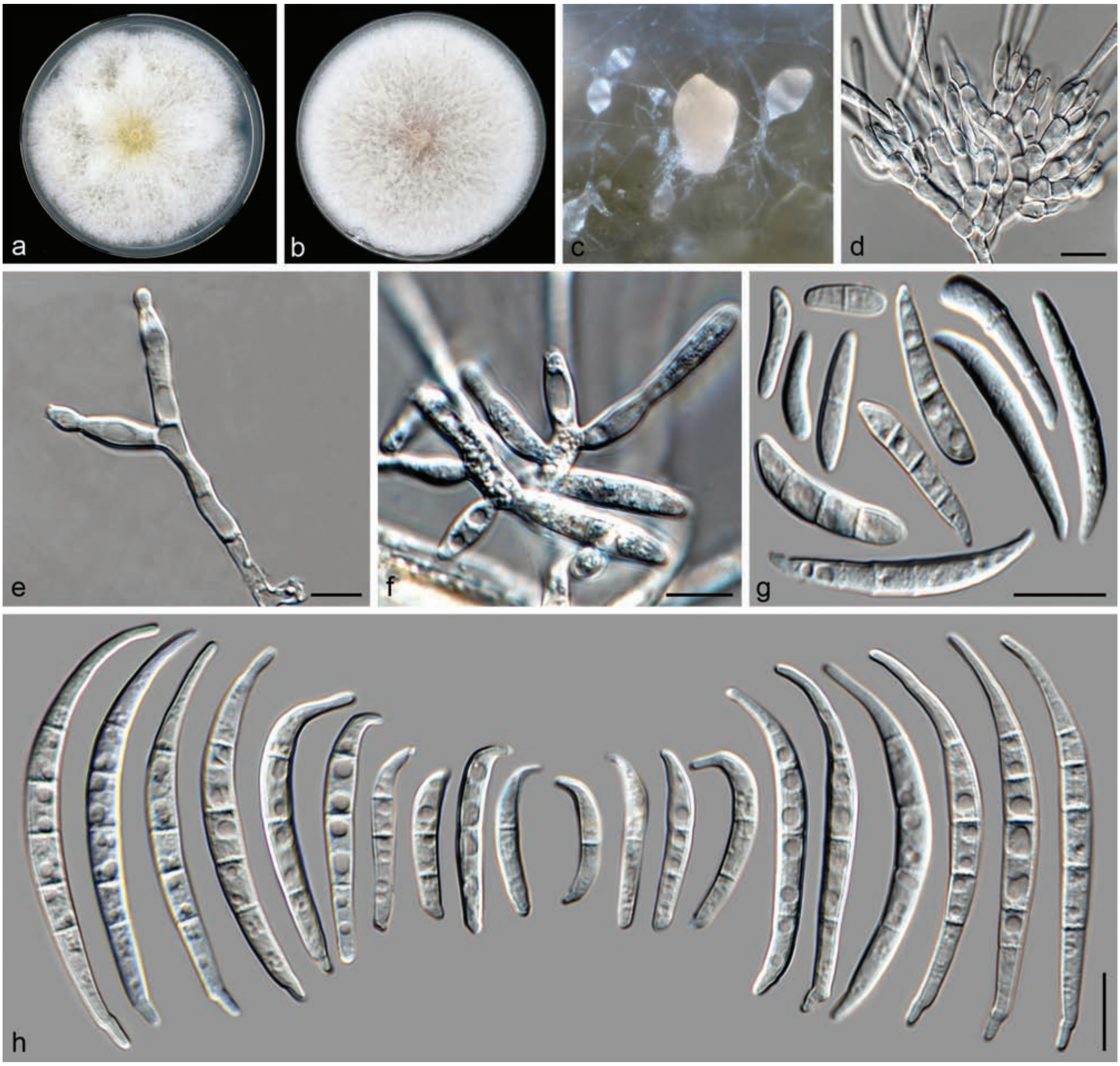


Fig. 19 *Fusarium neoscirpi* (CBS 610.95, ex-type culture). a. Colony on PDA; b. colony on OA; c. sporodochia on carnation leaves; d. sporodochial conidiophores; e–f. conidiophores on aerial mycelium with monophialides; g. aerial conidia; h. sporodochial conidia. — Scale bars = 10 μm.

by the formation of conidiophores and conidia on its aerial mycelia. Additionally, the sporodochial conidia of *F. neoscirpi* are (1–)3–5-septate, compared to the 5-septate of *F. arcuatisporum* (Wang et al. 2019), 1–5-septate of *F. brevicaudatum*, (3–)5–6(–7)-septate of *F. longicaudatum* and (3–)5–7(–8)-septate of *F. serpentinum*. This species can also be distinguished from *F. scirpi* by its less septate sporodochial conidia compared to the 6–7-septate of *F. scirpi* (Leslie & Summerell 2006) and the fact that *F. neoscirpi* produces falcate aerial conidia, not known for *F. scirpi* (Leslie & Summerell 2006). Furthermore, *F. scirpi* commonly has polyphialides (Leslie & Summerell 2006), not seen for *F. neoscirpi*.

Fusarium neosemitectum L. Lombard, J.W. Xia, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831845; Fig. 20

Etymology. Name reflects its morphological similarity to *F. semitectum*.

Typus. Democratic Republic of the Congo, from *Musa sapientum*, date and collector unknown (holotype CBS H-24067 designated here, culture ex-type CBS 189.60).

Conidiophores borne on aerial mycelium, 60–110 μm tall, unbranched or irregularly to rarely verticillately branched, bearing a single terminal or whorl of 2–3 phialides; *aerial phialides* mono- and polyphialidic, subulate to subcylindrical, smooth- and thin-walled, 10–30 × 2–4 μm, periclinal thickening inconspicuous or absent, often reduced to single phialidic pegs, 1.5–5 μm tall. *Aerial conidia* hyaline, ellipsoidal to falcate, curved dorsiventrally, with a blunt, conical to slightly papillate apical cell and a blunt to barely notched basal cell, smooth- and thin-walled, (1–)2–4(–5)-septate; 1-septate conidia: (17–)18–22(–24) × 3–5 μm (av. 20 × 4 μm; n = 13); 2-septate conidia: (14–)22–30(–36) × 4–6 μm (av. 26 × 5 μm); 3-septate conidia: (21–)25–33(–36) × 4–6 μm (av. 29 × 5 μm); 4-septate conidia: 30–38(–41) × 4–6 μm (av. 34 × 5 μm); 5-septate conidia: 35–39 × 5–6 μm (av. 37 × 5 μm; n = 3). *Sporodochia* and *chlamydospores* not observed.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 4–7 mm/d and reaching 75–82 mm diam in 7 d; surface white, flat, felty to velvety, radiate, with abundant aerial mycelium, margin entire. Odour mouldy. Reverse without colour. Diffusible pig-

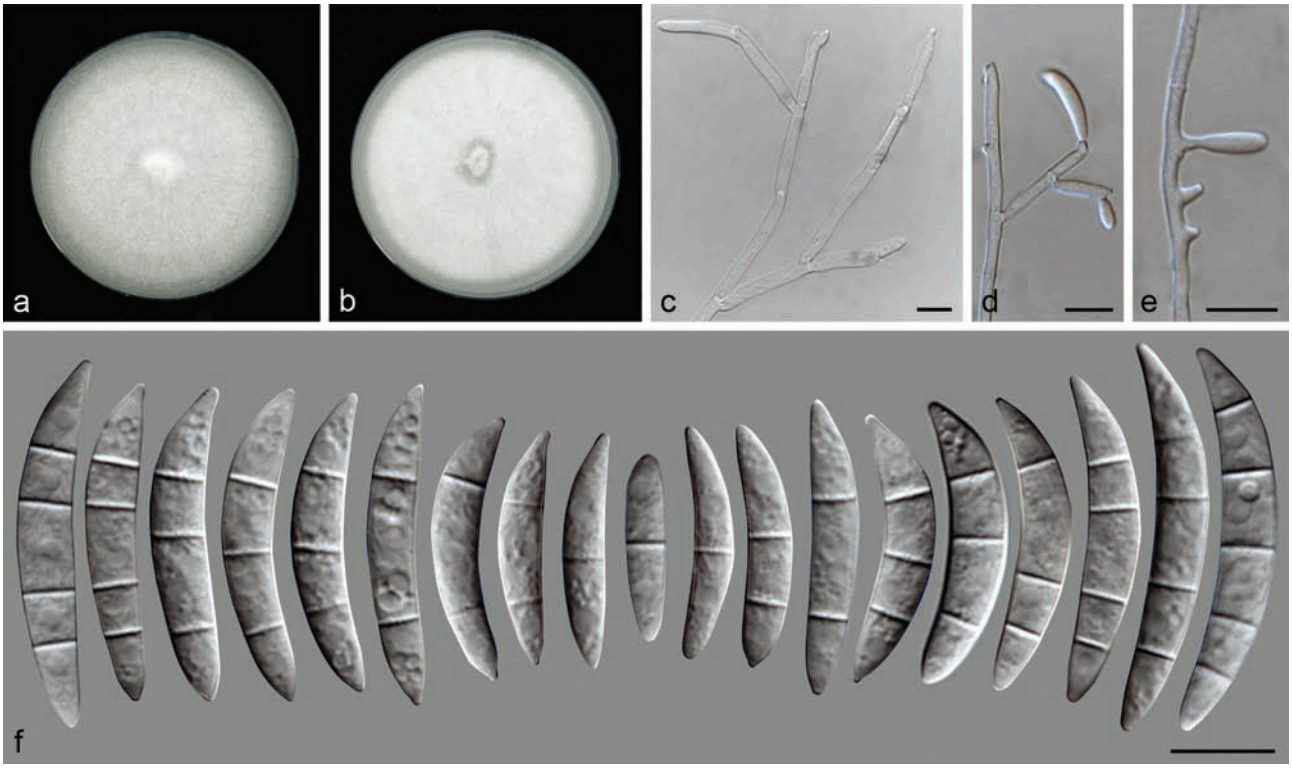


Fig. 20 *Fusarium neosemitectum* (CBS 189.60, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. conidiophores on aerial mycelium with mono- and polyphialides; e. lateral phialidic peg on aerial mycelium; f. aerial conidia. — Scale bars = 10 μm.

ments absent in the dark. On OA in the dark reaching 90 mm in 7 d; surface white, flat, felty to dusty, with abundant aerial mycelium, margin entire. Reverse colourless, without diffusible pigments. On SNA with sparse aerial mycelium, sporulation abundant on the surface of the medium.

Additional material examined. Democratic Republic of the Congo, from *Musa sapientum*, date and collector unknown, CBS 190.60 = NRRL 25801.

Notes — *Fusarium neosemitectum* formed a fully supported clade (ML & MP-BS = 100 %; PP = 1.0) in the FCAMSC. It can be distinguished from its closest phylogenetic neighbours (*F. kotabaruense* and *F. camptoceras*) by the presence of short phialidic pegs on the aerial mycelium, not observed for the latter two species. Furthermore, *F. neosemitectum* only produces up to 5-septate falcate aerial conidia, whereas up to 7-septate falcate aerial conidia have been reported for both *F. kotabaruense* and *F. camptoceras* (Gerlach & Nirenberg 1982, Marasas et al. 1998, Maryani et al. 2019). All three species in FCAMSC appear to be tropical species due to their origins and they also share a mutual host genus, *Musa* (Marasas et al. 1998, Maryani et al. 2019). However, their relevance as pathogens to this host (and other plants) still remains to be determined.

Fusarium pernambucanum A.C.S. Santos et al., Mycologia 111: 253. 2019

Typus. Brazil, Pernambuco, Paudalho, from *Aleurocanthus woglumi*, June 2016, *A.C.S. Santos* (holotype URM 91193, culture ex-type MUM 1862 = URM 7559).

Description & Illustration — Santos et al. (2019).

Additional materials examined. Iran, Parsabad, Natural Resource site, from *Setaria verticilata*, date unknown, *M. Davari*, CBS 131097. – Thailand, Bangkok, Mahidol University, from human fingernail, date and collector unknown, CBS 132194; from human foot, *M. Sudhabham & S. Bunyarata*, CBS 133024; from human toenail, date and collector unknown, CBS 132894. – USA, Texas, from human, date unknown, *J. Swezey*, CBS 130312 = NRRL 32864 = FRC R-7245. – Unknown locality, from *Musa sampientum*, unknown date and collector, CBS 791.70.

Notes — *Fusarium pernambucanum* represents phylo-species FIESC 17 forming a well-supported clade (ML & MP-BS = 92 %, PP = 1.0) in the Incarnatum clade. This species was first introduced by Santos et al. (2019), producing a gibberella-like sexual morph in heterothallic matings. For morphological comparisons, see notes under *F. irregulare* and *F. luffae*, and Santos et al. (2019).

Fusarium persicinum J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831846; Fig. 21

Etymology. Name refers to the peach-coloured colonies formed on OA and PDA by this fungus.

Typus. Unknown locality, substrate and date, *R.L. Quiroga de Pascual* (holotype CBS H-24068 designated here, culture ex-type CBS 479.83)

Conidiophores borne on aerial mycelium, 20–205 μm tall, unbranched, sympodial or irregularly branched, bearing terminal or lateral phialides, often reduced to single phialides; phialides mono- and polyphialidic, subulate to subcylindrical, proliferating percurrently, smooth- and thin-walled, 13–19 × 3–5 μm, with inconspicuous periclinal thickening; aerial conidia falcate, slender, straight to slightly curved dorsiventrally, tapering towards both ends, with a conical to slightly papillate apical cell and a blunt to barely notched basal cell, 3–5-septate; 3-septate conidia: (26–)31–41(–44) × 4–6 μm (av. 36 × 5 μm); 4-septate conidia: (37–)39–45(–49) × 4–6 μm (av. 42 × 5 μm); 5-septate conidia: (39–)43–49(–54) × 5–6 μm (av. 46 × 5 μm). *Sporodochia* and *chlamydospores* not observed.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 2–4 mm/d and reaching 40–55 mm diam in 7 d; surface salmon to peach, flat, felty to velvety, radiate, with aerial mycelium, margin irregular, filiform. Odour mouldy. Reverse salmon. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface pale salmon to peach, flat, radiate, aerial mycelium sparse, margin irregular, filiform. Reverse straw. On

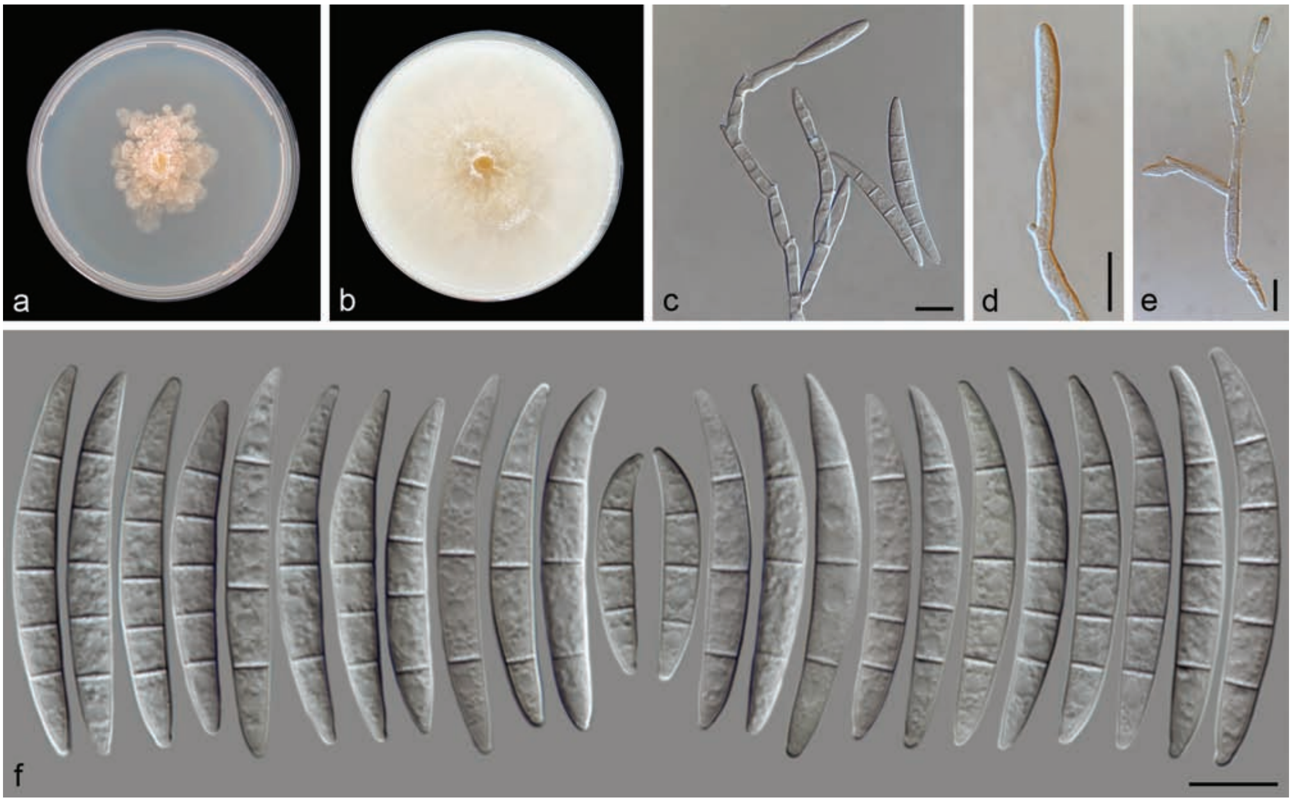


Fig. 21 *Fusarium persicinum* (CBS 479.83, ex-type culture). a. Colony on PDA; b. colony on OA; c–e. conidiophores on aerial mycelium with mono- and polyphialides; f. aerial conidia. — Scale bars = 10 µm.

SNA with abundant aerial mycelium and sporulation on the aerial mycelium.

Additional materials examined. Iran, Lake Urmia, from soil near lake, date unknown, *M.J. Najafzadeh*, CBS 132821; Golestan, Kalaleh, from *Triticum* sp., date unknown, *M. Davari*, CBS 131780; Moghan-Ardabil province, from *Ganoderma* sp., 4 Oct. 2015, *M. Torbati*, CBS 143595 = CPC 30847; ibid., from *Stereum hirsutum*, 5 Oct. 2015, *M. Torbati*, CBS 143596 = CPC 30848; ibid., from smut, 6 Oct. 2015. *M. Torbati*, CBS 143597 = CPC 30849, CBS 143598 = CPC 30850, CBS 143600 = CPC 30852, CBS 143603 = CPC 30855, CBS 143606 = CPC 30858.

Notes — *Fusarium persicinum* formed a well-supported clade (ML & MP-BS = 97 %, PP = 1.0) in the Incarnatum clade, sister to the *F. nanum* clade. This clade was initially assigned to phylo-species FIESC 29 & 30 by Torbati et al. (2019) and includes numerous fungicolus isolates originating mostly from Basidiomycetes (Torbati et al. 2019). Similar to *F. nanum*, no sporodochia were formed in culture by any of the isolates of *F. persicinum* studied here. However, abundant falcate aerial conidia (3–5-septate) were produced by *F. persicinum*, whereas *F. nanum* also produced falcate (3-septate) and obovoid (i.e., microconidia) aerial conidia (Wang et al. 2019), the latter not seen for *F. persicinum*. The 3-septate falcate aerial conidia of *F. nanum* (20.5–32 × 3–5 µm; Wang et al. 2019) are smaller than those of *F. persicinum* ((26–)31–41(–44) × 4–6 µm).

Fusarium scirpi Lambotte & Fautrey, Rev. Mycol. (Toulouse) 16: 111. 1894 — Fig. 22

Synonyms. *Fusisporium chenopodium* Thüm., Bull. Soc. Imp. Naturalistes Moscou: no. 1378. 1879.

Fusarium chenopodinum (Thüm.) Sacc., Syll. Fung. 4: 701. 1886.

Fusarium sclerotium Wollenw., Ber. Deutsch. Bot. Ges. 31: 31. 1913.

Fusarium bullatum Sherb., Cornell Univ. Agric. Exp. Sta. Mem. 6: 198. 1915.

Fusarium equiseti var. *bullatum* (Sherb.) Wollenw., Fus. Autogr. Del. 3: 916. 1930.

Fusarium gibbosum var. *bullatum* (Sherb.) Bilaĭ, Mykro. Zhu. Kiev 49: 6. 198. 1987.

For more synonyms see Wang et al. 2019.

Typus. France, from *Schoenoplectus lacustris* (= *Scirpus lacustris*), 1893, F. Fautrey, Roumeguere #6540 in BPI and NY. – Australia, New South Wales, near Broken Hill, from pasture soil, 1981, *P.E. Nelson* (epitype CBS H-24069 designated here, MBT387961, culture ex-epitype CBS 447.84 = FRC R-6252 = NRRL 36478).

Descriptions & Illustrations — Wollenweber (1916–1935), Wollenweber & Reinking (1935), Burgess et al. (1985), Leslie & Summerell (2006).

Additional material examined. Australia, New South Wales, near Broken Hill, from pasture soil, 1981, *P.E. Nelson*, CBS 448.84 = FRC R-6253.

Notes — Wollenweber (1916–1935) first illustrated *F. scirpi* as *F. chenopodium* and/or *F. equiseti* var. *bullatum*. However, Wollenweber & Reinking (1935) later recognised *F. scirpi* as a species and synonymised both *F. chenopodium* and *F. equiseti* var. *bullatum* under *F. scirpi.* Both Gordon (1952) and Booth (1971) regarded *F. scirpi* as a synonym of *F. equiseti*, whereas Gerlach & Nirenberg (1982) and Nelson et al. (1983) recognised *F. scirpi* as a distinct species. Burgess et al. (1985) studied the type materials of both *F. chenopodinum* (Mycotheca Universalis Thuemen #1378) and *F. scirpi* (Roumeguere #6540) and could not find any *Fusarium* structures on the latter type material examined. Although Burgess et al. (1985) were able to find a few sporodochia containing sporodochial conidia (i.e., macroconidia) on the *F. chenopodinum* type material, no microconidia or polyphialides could be found. Therefore, they emended *F. scirpi* based on 100 cultures collected in Australia, characterised by fusiform, obovoid and allantoid, 0–3-septate microconidia borne on short, truncate and often cross-shaped polyphialides borne on the aerial mycelium, selecting FRC R-6252 (= CBS 447.84) and FRC R-6253 (= CBS 448.84) as representatives. As the name *F. scirpi* has been applied to the phylo-species FIESC 9 (O'Donnell et al. 2009, Villani et al. 2016, 2019, Jacobs et al. 2018, Santos et al. 2019, Wang et al. 2019), we prefer to fix the name to FIESC 9 through epitypification. The ex-epitype of *F. scirpi* clustered in a fully supported clade (ML & MP-BS = 100 %, PP = 1.0) in the Equiseti clade.

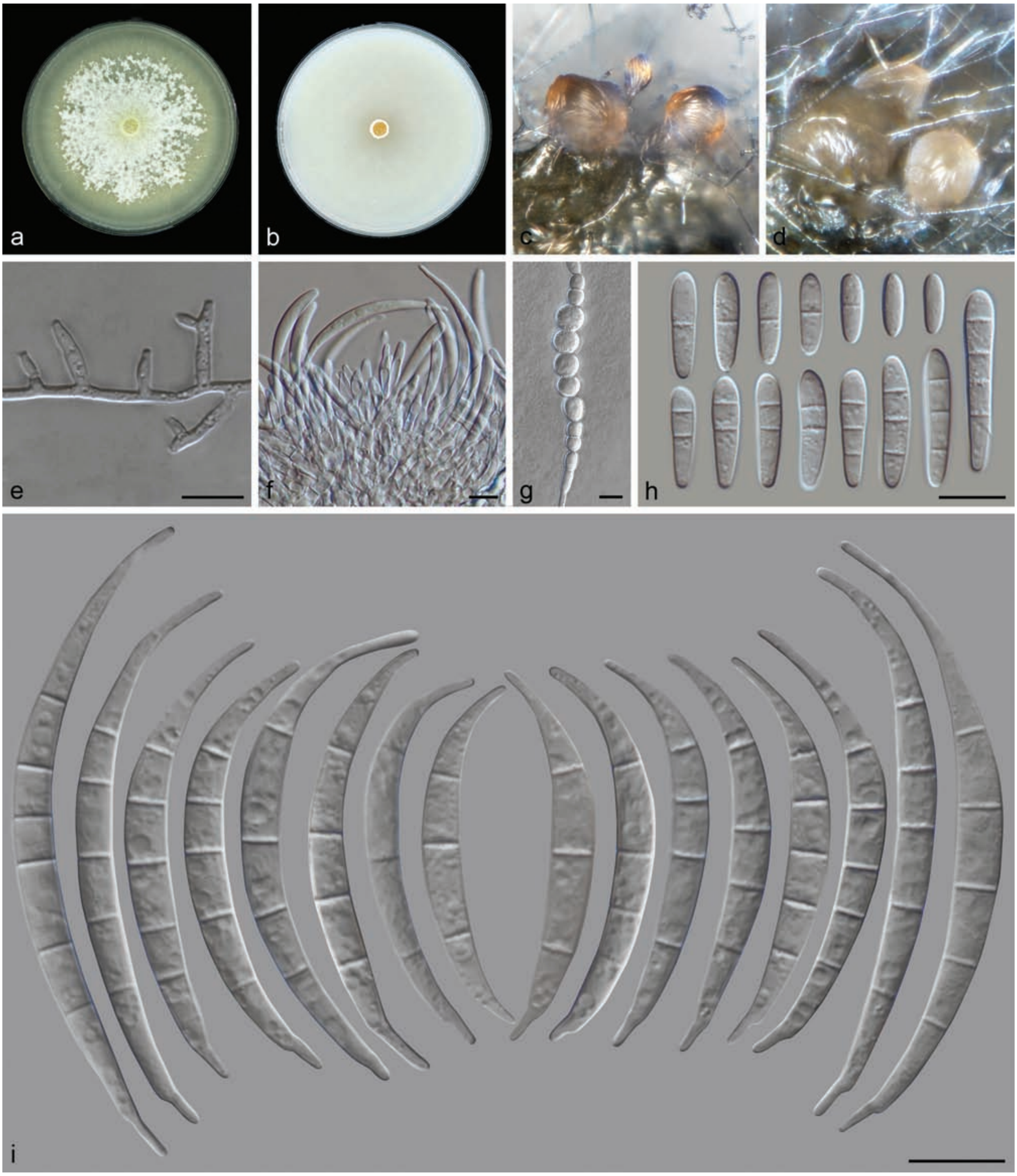


Fig. 22 *Fusarium scirpi* (CBS 447.84, ex-neotype culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on carnation leaves; e. conidiophores on aerial mycelium with mono- and polyphialides; f. sporodochial conidiophores; g. chlamydospores; h. aerial conidia; i. sporodochial conidia. — Scale bars = 10 μm.

Fusarium serpentinum J.W. Xia, L. Lombard, Sand.-Den., X.G. Zhang & Crous, *sp. nov.* — MycoBank MB831847; Fig. 23

Etymology. Name refers to the elongated serpentine-like apical cells of the sporodochial conidia produced by this fungus.

Typus. Unknown location, substrate and date, *W.F.O. Marasas* (holotype CBS H-24070 designated here, culture ex-type CBS 119880 = BBA 62209 = MRC 1813).

Conidiophores and *aerial conidia* borne on aerial mycelium not observed. *Sporodochia* saffron to brick, formed abundantly on carnation leaves. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, 12–24 × 4–5 μm, smooth, thin-walled, with a short-flared apical collarette. *Sporodochial conidia* falcate, sometimes sinuate, slender, strongly curved or curved dorsiventrally, tapering towards both ends, with an elongate or whip-like curved apical cell and a notched, often prominent and extended basal cell, (3–)5–7(–8)-septate, hyaline, thin- and smooth-walled, microcyclic conidiogenesis commonly observed; 3-septate conidia: (42–)43–51(–54) × 4–6 μm (av. 47 × 5 μm, *n* = 6); 4-septate conidia: 54–75 × 4–6 μm (av. 57 × 5 μm, *n* = 4); 5-septate conidia: (57–)67–85(–92) × 4–6 μm (av. 76 × 5 μm); 6-septate

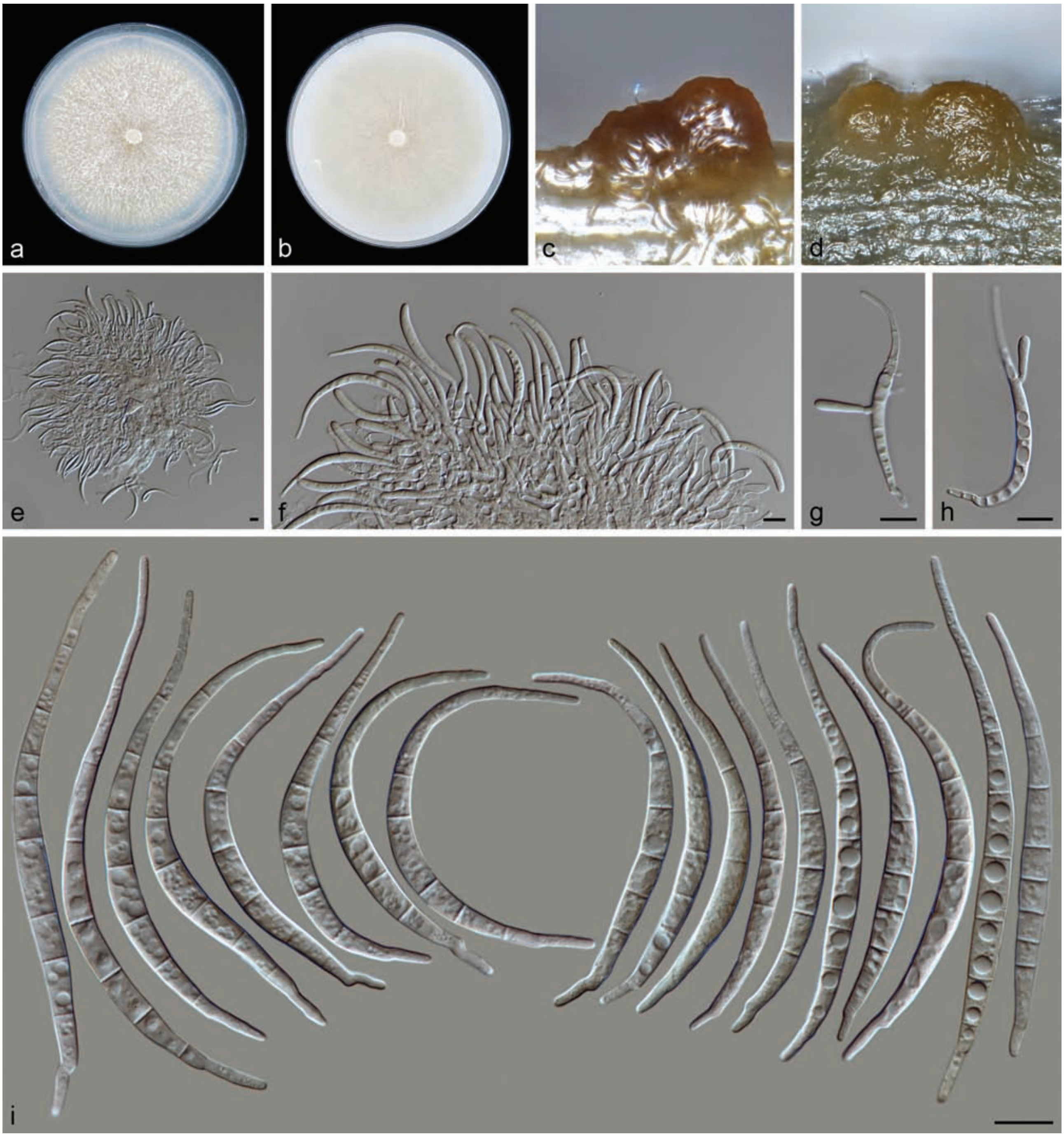


Fig. 23 *Fusarium serpentinum* (CBS 119880, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on carnation leaves; e–f. sporodochial conidiophores; g–h. microcyclic conidiation; i. sporodochial conidia. — Scale bars = 10 μm.

conidia: (70–)77–91(–97) × 4–6 μm (av. 84 × 5 μm); 7-septate conidia: (69–)80–96(–107) × 4–6 μm (av. 88 × 5 μm); 8-septate conidia: (87–)90–104(–107) × 4–6 μm (av. 97 × 5 μm, *n* = 6). *Chlamydospores* not observed.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 7–10 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface salmon, floccose, radiate, with abundant aerial mycelium, margin irregular, filiform. Odour mouldy. Reverse pale straw. Diffusible pigments absent. On OA in the dark occupying an entire 90 mm Petri dish in 7 d; surface pale primrose, membranous to dust, aerial mycelium sparse, margin irregular, filiform. Reverse pale primrose, without diffusible pigments. On SNA with sparse aerial mycelium.

Notes — *Fusarium serpentinum* represents a new single strain lineage resolved in the Equiseti clade. This species can be distinguished from other species in the complex based on the extraordinary long sporodochial conidia due to the elongated apical cells and microcyclic conidiogenesis that was commonly observed in culture.

Fusarium sulawesiense Maryani et al. (as '*sulawense*'), Persoonia 43: 65. 2019

Typus. Indonesia, Desa Seli, Kecamatan Bengo, Bone, Sulawesi Selatan (E120°1'12.8" S4°37'26"), on infected pseudostem of *Musa acuminata* var. Pisang Cere (AAA), 12 Aug. 2015, *N. Maryani* (holotype specimen and culture, InaCC F940, preserved in metabolically inactive state).

Description & Illustration — Maryani et al. (2019).

Additional materials examined. Bahamas, Windward Islands, from *Musa sapientum* var. *robusta*, date unknown, *O.J. Burden*, CBS 131.73 = ATCC 24386 = IMI 160602 = NRRL 20425. – Brazil, from seed of *Bixa orellana*, 9 Dec. 1986, *J.C. Frisvard*, CBS 622.87 = NRRL 26858 = NRRL

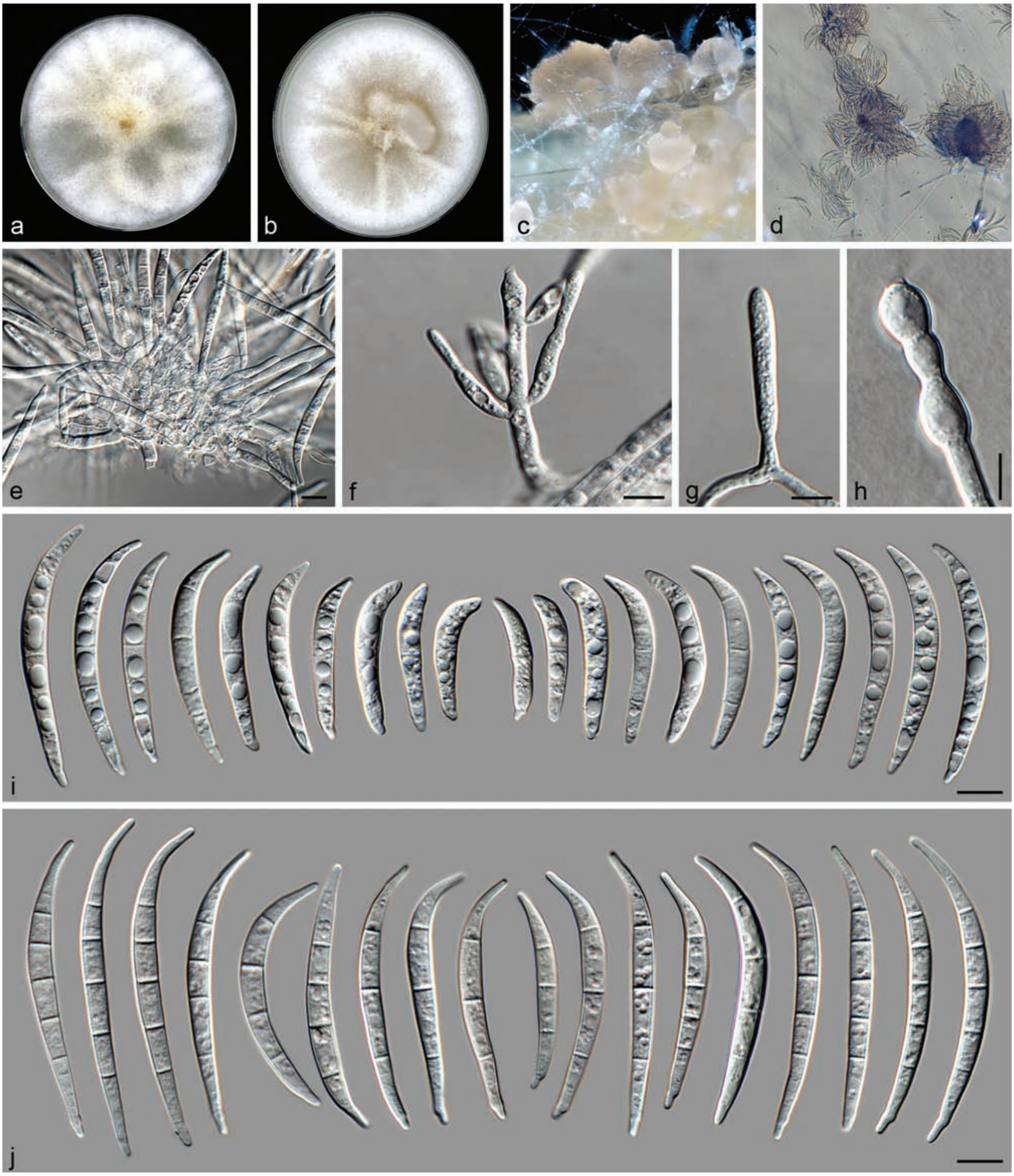


Fig. 24 *Fusarium toxicum* (CBS 406.86, ex-type culture). a. Colony on PDA; b. colony on OA; c–d. sporodochia on carnation leaf and medium; e. sporodochial conidiophores; f. conidiophore on aerial conidia; g. lateral monophialides on aerial mycelium; h. chlamydospores. i. aerial conidia; j. sporodochial conidia. — Scale bars = 10 μm.

26919 = NRRL 28583; from Galia melon imported into the Netherlands, 2007, *J. Houbraken*, CBS 122439. – El Salvador, from *Gossypium hirsutum*, Nov. 1959, *R. Schneider*, CBS 193.60 = BBA 9002 = DSM 62204 = MUCL 27679. – Trinidad and Tobago, from *Sorghum vulgare*, date unknown, *M.A. Gordon*, CBS 163.57. – USA, Texas, from human BAL fluid, date and collector unknown, CBS 130318 = NRRL 34004 = UTHSC 64-2581.

Notes — Maryani et al. (2019) introduced *F. sulawesiense* (as *F. sulawense*) representing phylo-species FIESC 16. This species formed a well-supported clade (ML-BS = 79 %, MP-BS = 96 %, PP = 0.99) in the Incarnatum clade. This species displays a broad host range which includes both human and plant substrates. For morphological comparisons, see notes under *F. irregulare* and Wang et al. (2019).

Fusarium tanahbumbuense N. Maryani et al., Persoonia 43: 63. 2019

Typus. Indonesia, Desa Betung, Kecamatan Kusan Hilir, Tanah Bumbu, Kalimantan Selatan (E115°37'477" S3°50'77"), on infected pseudostem of *Musa* sp. var. Pisang Hawa (ABB), 20 June 2014, *N. Maryani* (holotype specimen and culture, InaCC F965, preserved in metabolically inactive state).

Description & Illustration — Maryani et al. (2019).

Additional materials examined. Iran, Aslandooz, Parsabad, from *Triticum* sp., date unknown, *M. Davari*, CBS 131009. – Unknown locality, substrate and date, *H.W. Wollenweber*, CBS 145.44 = BBA 4095.

Notes — *Fusarium tanahbumbuense* was introduced by Maryani et al. (2019) to represent phylo-species FIESC 24, resolved here as a fully supported clade (ML & MP-BS = 100 %, PP = 1.0) closely related to *F. bubalinum*, *F. incarnatum* and *F. monophialidicum*. See notes under *F. bubalinum* and *F. monophialidicum* for morphological differences.

Fusarium toxicum L. Lombard & J.W. Xia, *sp. nov.* — MycoBank MB831848; Fig. 24

Etymology. Name refers to the mycotoxins, zearalenone and equisetin produced by the ex-type culture of this fungus.

Typus. Germany, Berlin, from soil, 25 Nov. 1985, *U. Thrane* (holotype CBS H-24071 designated here, culture ex-type CBS 406.86 = FRC R-8507 = IMI 309347 = NRRL 25796).

Conidiophores borne on aerial mycelium, 30–50 µm tall, unbranched or rarely verticillately branched, bearing a whorl of 2–4 phialides, sometimes reduced to a single lateral phialide or phialidic peg; *aerial phialides* monophialidic, subulate to subcylindrical, smooth- and thin-walled, 12–22 × 3–5 µm, periclinal thickening inconspicuous. *Aerial conidia* hyaline, falcate, curved dorsiventrally, with a blunt to slightly papillate or elongated apical cell and a blunt to barely notched or foot-like basal cell, smooth- and thin-walled, 1–5-septate; 1-septate conidia: (22–)26–34(–38) × 4–6 µm (av. 30 × 5 µm); 2-septate conidia: (32–)34–40(–43) × 5–6 µm (av. 37 × 5 µm; n = 19); 3-septate conidia: (29–)34–46(–52) × 4–6 µm (av. 40 × 5 µm); 4-septate conidia: (40–)41–49(–51) × 4–6 µm (av. 45 × 5 µm; n = 12); 5-septate conidia: (42–)46–54(–57) × 4–6 µm (av. 50 × 5 µm). *Sporodochia* peach to saffron, formed abundantly on carnation leaves and media surface. *Sporodochial conidiophores* densely and irregularly branched, bearing apical whorls of 2–3 phialides; *sporodochial phialides* monophialidic, subulate to subcylindrical, 10–19 × 3–5 µm, smooth-walled to slightly roughened, thin-walled, with a short-flared apical collarette. *Sporodochial conidia* falcate, slender, curved dorsiventrally, tapering towards both ends, with an elongate or whip-like curved apical cell and a foot-like to notched basal cell, 3–5-septate, hyaline, thin- and smooth-walled; 3-septate conidia: (32–)39–51(–55) × 4–5 µm (av. 45 × 5 µm); 4-septate conidia: (45–)48–54(–57) × 4–6 µm (av. 51 × 5 µm); 5-septate conidia: (50–)52–58(–64) × 4–6 µm (av. 55 × 5 µm). *Chlamydospores* abundant, globose to subglobose, subhyaline, smooth- to slightly rough-walled, terminal or intercalary, solitary or in pairs forming chains, 6–12 µm diam.

Culture characteristics — Colonies on PDA incubated at 24 °C in the dark with an average radial growth rate of 6–11 mm/d and occupying an entire 90 mm Petri dish in 7 d; surface white to buff, felty to velvety, radiate, with abundant aerial mycelium, margin entire. Odour mouldy. Reverse without colour. Diffusible pigments absent. On OA in the dark reaching 90 mm in 7 d; surface white to salmon with buff centre, flat, felty to dusty, with abundant aerial mycelium, margin entire. Reverse colourless, without diffusible pigments. On SNA with sparse aerial mycelium, sporulation abundant on the surface of the medium.

Additional material examined. Germany, Darmstadt, from soil, date unknown, *E. Merck*, CBS 219.63. – USA, Texas, from dog, date unknown, *J. Swezey*, CBS 130385.

Notes — *Fusarium toxicum* represents phylo-species FIESC 14-b, and forms a well-supported clade (ML-BS = 96 %, MP-BS = 98 %, PP = 0.99), sister to *F. equiseti* (FIESC 14-a; O'Donnell et al. 2009). Similar to *F. equiseti*, *F. toxicum* only produced falcate aerial- and sporodochial conidia in culture. However, *F. toxicum* only produced 1–5-septate falcate conidia (aerial and sporodochial), whereas *F. equiseti* usually produce 5–7-septate falcate conidia (Gerlach & Nirenberg 1982, Leslie & Summerell 2006). Additionally, the apical cells of both the aerial and sporodochial falcate conidia of *F. toxicum* are much less elongated and whip-like than those illustrated for *F. equiseti* (Leslie & Summerell 2006). Metadata of the ex-type culture CBS 406.86 indicates that this isolate is able to produce the mycotoxins zearalenone and equisetin.

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