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ORIGINAL ARTICLE

Cylindrocarpon root rot: multi-gene analysis reveals novel species within the *Ilyonectria radicicola* species complex

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Abstract *Ilyonectria radicicola* and its *Cylindrocarpon*-like anamorph represent a species complex that is commonly associated with root rot disease symptoms on a range of hosts. During the course of this study, several species could be distinguished from *I. radicicola* sensu stricto based on morphological and culture characteristics. DNA sequence analysis of the partial β-tubulin, histone H3, translation elongation factor 1-α and nuclear ribosomal RNA-Internal Transcribed Spacer (nrRNA-ITS) genes were employed to provide further support for the morphological species resolved among 68 isolates associated with root rot disease symptoms. Of the various loci screened, nrRNA-ITS sequences were the least informative, while histone H3 sequences were the most informative, resolving the same number of species as the combined dataset across the four genes. Within the *Ilyonectria radicicola* species complex, 12 new taxa are delineated occurring on a diverse range of hosts, the most common being *Cyclamen*, *Lilium*, *Panax*, *Pseudotsuga*, *Quercus* and *Vitis*.

Keywords *Cylindrocarpon* root rot · *Nectria*-like fungi · Phylogeny · Systematics

Introduction

The genus *Cylindrocarpon* was introduced in 1913 by Wollenweber, with *C. cylindroides* as type. *Cylindrocarpon* and *Cylindrocarpon*-like species have since been commonly associated with root and decay of woody and herbaceous plants (Domsch et al. 2007). Cylindrocarpon root rot causes losses up to 30% on ginseng (*Panax quinquefolium*) (Seifert et al. 2003), and plays an important role in black foot rot of grapevines (Halleen et al. 2004, 2006), apple replant disease (Tewoldemedhin et al. 2010), and beech cankers (Castlebury et al. 2006), to name but a few hosts of economic importance.

In his taxonomic revision of *Cylindrocarpon*, Booth (1966) divided this genus into four groups based on the presence or absence of microconidia or chlamydospores. Booth's group 4 represents *Neonectria* s. str., as it accommodates the type species *N. ramulariae* (anamorph: *C. obtusiusculum*). Most of the teleomorphs of *Cylindrocarpon* species have since this date been classified in *Neonectria* (Brayford et al. 2004; Halleen et al. 2004, 2006; Mantiri et al. 2001; Rossman et al. 1999). Several phylogenetic studies have, however, revealed that *Neonectria/Cylindrocarpon* is paraphyletic (Castlebury et al. 2006; Halleen et al. 2004, 2006; Hirooka et al. 2005; Mantiri et al. 2001). The first step in resolving this issue was taken by Halleen et al. (2004), who proposed *Campylocarpon* for species resembling *Cylindrocarpon* with 3–5-septate, curved macroconidia, and

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lacking microconidia. A further phylogenetic study (Chaverri et al. 2011) divided the *Neonectria* complex into four genera based on a combination of characters linked to perithecial anatomy and conidial septation: *Ilyonectria, Neonectria/Cylindrocarpon* s. str., *Rugonectria* and *Thelonectria*. In this study, a single generic name was proposed for each clade in an attempt to move towards a single nomenclature for pleomorphic fungi, meaning that the *Cylindrocarpon*-like anamorphs of *Ilyonectria, Rugonectria* and *Thelonectria* were placed in teleomorph genera, as recently done with other groups of pleomorphic fungi (Crous et al. 2006, 2007, 2009a; Gräfenhan et al. 2011; Lombard et al. 2010; Schroers et al. 2011).

Cylindrocarpon root rot is commonly associated with "*Cylindrocarpon*" *destructans* in the literature (Halleen et al. 2004; Samuels and Brayford 1990). This fungus was originally described as *Ramularia destructans* from roots of ginseng (*Panax quinquefolium*) collected in the USA (Zinssmeister 1918). Furthermore, it has been linked to the teleomorph *Ilyonectria radicicola* (Booth 1966; Chaverri et al. 2011; Samuels and Brayford 1990), which Gerlach and Nilsson (1963) described from rotting bulbs of *Cyclamen persicum* collected in Sweden. Samuels and Brayford (1990) commented on the morphological variation in collections of *I. radicicola* and its anamorph *"C." destructans*. Seifert et al. (2003) showed that there was more than one *"C." destructans*-like species occurring on *Panax,* and that none of the resolved clades correlated to the ex-type strain of *I. radicicola*, leading Halleen et al. (2006) to question the purported anamorph/teleomorph link between *I. radicicola* (from *Cyclamen*, Sweden) and *"C." destructans* (from *Panax*, USA). Based on a phylogenetic analysis of ITS nrRNA gene sequences, Schroers et al. (2008) concluded that the *I. radicicola* complex includes *"C." destructans*, *"C." destructans* var *crassum*, *I. coprosmae*, *I. liriodendri, N. austroradicicola* and *N. macroconidialis*.

The aim of the present study was to elucidate the morphological variation present within the *I. radicicola* complex, and to link fresh collections to older names introduced for species in this complex. This was addressed by combining morphological and culture characteristics with DNA sequence data derived from the Internal Transcribed Spacers (ITS) of the nrRNA gene operon, and partial β-tubulin (TUB), histone H3 (HIS), and translation elongation factor 1-α (TEF) genes.

Materials and methods

Isolates

This study (Table 1) included 42 "*C.*" *destructans* s. lat. isolates [including the ex-type strains of *I. radicicola* (CBS 264.65) and "*C.*" *destructans* f.sp. *panacis* (CBS 124662), "*C.*" *destructans* var. *destructans* and "*C.*" *destructans* var. *crassum*], six "*C.*" *didymum* isolates, six *I. liriodendri* isolates, one *N. macroconidialis* isolate and one *I. coprosmae* isolate, all deposited at the CBS-KNAW Fungal Biodiversity Centre, Utrecht, the Netherlands (CBS). Also included are two isolates that were previously identified as *Ramularia mors-panacis* (CBS 306.35) and *R. panacicola* (CBS 307.35) by Hildebrand (1935).

Besides those, 10 "*Cylindrocarpon*" spp. isolates were obtained in Portugal from grapevine plants showing decline symptoms, either 1- to 6-year-old plants in vineyards (Cy22, Cy155, Cy158, Cy190, CBS 129078, CBS 129080, CBS 129081, CBS 129082) or from rootstock nurseries (Cy23), and from a 25-year-old grapevine plant with esca symptoms (CBS 129084). Furthermore, isolates were obtained from a young *Malus domestica* (Cy164) and from the stem of a young *Quercus suber* (Cy232) plant, both showing decline symptoms, and from *Thymus* sp. (Cy231) and *Ficus* sp. (Cy228). One isolate (Cy131) was made available by P. Lecomte (Institut National de la Recherche Agronomique, Bordeaux-Aquitaine, France) and was obtained from an internal lesion of a stem of *Actinidia chinensis* 'Hayward'. Another isolate (Cy122) was made available by W.D. Gubler (University of California, Davis, USA) and was obtained from *Vitis* sp. All of these isolates are stored in a culture collection at the Laboratório de Patologia Vegetal "Veríssimo de Almeida" (LPVVA-ISA, Lisbon, Portugal).

An additional 25 "*C.*" *destructans* isolates used during this study were made available by K.A. Seifert (Agriculture and Agri-Food, Canada), and were isolated from commercial *Panax quinquefolium* gardens (CBS 120359–120369, CBS 129079, CBS 129083, CD1666, CPC 13535, CPC 13537, NSAC-SH2, NSAC-SH2.5), *Picea glauca* (94–1628, CPC 13539), *Poa pratensis* (CPC 13534), *Pseudotsuga menziesii* (CBS 120370–120372, CPC 13536) and *Prunus cerasus* (CPC 13532) (Seifert et al. 2003).

Another 109 isolates were also included in the analysis to add phylogenetic support to this study and represent strains of the following taxa: *C. cylindroides*, *C. obtusisporum*, *C. pauciseptatum*, species 1 to 6 (Mostert et al., in preparation; Cabral et al., in preparation), *I. macrodidyma*, *N. ditissima*, *N. major*, *N. neomacrospora* and *N. ramulariae*.

DNA isolation, sequencing and phylogenetic analysis

For each isolate, genomic DNA was isolated from mycelium following the protocol of Möller et al. (1992), adapted by Crous et al. (2009b). Sequencing of the ITS and part of the β-tubulin (TUB), histone H3 (HIS) and translation elongation factor 1-α (TEF) genes was performed after PCR amplification using 1× PCR buffer (Bioline, London,

Table 1 Details pertaining to isolates investigated during this study

Species	Strain number[a]	Collected/isolated by, year	Isolated from	Location	GenBank accession numbers			
					ITS	TUB	H3	EF1
Campylocarpon fasciculare, Holotype	CBS 112613; STE-U 3970; C 76	F. Halleen, 2000	*Vitis vinifera*, trunk of young grapevine showing decline symptoms; scion Cabernet Sauvignon; rootstock Richter 99	South Africa, Western Cape, Riebeeck Kasteel	AY677301	AY677221	JF735502	JF735691
Campylocarpon pseudofasciculare, Holotype	CBS 112679; STE-U 5472; HJS-1227	F. Halleen, 2000	*Vitis vinifera*, roots, asymptomatic nursery grapevine plant; scion Sultana; rootstock Ramsey	South Africa, Western Cape, Wellington	AY677306	AY677214	JF735503	JF735692
Neonectria macroconidialis	CBS 119596; ICMP 9349; IMI 332705; GJS 85-59	G.J. Samuels, 1985	*Astelia* sp.	New Zealand, Gisborne, Urewera National Park	JF735259	JF735372	JF735504	JF735693
Ilyonectria coprosmae	CBS 119606; GJS 85-39	G.J. Samuels, 1985	*Metrosideros* sp.	Canada, Ontario	JF735260	JF735373	JF735505	JF735694
Ilyonectria radicicola, type strain	CBS 264.65	L. Nilsson, 1961	*Cyclamen persicum*	Sweden, Skåne, Bjärred	AY677273	AY677256	JF735506	JF735695
Ilyonectria liriodendri, type strain of "*C.*" *liriodendri*	CBS 110.81; IMI 303645	J.D. MacDonald & E.E. Butler, 1978	*Liriodendron tulipifera*, root	USA, California, Yolo Co., Davis	DQ178163	DQ178170	JF735507	JF735696
Ilyonectria liriodendri	CBS 117526; Cy68	C. Rego, 1999	*Vitis vinifera*, asymptomatic rootstocks; rootstock 99 R, clone 179 F	Portugal, Ribatejo e Oeste	DQ178164	DQ178171	JF735508	JF735697
Ilyonectria liriodendri	CBS 117527; Cy76	C. Rego, 1999	*Vitis vinifera*, asymptomatic rootstocks; rootstock 110 R, clone 164E	Portugal, Ribatejo e Oeste	DQ178165	DQ178172	JF735509	JF735698
Ilyonectria liriodendri	CBS 117640; IMI 357400; Cy1	C. Rego, 1992	*Vitis vinifera*, 4-year-old plant showing decline symptoms; scion Seara Nova; rootstock 99R	Portugal, Torres Vedras, Dois Portos	DQ178166	DQ178173	JF735510	JF735699
Ilyonectria liriodendri	CBS 112596; STE-U 3994; C 14	F. Halleen, 1999	*Vitis vinifera*, roots	South Africa, Western Cape, De Wet	AY677264	AY677239	JF735511	JF735700
Ilyonectria liriodendri	CBS 112607; STE-U 3986; C 81	F. Halleen, 2000	*Vitis vinifera*, basal end of trunk	South Africa, Western Cape, Robertson	AY677269	AY677241	JF735512	JF735701
Ilyonectria liriodendri	Cy164	C. Rego, 1997	*Malus domestica*; cultivar Lysgolden; rootstock MM106	Portugal, Porto de Mós, Valbom	AM419079	AM419112	JF735513	JF735702
Ilyonectria liriodendri	Cy122	W.D. Gubler	*Vitis vinifera*	USA, California	JF735261	JF735374	JF735514	JF735703
Ilyonectria liriodendri	Cy190	N. Cruz, 2005	*Vitis vinifera*, basal end of 6-year-old plant; scion Alvarinho; rootstock 196-17	Portugal, Monção, Cortes	JF735262	JF735375	JF735515	JF735704
Ilyonectria liriodendri	Cy232	L. Inácio & J. Henriques, 2007	*Quercus suber*, stem	Portugal, Macedo de Cavaleiros	JF735263	JF735376	JF735516	JF735705
Ilyonectria robusta	CBS 321.34	-	*Loroglossum hircinum*, root	Tunisia, Tunis	AY677275	AY677253	JF735517	JF735706
Ilyonectria robusta, type strain of *Ramularia robusta*	CBS 308.35	A.A. Hildebrand	*Panax quinquefolium*	Canada, Ontario	JF735264	JF735377	JF735518	JF735707
Ilyonectria robusta	CBS 773.83	J. Hemelraad	water, in aquarium with *Anodonta*	Netherlands, Utrecht	AY677276	AY677254	JF735519	JF735708
Ilyonectria robusta	CBS 605.92	R. Schröer, 1992	*Tilia petiolaris*, root	Germany, Hamburg	EF607078	EF607065	JF735520	JF735709
Ilyonectria robusta	CBS 117813; IFFF 84	E. Halmschlager, 1993	*Quercus robur*, root	Austria, Niederweiden	-	JF735378	-	-
Ilyonectria robusta	CBS 117814; IFFF 85	E. Halmschlager, 1993	*Quercus* sp., root	Austria, Patzmannsdorf	JF735265	JF735379	JF735521	JF735710
Ilyonectria robusta	CBS 117815; IFFF 86	E. Halmschlager, 1993	*Quercus* sp., root	Austria, Patzmannsdorf	JF735266	JF735380	JF735522	JF735711
Ilyonectria robusta	CBS 117817; IFFF 88	E. Halmschlager, 1993	*Quercus* sp., root	Austria, Patzmannsdorf	-	JF735381	-	-
Ilyonectria robusta	CBS 117818; IFFF 89	E. Halmschlager, 1993	*Quercus* sp., root	Austria, Patzmannsdorf	JF735267	JF735382	JF735523	JF735712
Ilyonectria robusta	CBS 117819; IFFF 90	E. Halmschlager, 1993	*Quercus robur*, root	Austria, Niederweiden	-	JF735383	-	-
Ilyonectria robusta	CBS 117820; IFFF 91	E. Halmschlager, 1993	*Quercus robur*, root	Austria, Niederweiden	JF735268	JF735384	JF735524	JF735713
Ilyonectria robusta	CBS 117821; IFFF 93	E. Halmschlager, 1993	*Quercus robur*, root	Austria, Niederweiden	JF735269	JF735385	JF735525	JF735714

Table 1 (continued)

Species	Strain number[a]	Collected/isolated by, year	Isolated from	Location	GenBank accession numbers			
					ITS	TUB	H3	EF1
Ilyonectria robusta	CBS 117822; IFFF 94	E. Halmschlager, 1993	*Quercus robur*, root	Austria, Niederweiden	JF735270	JF735386	JF735526	JF735715
Ilyonectria robusta	CBS 117823; IFFF 95	E. Halmschlager, 1993	*Quercus robur*, root	Austria, Niederweiden	JF735271	JF735387	JF735527	JF735716
Ilyonectria robusta	CD1666	R. D. Reeleder, 1998	*Panax quinquefolium*	Canada, Nova Scotia	AY295331	JF735388	JF735528	JF735717
Ilyonectria robusta	CPC 13532; DAOM 139398; K 18-3A	-	*Prunus cerasus* cultivar Montmorency	Canada, Ontario	AY295330	JF735389	JF735529	JF735718
Ilyonectria robusta	Cy23	C. Rego, 1997	*Vitis* sp. rootstock 99R clone 179 F in nursery	Portugal, Ribatejo e Oeste	AJ875333	AM419093	JF735530	JF735719
Ilyonectria robusta	Cy158	C. Rego & T. Nascimento, 2004	*Vitis vinifera*, 1-year-old, died before sprouting; scion Alicante Bouschet; rootstock 1103P	Portugal, Lamego, Cambres	JF735272	JF735390	JF735531	JF735720
Ilyonectria robusta	CBS 129084; Cy192	N. Cruz, 2005	*Vitis vinifera*, basal end of 25-year-old plant; scion Alicante; rootstock 196-17	Portugal, Monção	JF735273	JF735391	JF735532	JF735721
Ilyonectria robusta	Cy231	F. Caetano, 2005	*Thymus* sp.	Portugal, Lisbon	JF735274	JF735392	JF735533	JF735722
Ilyonectria crassa	CBS 139.30	W.F. van Hell, 1930	*Lilium* sp., bulb	Netherlands	JF735275	JF735393	JF735534	JF735723
Ilyonectria crassa	CBS 158.31; IMI 061536; NRRL 6149	1930	*Narcissus* sp., root	Netherlands	JF735276	JF735394	JF735535	JF735724
Ilyonectria crassa	CBS 129083; NSAC-SH-1	S. Hong, 1998	*Panax quinquefolium*	Canada, Nova Scotia	AY295311	JF735395	JF735536	JF735725
Ilyonectria crassa	NSAC-SH-2	S. Hong, 1998	*Panax quinquefolium*	Canada, Nova Scotia	AY295313	JF735396	JF735537	JF735726
Ilyonectria crassa	NSAC-SH-2.5	S. Hong, 1998	*Panax quinquefolium*	Canada, Nova Scotia	AY295314	JF735397	JF735538	JF735727
"*Cylindrocarpon*" sp.	CBS 120370; CR 20	P. Axelrood, 1998	*Pseudotsuga menziesii*	Canada, British Columbia	AY295317	JF735398	JF735539	JF735728
Ilyonectria rufa Authentic strain of *Coleomyces rufus*	CBS 153.37	F. Moreau, 1937	Dune sand	France	AY677271	AY677251	JF735540	JF735729
Ilyonectria rufa	CBS 156.47; IAM 14673; JCM 23100	-	*Azalea indica*	Belgium, Amandsberg	AY677272	AY677252	JF735541	JF735730
Ilyonectria rufa	CBS 640.77	F. Gourbière, 1977	*Abies alba*	France, Villeurbanne	JF735277	JF735399	JF735542	JF735731
Ilyonectria rufa	CBS 120371; CR 26	P. Axelrood, 1998	*Pseudotsuga menziesii*	Canada, British Columbia	AY295318	JF735400	JF735543	JF735732
Ilyonectria rufa	CBS 120372; CR 29	P. Axelrood, 1998	*Pseudotsuga menziesii*	Canada, British Columbia	JF735278	JF735401	JF735544	JF735733
Ilyonectria rufa	CPC 13536; DAOM 226721; CR36	P. Axelrood, 1998	*Pseudotsuga menziesii*	Canada, British Columbia	JF735279	JF735402	JF735545	JF735734
Ilyonectria rufa	94-1628	R.C. Hamelin, 1994	*Picea glauca*	Canada, Quebec	AY295315	JF735403	JF735546	JF735735
Ilyonectria mors-panacis	CBS 120359; CD1561	R. D. Reeleder, 1996	*Panax quinquefolium*	Canada, Ontario	AY295309	JF735404	JF735547	JF735736
Ilyonectria mors-panacis	CBS 120360; CD1567	R. D. Reeleder, 1996	*Panax quinquefolium*	Canada, Ontario	-	AY297200	-	-
Ilyonectria mors-panacis	CBS 120361; CD1596	R. D. Reeleder, 1996	*Panax quinquefolium*	Canada, Ontario	JF735280	JF735405	JF735548	JF735737
Ilyonectria mors-panacis	CBS 120362; CD1598	R. D. Reeleder, 1996	*Panax quinquefolium*	Canada, Ontario	-	AY297202	-	-
Ilyonectria mors-panacis	CBS 120363; CD1635	R. D. Reeleder, 1997	*Panax quinquefolium*	Canada, Ontario	-	AY297204	-	-
Ilyonectria mors-panacis	CBS 120364; CD1636	R. D. Reeleder, 1997	*Panax quinquefolium*	Canada, Ontario	JF735281	JF735406	JF735549	JF735738
Ilyonectria mors-panacis	CBS 120365; CD1637	R. D. Reeleder, 1997	*Panax quinquefolium*	Canada, Ontario	JF735282	JF735407	JF735550	JF735739
Ilyonectria mors-panacis	CBS 120366; CD 1639	R. D. Reeleder, 1997	*Panax quinquefolium*	Canada, Ontario	JF735283	JF735408	JF735551	JF735740
Ilyonectria mors-panacis	CBS 120367; CD1640	R. D. Reeleder, 1997	*Panax quinquefolium*	Canada, Ontario	AY295321	JF735409	JF735552	JF735741
Ilyonectria mors-panacis	CBS 120368; CD1641	R. D. Reeleder, 1997	*Panax quinquefolium*	Canada, Ontario	JF735284	JF735410	JF735553	JF735742
Ilyonectria mors-panacis	CBS 120369; CD1642	R. D. Reeleder, 1997	*Panax quinquefolium*	Canada, Ontario	JF735285	JF735411	JF735554	JF735743
Ilyonectria mors-panacis	CPC 13535; DAOM 221059; CD 0265	R. D. Reeleder, 1989	*Panax quinquefolium*	Canada, Ontario	JF735286	JF735412	JF735555	JF735744

Table 1 (continued)

Species	Strain number[a]	Collected/isolated by, year	Isolated from	Location	GenBank accession numbers			
					ITS	TUB	H3	EF1
Ilyonectria mors-panacis	CPC 13537; DAOM 226727; CD 1570	R. D. Reeleder, 1996	*Panax quinquefolium*	Canada, Ontario	JF735287	JF735413	JF735556	JF735745
Ilyonectria mors-panacis, type of *Ramularia mors-panacis*	CBS 306.35	A.A. Hildebrand	*Panax quinquefolium*	Canada, Ontario	JF735288	JF735414	JF735557	JF735746
Ilyonectria mors-panacis	CBS 307.35	A.A. Hildebrand	*Panax quinquefolium*	Canada, Ontario	JF735289	JF735415	JF735558	JF735747
Ilyonectria mors-panacis, type of "*C.*" *destructans* f.sp. *panacis*	CBS 124662; NBRC 31881; SUF 811	Y. Miyazawa	*Panax ginseng*	Japan, Nagano, Kitasaku-gun	JF735290	JF735416	JF735559	JF735748
Ilyonectria pseudodestructans	CPC 13534; DAOM 150670; Berkenkamp 1	B. Berkenkamp, 1974	*Poa pratensis*	Canada, Alberta, Lacombe	AY295319	JF735417	JF735560	JF735749
Ilyonectria pseudodestructans	CBS 117812; IFFF 83	E. Halmschlager, 1993	*Quercus* sp., root	Austria, Patzmannsdorf	JF735291	JF735418	JF735561	JF735750
Ilyonectria pseudodestructans	CBS 117824; IFFF 98	E. Halmschlager, 1993	*Quercus* sp., root	Austria, Patzmannsdorf	JF735292	JF735419	JF735562	JF735751
Ilyonectria pseudodestructans	CBS 129081; Cy20	C. Rego, 1996	*Vitis vinifera*, 4-year-old, showing decline symtoms, scion Malvasia Fina; rootstock 1103P	Portugal, Gouveia, São Paio	AJ875330	AM419091	JF735563	JF735752
Ilyonectria pseudodestructans	Cy22	C. Rego, 1996	*Vitis vinifera*, 5-year-old, showing decline symtoms, scion Aragonez; rootstock 99R	Portugal, Viseu, Silgueiros	AJ875331	AM419092	JF735564	JF735753
Ilyonectria europaea	Cy131	P. Lecomte & S. Chamont, 2000	*Actinidia chinensis* 'Hayward', internal lesion of stem	France, St. Chicq-du-Gaue	AM419067	AM419103	JF735565	JF735754
Ilyonectria europaea	Cy155	C. Rego & H. Oliveira, 2004	*Vitis vinifera*, 2-year-old, showing decline symtoms, scion Alfrocheiro; rootstock SO4	Portugal, Alter do Chão	JF735293	JF735420	JF735566	JF735755
Ilyonectria europaea	CBS 129078; Cy241	C. Rego, 2008	*Vitis vinifera*, basal end of a 2-year-old plant; scion Petit Verdot; rootstock 110R	Portugal, Vidigueira	JF735294	JF735421	JF735567	JF735756
Ilyonectria europaea	CBS 537.92	V. Demoulin, 1992	*Aesculus hippocastanum*, wood	Belgium, Liège	EF607079	EF607064	JF735568	JF735757
Ilyonectria europaea	CBS 102892; No.5/97-12	W. Leibinger, 1997	*Phragmites australis*, stem	Germany, Lake Constance	JF735295	JF735422	JF735569	JF735758
Ilyonectria lusitanica	CBS 129080; Cy197	N. Cruz, 2005	*Vitis vinifera*, below grafting zone, 6-year-old plant; scion Alvarinho; rootstock 196-17	Portugal, Melgaço, Alvaredo	JF735296	JF735423	JF735570	JF735759
Ilyonectria venezuelensis	CBS 102032; ATCC 208837; AR2553	A. Rossman, 1985	Bark	Venezuela, Amazonas, Cerro de la Neblina	AM419059	AY677255	JF735571	JF735760
Ilyonectria panacis	CBS 129079; CDC-N-9a	K. F. Chang, 1998	*Panax quinquefolium*	Canada, Alberta	AY295316	JF735424	JF735572	JF735761
Ilyonectria liliigena	CBS 189.49; IMI 113882	M.A.A. Schipper	*Lilium regale*, bulb	Netherlands, Hoorn	JF735297	JF735425	JF735573	JF735762
Ilyonectria liliigena	CBS 732.74	G.J. Bollen, 1973	*Lilium* sp.	Netherlands, Heemskerk	JF735298	JF735426	JF735574	JF735763
Ilyonectria liliigena	CBS 304.85	G.J. Bollen, 1985	*Lilium* sp., bulb	Netherlands	JF735299	JF735427	JF735575	JF735764
Ilyonectria liliigena	CBS 305.85	G.J. Bollen, 1985	*Lilium* sp., bulb	Netherlands	JF735300	JF735428	JF735576	JF735765
Ilyonectria gamsii	CBS 940.97	J.T. Poll, 1997	Soil	Netherlands, Lelystad	AM419065	AM419089	JF735577	JF735766
"*Cylindrocarpon*" sp.	Cy228	F. Caetano, 2003	*Ficus* sp.	Portugal, Lisbon	JF735301	JF735429	JF735578	JF735767
Ilyonectria anthuriicola	CBS 564.95; PD 95/1577	R. Pieters, 1995	*Anthurium* sp., root	Netherlands, Bleiswijk	JF735302	JF735430	JF735579	JF735768
Ilyonectria vitis	CBS 129082; Cy233	C. Rego, 2008	*Vitis vinifera*, basal end of a 2-year-old plant; scion Touriga Nacional; rootstock 110R	Portugal, Vidigueira	JF735303	JF735431	JF735580	JF735769

Table 1 (continued)

Species	Strain number[a]	Collected/isolated by, year	Isolated from	Location	GenBank accession numbers			
					ITS	TUB	H3	EF1
Ilyonectria cyclaminicola	CBS 302.93	M. Hooftman, 1993	*Cyclamen* sp., bulb	Netherlands, Roelofarendsveen	JF735304	JF735432	JF735581	JF735770
Cylindrocarpon pauciseptatum	CBS 100819; LYN 16202/2	H.M. Dance, 1998	*Erica melanthera*, root	New Zealand, Tauranga	EF607090	EF607067	JF735582	JF735771
Cylindrocarpon pauciseptatum	CBS 113550	2003	*Vitis* sp, blackening areas in wood and base of trunk	New Zealand, Keesbury Estate	EF607080	EF607069	JF735583	JF735772
Cylindrocarpon pauciseptatum	CBS 120497; KIS 10763	H.-J. Schroers, 2006	*Vitis* sp.brownish spots of healthy looking root of ca. 12-year-old, possibly dead, in vineyard	Slovenia, Mrzlak	EF607085	EF607071	JF735584	JF735773
Cylindrocarpon pauciseptatum	CBS 120498; KIS 10775	M. Žerjav, 2006	*Vitis* sp., decayed secondary roots with black areas of 3-year-old, dead	Slovenia, Ljutomer	EF607087	EF607072	JF735585	JF735774
Cylindrocarpon pauciseptatum	CBS 120499; KIS 10780	M. Žerjav, 2006	*Vitis* sp., decayed secondary roots with black areas of 3-year-old, dead	Slovenia, Ljutomer	EF607084	EF607074	JF735586	JF735775
Cylindrocarpon pauciseptatum, type	CBS 120171; KIS 10467	M. Žerjav, 2005	*Vitis* sp., partly decayed roots of 4-year-old plant, still living but badly shooting; in vineyard	Slovenia, Krŝko	EF607089	EF607066	JF735587	JF735776
Cylindrocarpon pauciseptatum	CBS 120172; KIS 10729	M. Žerjav, 2006	*Vitis* sp., strongly decayed, blackish brown root of ca. 9-year-old plant, possibly dead; in vineyard	Slovenia, Žužemberk	EF607086	EF607070	JF735588	JF735777
Cylindrocarpon pauciseptatum	CBS 120173; KIS 10468	M. Žerjav, 2005	*Vitis* sp., partly decayed roots of 4-year-old plant, still living but badly shooting; in vineyard	Slovenia, Krŝko	EF607088	EF607068	JF735589	JF735778
Cylindrocarpon pauciseptatum	Cy196	N. Cruz, 2005	*Vitis vinifera*, basal end of 4-year-old plant; scion Alvarinho; rootstock 196-17	Portugal, Melgaço/Monção	JF735305	JF735433	JF735590	JF735779
Cylindrocarpon pauciseptatum	Cy217	A. Cabral, 2007	*Vitis vinifera*, asymptomatic; scion Gouveio	Portugal, Torres Vedras	JF735306	JF735434	JF735591	JF735780
Cylindrocarpon pauciseptatum	Cy238	C. Rego, 2008	*Vitis vinifera*, basal end of a 2-year-old plant; scion Petit Verdot; rootstock 110R	Portugal, Vidigueira	JF735307	JF735435	JF735592	JF735781
"*Cylindrocarpon*" sp 1	CBS 162.89	M. Barth, 1988	*Hordeum vulgare*, root	Netherlands, Noordoostpolder, Marknesse, Lovinkhoeve	AM419060	AM419084	JF735610	JF735799
"*Cylindrocarpon*" sp 2	Cy108	C. Rego, 1999	*Vitis vinifera*, basal end of a 4-year-old plant showing decline symptoms; scion Aragonez; rootstock SO4	Portugal, Nelas	JF735316	AM419100	JF735611	JF735800
"*Cylindrocarpon*" sp 2	Cy200	N. Cruz, 2005	*Vitis vinifera*, basal end of a 16-year-old plant; scion Alvarinho; rootstock 196-17	Portugal, Melgaço	JF735317	JF735445	JF735612	JF735801
"*Cylindrocarpon*" sp 2	CBS 159.34; IMI 113891; MUCL 4084; VKM F-2656	H.W. Wollenweber, 1934		Germany	JF735318	JF735446	JF735613	JF735802
"*Cylindrocarpon*" sp 2	CBS 173.37; IMI 090176	T.R. Peace, 1937	*Pinus laricio*, associated with dieback	UK, England, Devon, Haldon	JF735319	JF735447	JF735614	JF735803
"*Cylindrocarpon*" sp. 3	Cy135	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, basal end of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	AM419069	AM419105	JF735615	JF735804
"*Cylindrocarpon*" sp. 3	Cy144	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, grafting zone of a 1.5-year- old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	AM419074	AM419107	JF735616	JF735805
"*Cylindrocarpon*" sp. 3	CBS 129085; Cy145	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, basal end of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735320	JF735448	JF735617	JF735806
"*Cylindrocarpon*" sp. 3	Cy146	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, grafting zone of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735321	JF735449	JF735618	JF735807

Table 1 (continued)

Species	Strain number[a]	Collected/isolated by, year	Isolated from	Location	GenBank accession numbers			
					ITS	TUB	H3	EF1
"*Cylindrocarpon*" sp. 3	Cy147	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, grafting zone of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735322	JF735450	JF735619	JF735808
"*Cylindrocarpon*" sp. 3	Cy148	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, basal end of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735323	JF735451	JF735620	JF735809
"*Cylindrocarpon*" sp. 3	Cy149	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, basal end of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735324	JF735452	JF735621	JF735810
"*Cylindrocarpon*" sp. 3	Cy150	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, basal end of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735325	JF735453	JF735622	JF735811
"*Cylindrocarpon*" sp. 3	Cy151	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, asymptomatic 1.5-year-old plant; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735326	JF735454	JF735623	JF735812
"*Cylindrocarpon*" sp. 3	Cy152	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, asymptomatic 1.5-year-old plant; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735327	JF735455	JF735624	JF735813
"*Cylindrocarpon*" sp. 3	Cy153	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, asymptomatic 1.5-year-old plant; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735328	JF735456	JF735625	JF735814
"*Cylindrocarpon*" sp. 3	Cy243	C. Rego, 2008	*Vitis vinifera*, basal end of a 2-year-old-plant; scion Touriga Nacioal; rootstock 110R	Portugal, Vidigueira	JF735329	JF735457	JF735626	JF735815
"*Cylindrocarpon*" sp. 3	CPC 13539; 94–1685; CCFC226730	R. C. Hamelin, 1994	*Picea glauca*	Canada, Quebec	JF735330	JF735458	JF735627	JF735816
"*Cylindrocarpon*" sp. 5	Cy133; IAFM Cy9-1	J. Armengol	*Vitis vinifera*	Spain, Valencia, L'Alcudia	JF735331	JF735459	JF735628	JF735817
"*Cylindrocarpon*" sp. 5	Cy134; IAFM Cy20-1	J. Armengol	*Vitis vinifera*	Spain, Ciudad Real, Villarubia de los Ojos	JF735332	AM419104	JF735629	JF735818
"*Cylindrocarpon*" sp. 5	CBS 129087; Cy159	A. Cabral & H. Oliveira, 2004	*Vitis vinifera*, basal end of a 3-year-old plant with root discolouration and decline symptoms; scion Sangiovese; rootstock 1103P	Portugal, Alcácer do Sal, Torrão	JF735333	AM419111	JF735630	JF735819
"*Cylindrocarpon*" sp. 6	CBS 112593; STE-U 3990; C 107	F. Halleen, 2000	*Vitis vinifera*, roots of an asymptomatic nursery plant; scion Pinotage; rootstock 101–14 Mgt	South Africa, Western Cape, Wellington, Voorgroenberg	AY677281	AY677236	JF735631	JF735820
"*Cylindrocarpon*" sp. 6	CBS 112608; STE-U 3987; C 62	F. Halleen, 2000	*Vitis vinifera*, roots, scion Chardonnay; rootstock 101–14 Mgt	South Africa, Western Cape, Citrusdal	AY677288	AY677235	JF735632	JF735821
"*Cylindrocarpon*" sp. 6	CBS 113552; STE-U 5713; HJS-1306; NZ C 41	R. Bonfiglioli, 2003	*Vitis* sp. decline of nursery plants dead rootstocks	New Zealand, Candy P New Ground	JF735334	AY677237	JF735633	JF735822
"*Cylindrocarpon*" sp. 6	Cy115	W.D. Gubler	*Vitis vinifera*	USA, California	JF735335	JF735460	JF735634	JF735823
"*Cylindrocarpon*" sp. 6	Cy116	W.D. Gubler	*Vitis vinifera*	USA, California	AJ875322	JF735461	JF735635	JF735824
"*Cylindrocarpon*" sp. 6	Cy117	W.D. Gubler	*Vitis vinifera*	USA, California	AJ875321	JF735462	JF735636	JF735825
"*Cylindrocarpon*" sp. 6	Cy119	W.D. Gubler	*Vitis vinifera*	USA, California	JF735336	JF735463	JF735637	JF735826
"*Cylindrocarpon*" sp. 6	Cy124	W.D. Gubler	*Vitis vinifera*	USA, California	JF735337	JF735464	JF735638	JF735827
"*Cylindrocarpon*" sp. 6	Cy125	W.D. Gubler	*Vitis vinifera*	USA, California	AM419066	JF735465	JF735639	JF735828
"*Cylindrocarpon*" sp. 6	Cy129	W.D. Gubler	*Vitis vinifera*	USA, California	JF735338	JF735466	JF735640	JF735829
"*Cylindrocarpon*" sp. 6	Cy130	W.D. Gubler	*Vitis vinifera*	USA, California	JF735339	JF735467	JF735641	JF735830
"*Cylindrocarpon*" sp. 6	Cy230	F. Caetano, 2005	*Festuca duriuscula*	Portugal, Lisbon	JF735340	JF735468	JF735642	JF735831

Table 1 (continued)

Species	Strain number[a]	Collected/isolated by, year	Isolated from	Location	GenBank accession numbers			
					ITS	TUB	H3	EF1
Ilyonectria macrodidyma	CBS 112594; STE-U 3991; C 111	F. Halleen, 2000	*Vitis vinifera*, roots of an asymptomatic nursery plant; scion Pinotage; rootstock Richter 99	South Africa, Western Cape, Malmesbury, Jakkalsfontein	AY677282	AY677231	JF735643	JF735832
Ilyonectria macrodidyma	CBS 112601; STE-U 3983; C 82	F. Halleen, 1999	*Vitis vinifera*, roots with black foot symtoms; scion Pinotage; rootstock US 8-7	South Africa, Western Cape, Tulbagh	AY677284	AY677229	JF735644	JF735833
Ilyonectria macrodidyma	CBS 112603; STE-U 4007; C 8	F. Halleen, 1999	*Vitis vinifera*, trunk of a plant showing decline symptoms, scion Sauvignon blanc; rootstock Richter 110	South Africa, Western Cape, Darling	AY677285	JF735469	JF735645	JF735834
Ilyonectria macrodidyma	CBS 112605; STE-U 3984; C 106	F. Halleen, 2000	*Vitis vinifera*, basal end of an asymptomatic nursery plant; scion Sultana; rootstock 143-B Mgt	South Africa, Western Cape, Malmesbury, Jakkalsfontein	AY677287	AY677230	JF735646	JF735835
Ilyonectria macrodidyma, holotype of *C. macrodidymum*	CBS 112615; STE-U 3976; C 98	F. Halleen, 2000	*Vitis vinifera*, roots, asymptomatic nursery grapevine plant scion Sultana; rootstock 143-B Mgt	South Africa, Western Cape, Malmesbury, Jakkalsfontein	AY677290	AY677233	JF735647	JF735836
Ilyonectria macrodidyma	Cy123	W.D. Gubler	*Vitis vinifera*	USA, California	JF735341	JF735470	JF735648	JF735837
Ilyonectria macrodidyma	Cy128	W.D. Gubler	*Vitis vinifera*	USA, California	JF735342	JF735471	JF735649	JF735838
Ilyonectria macrodidyma	Cy139	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, basal end of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	AM419071	AM419106	JF735650	JF735839
Ilyonectria macrodidyma	Cy140	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, grafting zone of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735343	JF735472	JF735651	JF735840
Ilyonectria macrodidyma	Cy175	C. Rego, 2004	*Vitis vinifera*, basal discolouration in rootstocks; scion Touriga Nacional; rootstock 1103P	Portugal, Torre de Moncorvo	JF735344	JF735473	JF735652	JF735841
Ilyonectria macrodidyma	Cy181	C. Rego, 2005	*Vitis vinifera*, scion 140-Ru; rootstock Aragonês	Portugal, Alcácer do Sal	JF735345	JF735474	JF735653	JF735842
Ilyonectria macrodidyma	Cy216	A. Cabral, 2007	*Vitis vinifera*, asymptomatic; scion Marssanne	Portugal, Torres Vedras	JF735346	JF735475	JF735654	JF735843
Ilyonectria macrodidyma	Cy244	C. Rego, 2008	*Vitis vinifera*, basal end of a 2-year-old plant; scion Petit Verdot; rootstock 110R	Portugal, Vidigueira	JF735347	JF735476	JF735655	JF735844
Ilyonectria macrodidyma	Cy258	C. Rego, 2008	*Vitis vinifera*, basal end of a 2-year-old plant; scion Cabernet Sauvignon; rootstock 110R	Portugal, Vidigueira	JF735348	JF735477	JF735656	JF735845
"*Cylindrocarpon*" sp.4	CBS 119.41	H.C. Koning	*Fragaria* sp., root	Netherlands, Baarn	JF735349	JF735478	JF735657	JF735846
"*Cylindrocarpon*" sp.4	CBS 188.49	J.A. von Arx	*Abies nordmanniana*, root	Netherlands, Egmond	AM419063	AM419087	JF735658	JF735847
"*Cylindrocarpon*" sp.4	CBS 112604; STE-U 4004; C 10	F. Halleen, 1999	*Vitis vinifera*, roots; scion Cabernet Sauvignon; rootstock 101–14 Mgt	South Africa, Western Cape, Paarl	AY677286	AY677227	JF735659	JF735848
"*Cylindrocarpon*" sp.4	CBS 112609; STE-U 3969; HJS-1217	M. Sweetingham, 1979	*Vitis* sp., dark brown discoloration in trunk; scion Cabernet Sauvignon	Australia, Tasmania, Bream Creek	AY677289	AY677226	JF735660	JF735849
"*Cylindrocarpon*" sp.4	CBS 113555; STE-U 5715; HJS-1309; NZ C 60	R. Bonfiglioli, 2003	*Vitis* sp., blackening areas in wood and roots; scion Pinot Noir; rootstock 101-14	New Zealand, Fiddlers Green	JF735350	AY677234	JF735661	JF735850
"*Cylindrocarpon*" sp.4	CBS 112598; STE-U 3997; C 115	F. Halleen, 2000	*Vitis vinifera*, roots of an asymptomatic plant; scion Sultana; rootstock Ramsey	South Africa, Western Cape, Wellington, Lelienfontein	JF735351	JF735479	JF735662	JF735851
"*Cylindrocarpon*" sp.4	CPC 13533; CCFC 144524; Dias 2B	H.F. Dias, 1972	*Vitis vinifera*, Concord Bradt grapes, roots and stems	Canada, Ontario	AY295332	JF735480	JF735663	JF735852
"*Cylindrocarpon*" sp.4	Cy69	C. Rego, 1999	*Vitis vinifera*, asymptomatic rootstocks; rootstock SO4, clone 102 F	Portugal, Ribatejo e Oeste	AJ875332	AM419095	JF735664	JF735853
"*Cylindrocarpon*" sp.4	Cy71	C. Rego, 1999	*Vitis vinifera*, asymptomatic rootstocks; rootstock 99R, clone 96 F	Portugal, Ribatejo e Oeste	AJ875335	AM419096	JF735665	JF735854

Table 1 (continued)

Species	Strain number[a]	Collected/isolated by, year	Isolated from	Location	GenBank accession numbers			
					ITS	TUB	H3	EF1
"*Cylindrocarpon*" sp.4	Cy72	C. Rego, 1999	*Vitis vinifera*, asymptomatic rootstocks; rootstock clone 113 F	Portugal, Ribatejo e Oeste	AJ875336	AM419097	JF735666	JF735855
"*Cylindrocarpon*" sp.4	Cy75	C. Rego, 1999	*Vitis vinifera*, asymptomatic rootstocks; rootstock 99R	Portugal, Ribatejo e Oeste	AJ875334	AM419098	JF735667	JF735856
"*Cylindrocarpon*" sp.4	Cy96	E. Halmschlager	*Quercus* sp., root	Austria, Patzmannsdorf	JF735352	JF735481	JF735668	JF735857
"*Cylindrocarpon*" sp.4	Cy97	E. Halmschlager	*Quercus* sp., root	Austria, Patzmannsdorf	JF735353	JF735482	JF735669	JF735858
"*Cylindrocarpon*" sp.4	Cy118	W.D. Gubler	*Vitis vinifera*	USA, California	JF735354	JF735483	JF735670	JF735859
"*Cylindrocarpon*" sp.4	Cy120	W.D. Gubler	*Vitis vinifera*	USA, California	AJ875320	AM419101	JF735671	JF735860
"*Cylindrocarpon*" sp.4	Cy132; IAFM Cy1-1	J. Armengol	*Vitis vinifera*	Spain, Alicante	JF735355	JF735484	JF735672	JF735861
"*Cylindrocarpon*" sp.4	Cy136	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, basal end of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735356	JF735485	JF735673	JF735862
"*Cylindrocarpon*" sp.4	Cy137	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, basal end of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	AM419070	JF735486	JF735674	JF735863
"*Cylindrocarpon*" sp.4	Cy138	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, basal end of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735357	JF735487	JF735675	JF735864
"*Cylindrocarpon*" sp.4	Cy141	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, basal end of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735358	JF735488	JF735676	JF735865
"*Cylindrocarpon*" sp.4	Cy142	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, grafting zone of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735359	JF735489	JF735677	JF735866
"*Cylindrocarpon*" sp.4	Cy143	C. Rego & T. Nascimento, 2003	*Vitis vinifera*, basal end of a 1.5-year-old plant showing decline symptoms; scion Aragonez; rootstock 3309 C	Portugal, Estremoz	JF735360	JF735490	JF735678	JF735867
"*Cylindrocarpon*" sp.4	Cy157	H. Oliveira, 2004	*Vitis vinifera*, scion Touriga Nacional; rootstock 99R	Portugal, Alenquer	AM419077	AM419110	JF735679	JF735868
"*Cylindrocarpon*" sp.4	Cy214	A. Cabral, 2007	*Vitis vinifera*, asymptomatic; scion Grenache	Portugal, Torres Vedras	JF735361	JF735491	JF735680	JF735869
"*Cylindrocarpon*" sp.4	CBS 129086; Cy218	A. Cabral, 2007	*Vitis vinifera*, asymptomatic; scion Chenin	Portugal, Torres Vedras	JF735362	JF735492	JF735681	JF735870
"*Cylindrocarpon*" sp.4	Cy221	L. Leandro	*Fragaria x ananassa*	USA, North Caroline, Asheville	JF735363	JF735493	JF735682	JF735871
"*Cylindrocarpon*" sp.4	Cy222	L. Leandro	*Fragaria x ananassa*	USA, North Caroline, Asheville	JF735364	JF735494	JF735683	JF735872
"*Cylindrocarpon*" sp.4	Cy223	L. Leandro	*Fragaria x ananassa*	USA, North Caroline, Asheville	JF735365	JF735495	JF735684	JF735873
"*Cylindrocarpon*" sp.4	Cy235	C. Rego, 2008	*Vitis vinifera*, basal end of a 2-year-old plant; scion Cabernet Sauvignon; rootstock 110R	Portugal, Vidigueira	JF735366	JF735496	JF735685	JF735874
"*Cylindrocarpon*" sp.4	Cy237	C. Rego, 2008	*Vitis vinifera*, basal end of a 2-year-old plant; scion Chardonnay; rootstock 110R	Portugal, Vidigueira	JF735367	JF735497	JF735686	JF735875
"*Cylindrocarpon*" sp.4	Cy240	C. Rego, 2008	*Vitis vinifera*, basal end of a 2-year-old plant; scion Touriga Nacional; rootstock 140RU	Portugal, Vidigueira	JF735368	JF735498	JF735687	JF735876
"*Cylindrocarpon*" sp.4	Cy246	C. Rego, 2008	*Vitis vinifera*, basal end of a 2-year-old plant; scion Antão Vaz; rootstock 110R	Portugal, Vidigueira	JF735369	JF735499	JF735688	JF735877
"*Cylindrocarpon*" sp.4	Cy260	C. Rego, 2008	*Vitis vinifera*, basal end of a 2-year-old plant; scion Cabernet Sauvignon; rootstock 110R	Portugal, Vidigueira	JF735370	JF735500	JF735689	JF735878

Table 1 (continued)

Species	Strain number[a]	Collected/isolated by, year	Isolated from	Location	GenBank accession numbers			
					ITS	TUB	H3	EF1
"*Cylindrocarpon*" sp.4	Cy262	C. Rego, 2008	*Vitis vinifera*, basal end of a 2-year-old plant; scion Cabernet Sauvignon; rootstock 110R	Portugal, Vidigueira	JF735371	JF735501	JF735690	JF735879
Neonectria major, type strain	CBS 240.29; IMI 113909	H.W. Wollenweber	*Alnus incana*, canker	Norway	JF735308	DQ789872	JF735593	JF735782
Neonectria ditissima, authentic strain of *C. willkommii*	CBS 226.31; IMI 113922	H.W. Wollenweber	*Fagus sylvatica*	Germany, Tharandt	JF735309	DQ789869	JF735594	JF735783
Neonectria ditissima, representative strain of *N. galligena*	CBS 835.97	W. Gams, 1997	*Salix cinerea*, dead branch of still living tree	Belgium, Marais de Sampant	JF735310	DQ789880	JF735595	JF735784
Neonectria ditissima	Cy169	H. Oliveira, 1997	*Malus domestica*	Portugal, Alcobaça	AM419080	AM419113	JF735596	JF735785
Neonectria ditissima	Cy172	T. Nascimento, 2004	*Malus domestica*; scion Oregon; rootstock MM107	Portugal, Caldas da Rainha	AM419081	AM419114	JF735597	JF735786
Neonectria neomacrospora, representative strain	CBS 118984; GJS 03-28	L. Reitman, 2005	*Arceuthobium tsugense*, parasiting *Abies balsams*	Canada, British Columbia, Vancouver Island, Spider Lake	JF735311	DQ789882	JF735598	JF735787
Cylindrocarpon cylindroides, representative strain	CBS 324.61; DSM 62489; IMB 9628	J.A. von Arx	*Abies concolor*	Netherlands, Zwolle	JF735312	DQ789875	JF735599	JF735788
Cylindrocarpon cylindroides	CBS 503.67	F. Roll-Hansen	*Abies alba*, wood	Norway, Hordaland, Fana	AY677261	JF735436	JF735600	JF735789
Cylindrocarpon sp.	CPC 13545; DAOM 185212; # 5	J.A. Traquair & B. Harrison, 1982	*Pyrus* sp.	Canada, Ontario, Harrow	AY295303	JF735437	JF735601	JF735790
Neonectria ramulariae, authentic strain of *C. obtusiusculum* (=*C. magnusianum*)	CBS 151.29; IMI 113894; MUCL 28083; MUCL 28094	H.W. Wollenweber	*Malus sylvestris*, fruit	UK, England, Cambridge	JF735313	JF735438	JF735602	JF735791
Neonectria ramulariae	CBS 182.36; IMI 113893; UPSC 1903	H.W. Wollenweber	*Malus sylvestris*, fruit	-	JF735314	JF735439	JF735603	JF735792
Cylindrocarpon sp.	CR21	P. Axelrood	*Pseudotsuga menziesii*	Canada, British Columbia	JF735315	JF735440	JF735604	JF735793
Cylindrocarpon sp.	CPC 13530; DAOM 185722; JAT 1591	J.A. Traquair, 1983	*Pyrus* sp., lesions on seedlings	Canada, Ontario, Harrow	AY295302	JF735441	JF735605	JF735794
Cylindrocarpon sp.	CPC 13531; CCFC 226722; DAOM 226722; CR6	P. Axelrood	*Pseudotsuga menziesii*, root	Canada, British Columbia	AY295301	JF735442	JF735606	JF735795
Cylindrocarpon obtusisporum	CBS 183.36; IMI 113895	H.W. Wollenweber, 1936	*Solanum tuberosum*, tuber	Germany	AM419061	AM419085	JF735607	JF735796
Cylindrocarpon obtusisporum	CPC 13544; DAOM 182772; JAT 1366	J.A. Traquair, 1982	*Prunus armenica*, twigs	Canada, Ontario, Ruthven	AY295306	JF735443	JF735608	JF735797
Cylindrocarpon obtusisporum	94-1356	R. C. Hamelin, 1994	*Picea mariana*	Canada, Quebec	AY295304	JF735444	JF735609	JF735798

[a] *ATCC* American Type Culture Collection, USA; *CBS* CBS-KNAW Fungal Biodiversity Centre (Centraalbureau voor Schimmelcultures), Utrecht, The Netherlands; *CCFC* Canadian Collection of Fungal Cultures, Agriculture and Agri-Food Canada, Ottawa, Canada; *CPC* Culture collection of Pedro Crous, housed at CBS; *Cy Cylindrocarpon* collection housed at Laboratório de Patologia Vegetal "Veríssimo de Almeida" - ISA, Lisbon, Portugal; *DAOM* Agriculture and Agri-Food Canada National Mycological Herbarium, Canada; *DSM* Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH, Braunschweig, Germany; *GJS* Gary J. Samuels collection; *HJS* Hans-Josef Schroers collection; *IAFM* Instituto Agroforestal Mediterráneo, Universidad Politécnica de Valencia, Spain; *IAM* Institute of Molecular and Cellular Biosciences, The University of Tokyo, Japan; *ICMP* International Collection of Microorganisms from Plants, Auckland, New Zealand; *IFFF* Institute of Forest Entomology, Forest Pathology and Forest Protection, Austria; *IMI* International Mycological Institute, CABI-Bioscience, Egham, Bakeham Lane, U.K.; *JAT* J. A. Traquair collection; *JCM* Japan Collection of Microorganisms, Japan; *KIS* Agricultural Institute of Slovenia, Ljubljana, Slovenia; *LYN* Lynchburg College, Biology Department, USA; *MUCL* Mycothèque de l'Université Catholique de Louvain, Belgium; *NBRC* NITE Biological Resource Center, Japan; *NRRL* Agricultural Research Service Culture Collection, USA; *STE-U* Stellenbosch University, South Africa; *UPSC* Fungal Culture Collection at the Botanical Museum, Uppsala University, Uppsala, Sweden; *VKM* All-Russian Collection of Microorganisms, Russia.

UK), 1.5 mM $MgCl_2$, 32 μM of each dNTPs, 0.24 μM of each primer, 0.5 units *Taq* DNA Polymerase (Bioline), and 1 μl of diluted gDNA in a final volume of 12.5 μl. The cycle conditions in a iCycler thermocycler (BioRad, Hercules, USA) were 94°C for 5 min, followed by 40 cycles at 94°C for 30 s, 52°C for 30 s and 72°C for 80 s, and a final elongation at 72°C for 10 min. Primers were V9G (de Hoog and Gerrits van den Ende 1998) and ITS4 (White et al. 1990) for ITS, T1 (O'Donnell and Cigelnik 1997) and Bt-2b (Glass and Donaldson 1995) for TUB, CYLH3F and CYLH3R (Crous et al. 2004b) for HIS, and EF1 and EF2 (O'Donnell et al. 1998) or CylEF-1 (5'- ATG GGT AAG GAV GAV AAG AC-3'; J.Z. Groenewald, unpublished) and CylEF-R2 (Crous et al. 2004b) for TEF. For TEF, the following modifications were made to the amplification protocol: 2.0 mM of $MgCl_2$, 40 μM of each dNTPs and addition of 5% of Dimethyl sulfoxide (DMSO; Sigma-Aldrich, Zwijndrecht, Netherlands).

After confirmation by agarose gel electrophoresis, amplicons were sequenced in both directions with the corresponding PCR primers and a DYEnamic ET Terminator Cycle Sequencing Kit (Amersham Biosciences, Diegem, Belgium) according to the manufacturer's recommendations. The products were analysed on an ABI Prism 3700 DNA Sequencer (Perkin-Elmer, Waltham, USA).

Sequences were assembled and edited to resolve ambiguities, using the EditSeq and SeqMan modules of the Lasergene software package (DNAStar, Madison, USA). Consensus sequences for all isolates were compiled into a single file (Fasta format) and aligned using CLUSTAL X v. 2.0.11 (Larkin et al. 2007). Following manual adjustment of the alignment by eye where necessary, the alignment was subjected to phylogenetic analyses as described by Crous et al. (2004b). Novel sequences were lodged in GenBank (Table 1), taxonomic novelties in MycoBank (Crous et al. 2004a), and the alignments and phylogenetic trees in TreeBASE (http://www.treebase.org).

Morphology

Isolates were grown for up to 5 weeks at 20°C on synthetic nutrient poor agar (SNA; Nirenberg 1976) with and without two 1-cm^2 filter paper pieces, carnation leaf agar (CLA; Crous et al. 2009b), potato-dextrose agar (PDA; Difco, Detroit, USA) and oatmeal agar (OA; Crous et al. 2009b) under continuous n-UV light (NUV, 400–315 nm; Blacklight-Blue; Sylvania, Capelle a/d Ijssel, Netherlands).

Measurements were done on a 1-cm^2 agar plug removed from the colony margin, placed on a microscope slide, to which a drop of water and coverslip were added. For each isolate, 30 measurements were obtained for each structure. Measurements were done at ×1,000 magnification using a Nikon Eclipse 80i microscope, or a Leica DM2500. Images were captured using a Nikon DS-Fi1 digital camera with NIS-Elements Software, or a Leica DFC295 digital camera with the Leica Application Suite. Measurements for length and width of conidia and ascospores are given as (Minimum) Lower Limit of a 95% Confidence Interval – Upper Limit of a 95% Confidence Interval (Maximum). For other measurements, only the extreme values are given.

Culture characteristics (texture, density, colour, growth front, transparency and zonation) were described on PDA after incubation at 20°C in the dark for 14 days. Colour (surface and reverse) was described using the colour chart of Rayner (1970). Cardinal temperatures for growth were assessed by inoculating 90-mm-diam PDA dishes with a 3-mm-diam plug cut from the edge of an actively growing colony. Growth was determined after 7 days in two orthogonal directions. Trials were conducted at various temperatures (4, 10, 15, 18, 20, 22, 25, 30 and 35°C) with three replicate plates per strain at each temperature.

To induce the formation of perithecia, isolates were crossed in 60-mm-diam Petri dishes containing a minimal salts medium supplemented with two sterile birch toothpicks (Guerber and Correll 2001). The plates were incubated at 20°C under n-UV light for 8–20 weeks. Two strains were considered sexually compatible if perithecia were formed that exuded masses of viable ascospores. The colour reaction of the perithecia was checked in 3% KOH and in lactic acid. For sectioning, perithecia were mounted in Jung Tissue Freezing Medium (Leica) or in Arabian Gum, and cut in 10- to 15-μm-thick sections using a Leica cryostat CM3050 S or CM1850 at −20°C.

Results

Phylogeny

Amplification products of approximately 700 bases (ITS), 650 bases (TUB), 500 bases (HIS) and 600–800 bases (TEF) were obtained for the isolates listed in Table 1. The manually adjusted combined alignment contains 189 sequences (including the two outgroup sequences) and the statistical parameters for the combined and individual analyses are presented in Table 2. For the combined analysis, only a maximum of 1,000 equally most parsimonious trees were saved, the first of which is presented as Fig. 1. Phylogenetic trees derived from the individual loci are available in TreeBASE. The combined analysis of the four genes enabled the identification of 37 species. However, the analysis of HIS data alone was enough to resolve these taxa. Sequences of TEF could not distinguish species 6, *I. robusta*, *I. europaea*, *I. lusitanica*, *I. rufa* and *N. ditissima*; whereas sequences of TUB could not separate *I. robusta*, species 4, and 6, while *"I." macro-*

Table 2 Statistical information on the individual datasets and number of equally most parsimonious trees for each locus [Internal Transcribed Spacers (*ITS*) of the nuclear ribosomal RNA gene operon, and partial β-tubulin (*TUB*), histone H3 (*HIS*) and translation elongation factor 1-α (*TEF*) genes]

	ITS	TUB	HIS	TEF	Combined
Aligned characters (including gaps)	475	502	440	696	2,113
Parsimony-informative characters	122	212	215	364	913
Variable and parsimony-uninformative characters	31	38	11	43	123
Constant characters	322	252	214	289	1,077
Equally most parsimonious trees obtained	136	384	1	60	1,000
Tree length	294	603	1,095	1,149	3,259
Consistency index (CI)	0.718	0.660	0.468	0.611	0.559
Retention index (RI)	0.978	0.972	0.946	0.966	0.959
Rescaled Consistency index (RC)	0.702	0.642	0.442	0.590	0.537

didyma, species 5, *I. liliigena* and *I. pseudodesctructans* were supported by low bootstrap values, and CBS 120370 clustered apart from the remaining isolates of *I. crassa*. Of all loci screened, ITS proved to be the least informative, being unable to resolve 22 of the species in this study. Neighbour-Joining (NJ) analyses using the three substitution models, as well as the parsimony analysis, yielded trees with similar topology and bootstrap support values for the individual and combined gene analyses. The trees obtained supported the same clades, sometimes with rearrangements in the order of these clades between the different analyses (data not shown). The results of the phylogenetic analyses are highlighted below under the taxonomic notes or in the Discussion, where applicable.

Taxonomy

The present study treats isolates that have been freshly collected, or previously identified and maintained in culture collections as "*Cylindrocarpon destructans*", meaning cylindrical, rarely curved, 3-septate macroconidia with obtuse apices, abundant microconidia and chlamydospores (Samuels and Brayford 1990). The latter species has in the past been acknowledged as anamorph of *I. radicicola* (Booth 1966; Chaverri et al. 2011; Samuels and Brayford 1990). However, an examination of the neotype of *"C." destructans* in this study [CUP-011985, conidia (18.0)23.0–30.0(35.0) × (6.0)6.5(7.0) μm], found conidia to be considerably smaller than those of *I. radicicola* (24.0)33.1 (47.0) × (4.9)6.4(7.8) μm (Gerlach and Nilsson 1963) (also confirmed in the present study by examination of CBS 264.65, ex-type), revealing them to represent two distinct species. Furthermore, based on the phylogenetic and morphological data obtained in the present study, several novel species could be distinguished that are phylogenetically distinct from *I. radicicola*, and morphologically distinct based on a range of characters linked to culture characteristics, conidiophores, macro- and microconidium morphology. Some of these could be linked to older names, or taxa long regarded as potential syonyms of "*destructans*", which could now be resurrected. These taxa are treated below:

Ilyonectria anthuriicola *A. Cabral & Crous, sp. nov.* *(Fig. 2)*

MycoBank 560108.

Etymology: Named after its host, *Anthurium*.

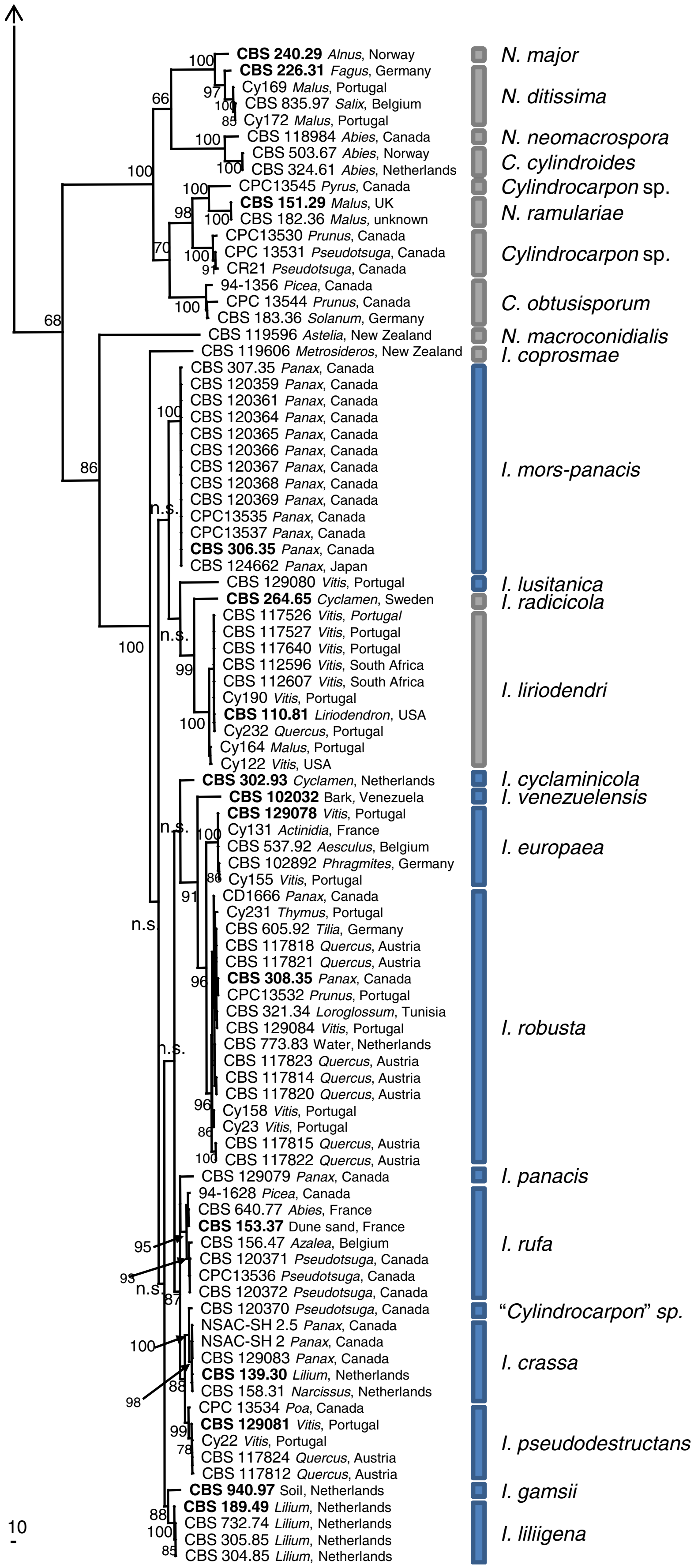
Cylindrocarpi destructantis morphologice simile, sed longitudine media conidiorum longiore, 29.5–32.2 μm, distinguitur.

Conidiophores simple or complex to sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched bearing up to three phialides, 1–3-septate, 40–95 μm long; phialides monophialidic, more or less cylindrical but slightly tapering towards the tip, 10.5–20.5 μm long, 2.5–3.5 μm wide at the base, 3.0–4.5 μm at widest point, 1.5–2.5 μm near the aperture. Conidiophores giving rise to microconidia, formed on mycelium at agar surface, penicillately mono- or bi-verticillate; phialides monophialidic, narrowly flask-shaped, typically with widest point near the middle, 8–15 μm long, 2.0–3.0 μm wide at the base, 2.5–4.5 μm at widest point, 1.0–2.0 μm near the apex. *Sporodochial conidiophores* irregularly branched; phialides cylindrical, mostly widest near the middle. *Macroconidia* formed in flat domes of slimy masses, (1–)

Fig. 1 The first of 1,000 equally most parsimonious trees obtained from the combined ITS, TUB, HIS and TEF sequence alignment of *Cylindrocarpon* isolates and relatives with a heuristic search using PAUP v. 4.0b10. The tree was rooted using *Campylocarpon* isolates as outgroup sequences and bootstrap support values are indicated near the nodes, where"ns" designates not supported. Ex-type strains are indicated in *bold*. Newly described species are indicated by blue boxes. *Scale bar* shows 10 changes ▶


CBS 112613 Vitis, South Africa
CBS112679 Vitis, South Africa
CBS 564.95 Anthurium, Netherlands
Cy228 Ficus, Portugal
CBS 129082 Vitis, Portugal
CBS 100819 Erica, New Zealand
CBS 113550 Vitis, New Zealand
Cy217 Vitis, Portugal
CBS 120497 Vitis, Slovenia
CBS 120171 Vitis, Slovenia
CBS 120172 Vitis, Slovenia
CBS 120173 Vitis, Slovenia
CBS 120499 Vitis, Slovenia
CBS 120498 Vitis, Slovenia
Cy238 Vitis, Portugal
Cy196 Vitis, Portugal
CBS 162.89 Hordeum, Netherlands
Cy108 Vitis, Portugal
Cy200 Vitis, Portugal
CBS 159.34 unknown, Germany
CBS 173.37 Pinus, UK
Cy135 Vitis, Portugal
Cy144 Vitis, Portugal
CBS 129085 Vitis, Portugal
Cy146 Vitis, Portugal
Cy147 Vitis, Portugal
Cy243 Vitis, Portugal
Cy148 Vitis, Portugal
Cy149 Vitis, Portugal
Cy150 Vitis, Portugal
Cy151 Vitis, Portugal
Cy152 Vitis, Portugal
Cy153 Vitis, Portugal
CPC 13539 Picea, Canada
CBS 129087 Vitis, Portugal
Cy134 Vitis, Portugal
Cy133 Vitis, Spain
CBS 112608 Vitis, South Africa
CBS 113552 Vitis, New Zealand
Cy117 Vitis, USA
Cy125 Vitis, USA
Cy230 Festuca, Portugal
CBS 112593 Vitis, South Africa
Cy130 Vitis, USA
Cy116 Vitis, USA
Cy129 Vitis, USA
Cy115 Vitis, USA
Cy119 Vitis, USA
Cy124 Vitis, USA
CBS 112603 Vitis, South Africa
CBS 112594 Vitis, South Africa
CBS 112601 Vitis South Africa
Cy128 Vitis, USA
CBS 112605 Vitis, South Africa
CBS 112615 Vitis, South Africa
Cy140 Vitis, Portugal
Cy175 Vitis, Portugal
Cy181 Vitis, Portugal
Cy216 Vitis, Portugal
Cy244 Vitis, Portugal
Cy258 Vitis, Portugal
Cy123 Vitis, USA
Cy139 Vitis, Portugal
Cy260 Vitis, Portugal
Cy132 Vitis, Portugal
Cy235 Vitis, Portugal
CBS 112604 Vitis, South Africa
Cy237 Vitis, Portugal
Cy214 Vitis, Portugal
Cy72 Vitis, Portugal
Cy142 Vitis, Portugal
Cy143 Vitis, Portugal
CBS 112609, Vitis Australia
CBS 112598, Vitis South Africa
Cy246 Vitis, Portugal
CBS 129086 Vitis, Portugal
CPC13533 Vitis, Canada
Cy157 Vitis, Portugal
Cy221 Fragaria, USA
Cy69 Vitis, Portugal
Cy118 Vitis, USA
Cy120 Vitis, USA
Cy222 Fragaria, USA
Cy71 Vitis, Portugal
Cy240 Vitis, Portugal
Cy96 Quercus, Austria
Cy262 Vitis, Portugal
CBS 119.41 Fragaria, Netherlands
Cy223 Fragaria, USA
Cy136 Vitis, Portugal
Cy137 Vitis, Portugal
Cy138 Vitis, Portugal
Cy141 Vitis, Portugal
CBS 113555 Vitis, New Zealand
CBS 188.49 Abies, Netherlands
Cy75 Vitis, Portugal
Cy97 Quercus, Austria
90
99
100
99
100
100
100
100
100
97
85
90
n.s.
100
75
100
91
100
86
100
90
94
97
86
100
100
Campyl. fasciculare
Campyl. pseudofasciculare
I. anthuriicola
"Cylindrocarpon" sp.
I. vitis
C. pauciseptatum
"Cylindrocarpon" sp. 1
"Cylindrocarpon" sp.2
"Cylindrocarpon" sp. 3
"Cylindrocarpon" sp. 5
"Cylindrocarpon" sp.6
I. macrodidyma
"Cylindrocarpon" sp. 4

Fig. 1 (continued)



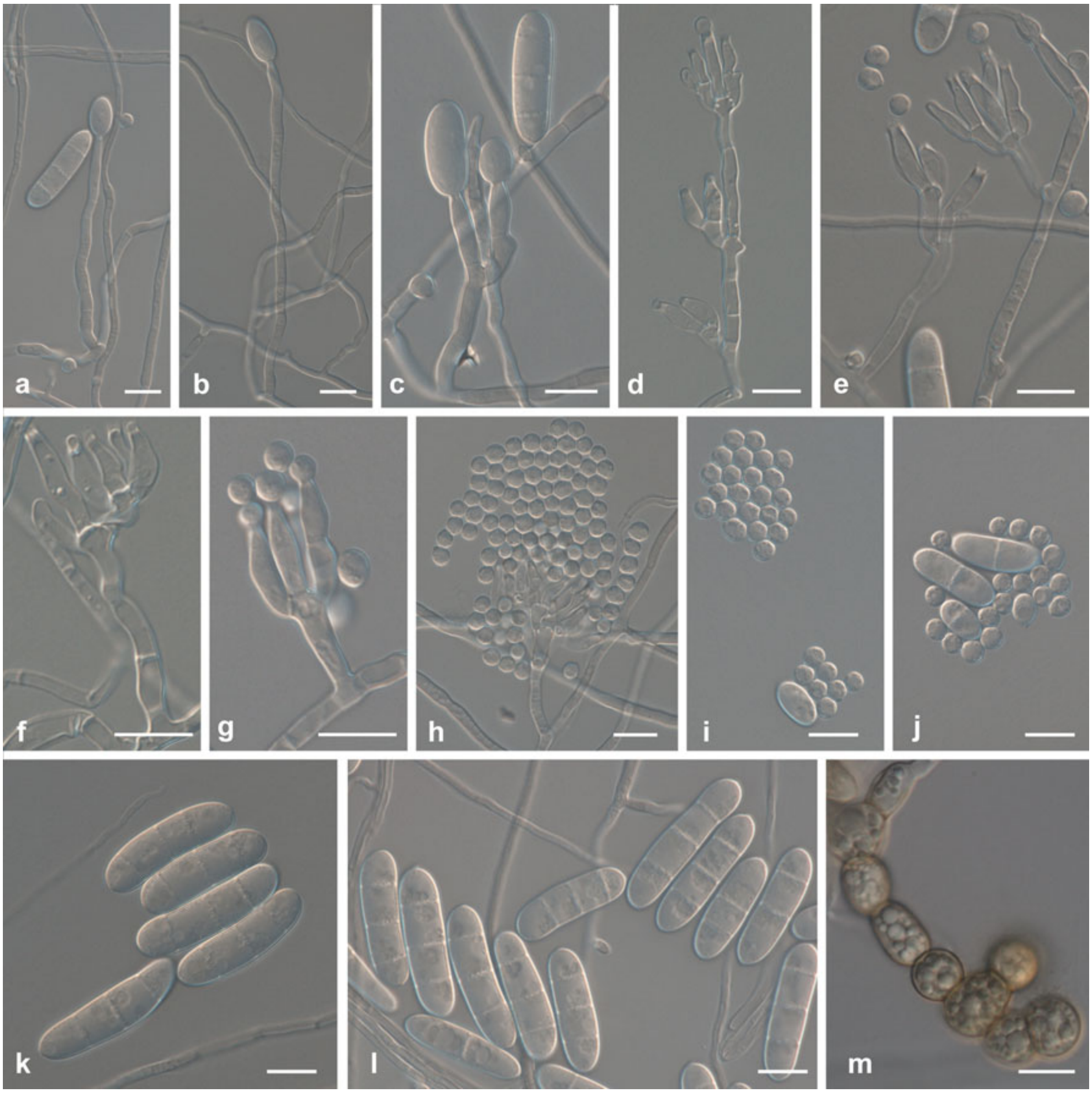


Fig. 2 *Ilyonectria anthuriicola* (CBS 564.95). **a**–**c** Simple conidiophores on aerial mycelium. **d**–**g** Conidiophores giving rise to microconidia, formed on mycelium at agar surface, penicillately mono- or bi-verticillate. **h**–**l** Micro- and macroconidia. **m** Chlamydospores in mycelium. *Bars* 10 μm

3-septate, straight or minutely curved, cylindrical with both ends more or less obtusely rounded, mostly without a visible hilum; 1-septate, (20.0)23.5–26.7(29.0) × (5.5)5.9–6.8(7.0) μm (average = 25.1 × 6.4 μm), with a length:width ratio of 3.6–4.8; 2-septate, (25.0)26.6–29.3(32.0) × (6.5) 6.8–7.8(8.5) μm (av. = 27.9 × 7.3 μm), with a length:width ratio of 3.2–4.8; 3-septate, (25.0)29.5–32.2(38.0) × (6.0) 7.5–8.1(9.0) μm (av. = 30.8 × 7.8 μm) with a length:width ratio of 3.1–5.2. *Microconidia* 0(−1)-septate, subglobose to ovoid, rarely ellipsoid, mostly with a visible centrally located or slightly laterally displaced hilum; aseptate microconidia, (4.9)5.0–8.1(12.0) × (4.0)4.3–5.5(6.5) μm (av. = 6.5 × 4.9 μm), with a length:width ratio of 1.0–1.8; 1-septate, (11.0)11.6–16.7(18.0) × (5.0)5.4–6.1(6.0) μm (av. = 14.1 × 5.8 μm), with a length:width ratio 1.8–3.0. *Chlamydospores* globose to subglobose to ellipsoid, 8–14 × 7–12 μm, smooth, but often appearing rough due to deposits, thick-walled, formed intercalary in chains or in clumps and also in the cells of macroconidia, hyaline, becoming golden-brown.

Holotype: Netherlands, Bleiswijk, root rot of *Anthurium* sp., 1995, coll./isol. R. Pieters, holotype CBS H-20555, culture ex-type CBS 564.95.

Culture characteristics: Mycelium felty with average density. Surface on OA chestnut, with aerial mycelium sparse, saffron; margin pure yellow to orange. Surface on PDA, chestnut with saffron aerial mycelium, growth at margin luteous; zonation absent, transparency homogeneous, margin even; reverse similar to surface, but chestnut to cinnamon on OA, and chestnut on PDA. Colonies on PDA do not grow at 4°C after 7 days. Optimum temperature 20°C when colonies reach 25–27 mm, after 7 days. Colony diam was 20–22 mm at 25°C, after 7 days. Hardly grows at 30°C (2 mm colony diam after 7 days).

Isolate studied: CBS 564.95 (Table 1).

Host and distribution: Roots of *Anthurium* sp. (Netherlands).

Ilyonectria crassa *(Wollenw.) A. Cabral & Crous, comb. et stat. nov. (Fig. 3)*

MycoBank 560109.

Basionym: *Cylindrocarpon radicicola* var. *crassum* Wollenw., Z. Parasitenkunde 3: 495. 1931.

≡ *Cylindrocarpon destructans* var *crassum* (Wollenw.) C. Booth, Mycol. Pap. 104: 37. 1966.

Conidiophores simple or complex, to sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched bearing up to two phialides, rarely consisting only of phialides, 1–4-septate, 40–180 μm long; phialides monophialidic, cylindrical to subulate, 20–55 μm long, 2.5–4.0 μm wide at the base, 1.5–2.0 μm near the apex. *Complex conidiophores* aggregated in small sporodochia (on carnation leaf), repeatedly and irregularly branched; phialides more or less cylindrical, but tapering slightly in the upper part towards the apex, or narrowly flask-shaped, mostly with widest point near the middle, 17–24 μm long, 2.0–3.0 μm wide at the base, 2.5–3.5 μm at the widest point, and 1.5–2.5 μm wide near the apex. *Macroconidia* predominating, formed on both type of conidiophores, on SNA formed in flat domes of slimy masses, 1–3-septate, straight, cylindrical, but may narrow towards the tip, more or less broadly rounded, and the base appearing somewhat acute due to the presence of the hilum, mostly centrally located; 1-septate, (21.0)25.7–27.3(34.0)× (4.5)5.0–5.3(6.5) μm (av. = 26.5×5.1 μm), with a length: width ratio of 3.8–6.7; 2-septate, (23.0)28.5–30.3(37.0)× (4.5)5.3–5.6(6.5) μm (av. = 29.4×5.4 μm)with a length: width ratio of 4.2–6.7; 3-septate, (29.0)34.1–36.0(49.0)× (5.0)5.6–5.8(7.0) μm (av. = 35.1×5.7 μm), with a length: width ratio of 4.8–8.9. *Microconidia* 0–1-septate, ellipsoid to subcylindrical, more or less straight, with a visible, truncate hilum; aseptate microconidia, (7.0)9.7–10.9 (15.0)×(3.0)3.3–3.6(4.5) μm (av. = 10.3×3.5 μm), with a length:width ratio of 1.8–4.3; 1-septate, (12.0)14.2–15.2 (19.0)×(3.0)3.8–4.2(5.0) μm (av. = 14.7×4.0 μm), with a length:width ratio 2.7–5.0. *Conidia* formed in heads on simple conidiophores or as white (OA) or unpigmented (SNA) masses. *Chlamydospores* globose to subglobose to cylindrical, 7–15×6–10 μm, smooth, but often appearing rough due to deposits, thick-walled, terminal on short

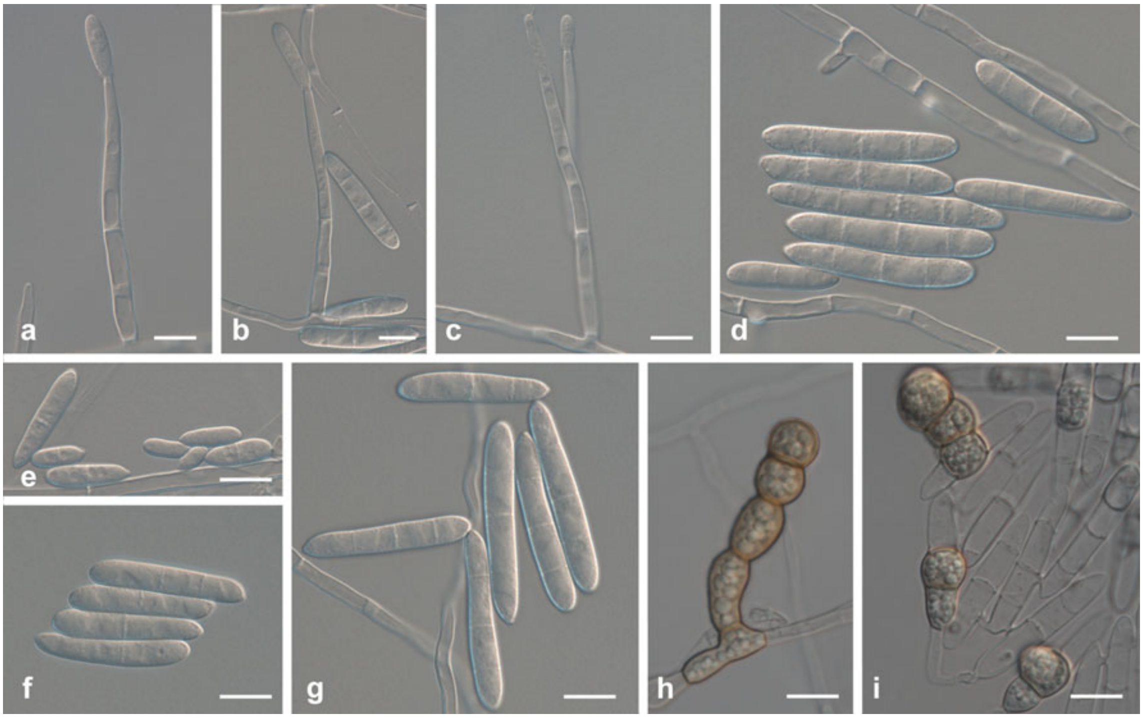


Fig. 3 *Ilyonectria crassa* (CBS 129083). **a**–**c** Simple conidiophores on aerial mycelium. **d**–**g** Micro- and macroconidia. **h**–**i** Chlamydospores and macroconidia. *Bars* 10 μm

lateral branches, rarely intercalary, single, in chains or in clumps, and also in the cells of the macroconidia, hyaline, becoming pale brown.

Lectotype: The Netherlands, on *Lilium* bulbs, Dec. 1930, coll./isol. W.F. van Hell, lectotype designated here CBS H-20556, culture ex-lectotype CBS 139.30.

Culture characteristics: Mycelium cottony to felty with average to strong density. Surface on OA cinnamon, with aerial mycelium sparse, buff. Surface on PDA saffron with aerial mycelium sparse buff to saffron to pale luteous. No zonation was observed, transparency was homogeneous and growth at margin even. Reverse similar to surface, except in colour, saffron to cinnamon on OA, and chestnut to sienna on PDA. Colonies on PDA grow 5–8 mm diam at 4°C after 7 days. Optimum temperature at 20°C, when colonies reach 31–46 mm diam, after 7 days. Colony diam was 19–34 mm at 25°C, after 7 days. No growth was observed at 30°C.

Isolates studied: CBS 139.30; CBS 158.31; CBS 129083; NSAC-SH-2; NSAC-SH-2.5 (Table 1).

Hosts and distribution: *Lilium* sp. (bulbs), *Narcissus* sp. (roots) (Netherlands), *Panax quinquefolium* (roots) (Canada).

Notes: In the original description, Wollenweber (1931) cites *Cylindrocarpon radicicola* var. *crassum* as occurring on roots of *Ulmus*, *Taxus* and *Lilium* in Europe (Germany and the Netherlands). He did not designate any type specimen. However, he specifically refers to a culture sent to him by Prof. J. Westerdijk on *Lilium* from the CBS in the Netherlands in 1930, which was regarded as authentic for the species. This culture is represented by CBS 139.30 (accessioned in 1930, from *Lilium*, the Netherlands), and thus we designate a dried, sporulating culture as lectotype for the species.

Ilyonectria cyclaminicola *A. Cabral & Crous, sp. nov. (Fig. 4)*

MycoBank 560110.

Etymology: Named after the host from which it was isolated, *Cyclamen* sp.

Cylindrocarpi destructantis morphologice simile, sed longitudine media conidiorum longiore, 26.9–31.9 µm, distinguitur.

Conidiophores simple or complex to sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched, bearing up to two phialides, 1–3-septate, 60–120 µm long; phialides monophialidic, more or less cylindrical but slightly tapering towards the tip, 20–60 µm long, 2.0–4.0 µm wide at the base, 3.0–4.5 µm at widest point, 1.5–2.5 µm near the aperture. Conidiophores giving rise to microconidia formed by mycelium at agar surface, penicillate to mono-verticillate; phialides monophialidic, more or less cylindrical, but with slight taper towards the tip, 19–34 µm long, 1.5–2.5 µm wide at the base, 2.0–3.0 µm

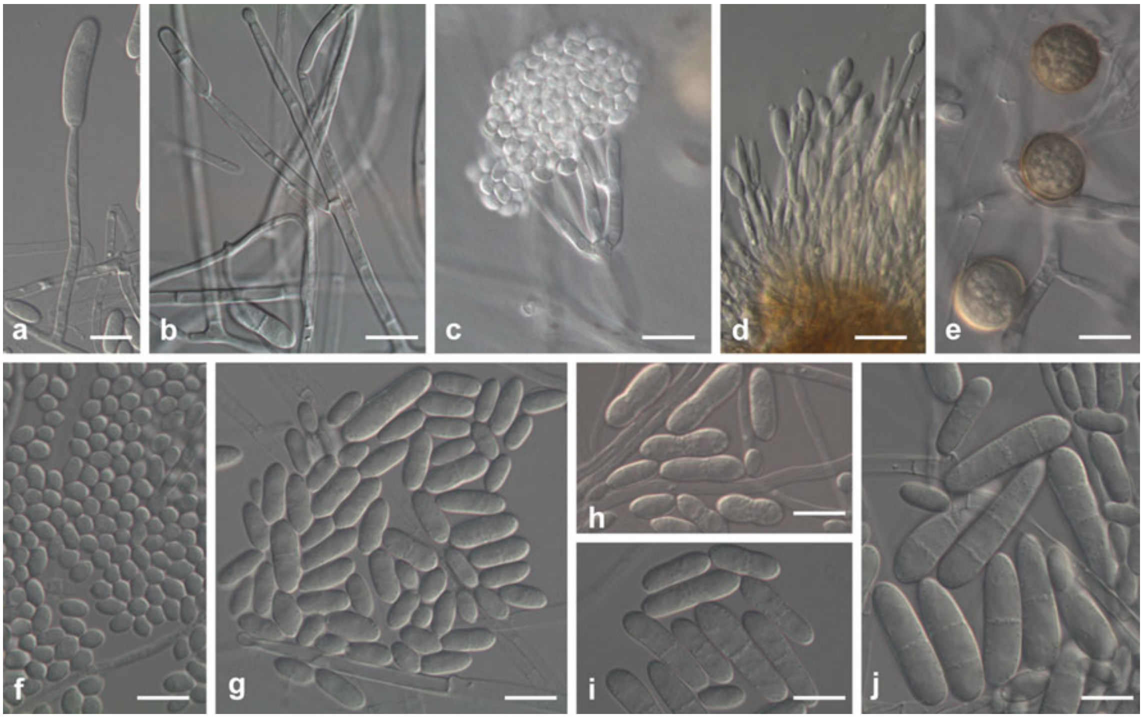


Fig. 4 *Ilyonectria cyclaminicola* (CBS302.93). **a**, **b** Simple conidiophores on aerial mycelium. **c** Pennicilate conidiophores with aseptate microconidia. **d** Sporodochial conidiophore on carnation leaf agar. **e** Isolated chlamydospores formed in lateral branches. **f**–**j** Micro- and macroconidia. *Bars* 10 µm

at widest point, 1.0–2.0 µm near the apex. *Sporodochial conidiophores* irregularly branched; phialides more or less cylindrical, but slightly tapering towards the tip, or narrowly flask-shaped, with widest point near the base, 14–26 µm long, 2.5–3.5 µm wide at the base 3.0–4.0 µm at widest point, 1.0–2.0 µm near the apex. *Macroconidia* formed in flat domes of slimy masses, 1(−3)-septate, straight or minutely curved, cylindrical with both ends more or less broadly rounded, sometimes with a constriction at the septa, mostly without a visible hilum; 1-septate, (19.2)21.3–23.6 (29.8)×(4.4)5.4–6.0(7.3) µm (av. = 22.5×5.7 µm), with a length:width ratio of 3.4–5.5; 2-septate, (23.8)24.0–28.4 (29.8)×(5.0)5.5–7.3(8.0) µm (av. = 26.2×6.4 µm), with a length:width ratio of 3.1–5.1; 3-septate, (25.3)26.9–31.9 (33.6)×(5.8)5.9–6.5(6.9) µm (av. = 29.4×6.2 µm), with a length:width ratio of 3.7–5.6. *Microconidia* formed in heads or on the agar surface, 0–1-septate, subglobose to ovoid to subcylindrical, mostly with a visible, centrally located or slightly laterally displaced hilum; aseptate microconidia, (3.9)7.6–8.9(12.9)×(2.2)3.6–3.9(5.4) µm (av. = 8.2×3.7 µm), with a length:width ratio of 1.2– 3.4; 1-septate, (11.5)13.8–15.2(17.5)×(3.7)4.6–4.9(5.5) µm (av. = 14.5×4.7 µm), with a length:width ratio of 2.3–3.9. *Chlamydospores* globose to subglobose, 10–18×10–16 µm, smooth, but often appearing rough due to deposits, thick-walled, formed in lateral branches, rarely intercalary, mostly isolated, hyaline, becoming medium brown.

Holotype: Netherlands, Roelofarendsveen, NAKS laboratory, *Cyclamen* bulb, May 1993, coll./isol. M. Hooftman, iden. E.J. Hermanides-Nijhof, holotype CBS H-20557, culture ex-type CBS 302.93.

Culture characteristics: Mycelium felty with average density. Surface on OA sepia to chestnut. Surface on PDA sepia to chestnut, with sparse, rust, aerial mycelium; no zonation was observed, and transparency was homogeneous; margins predominantly even. Reverse similar to surface, except in colour, sepia to dark brick on OA and chestnut on PDA. Colonies on PDA do not grow at 4°C after 7 days. Optimum temperature at 22°C, when colonies reach 68–70 mm diam, after 7 days. Colony diam was 63–64 mm at 25°C, after 7 days. No growth was observed at 30°C.

Isolate studied: CBS 302.93 (Table 1).

Host and distribution: Bulb of *Cyclamen* sp. (Netherlands).

Ilyonectria europaea *A. Cabral, Rego & Crous, sp. nov. (Fig. 5)*

MycoBank 560103.

Etymology: Named after the European continent, where this fungus appears to be widely distributed.

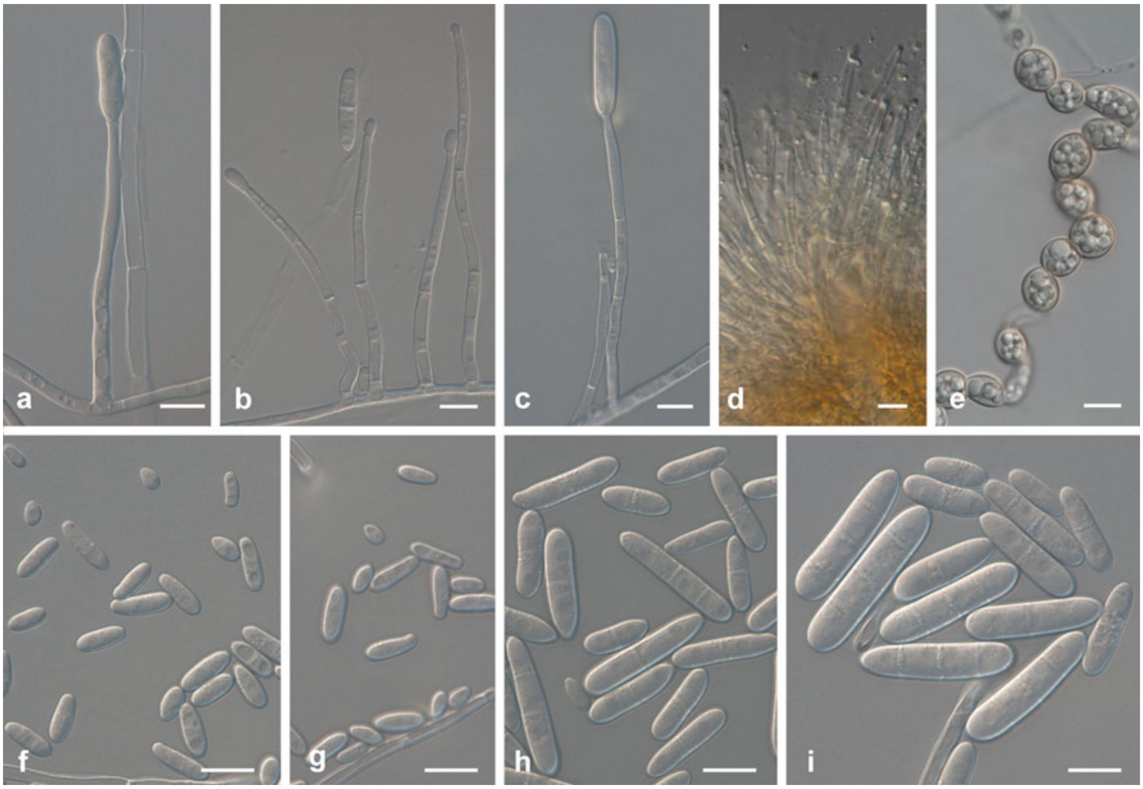


Fig. 5 *Ilyonectria europaea* (CBS 129078). **a**–**c** Simple conidiophores on aerial mycelium. **d** Sporodochial conidiophore on carnation leaf agar. **e** Chlamydospores in aerial mycelium. **f**–**i** Micro- and macroconidia. *Bars* 10 µm

Ilyonectriae robustae morphologice similis, sed longitudine media macroconidiorum breviore, 29.7–31.5 µm, distinguitur.

Conidiophores simple or complex to sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched, bearing up to three phialides, 1–3-septate, 50–120 µm long; phialides monophialidic, cylindrical to subulate, 26–60 µm long, 2.5–3.5 µm wide at the base, 1.5–2.5 µm near the apex. *Complex conidiophores* aggregated in small sporodochia (on carnation leaf), repeatedly and irregularly branched. *Macroconidia* predominating, formed on both type of conidiophores, on SNA formed in flat domes of slimy masses, 1(−3)-septate, straight or minutely curved, cylindrical with both ends more or less broadly rounded, but may narrow towards the tip, mostly without a visible hilum; 1-septate, (16.4)21.9–23.4(34.0)×(4.0)5.2–5.6(7.8) µm (av. = 22.7×5.4 µm), with a length:width ratio of 3.2–5.4; 2-septate, (22.0)26.4–28.1(34.0)×(4.4)5.9–6.4(8.0) µm (av. = 27.2×6.1 µm), with a length:width ratio of 3.4–6.4; 3-septate, (22.0)29.7–31.5(40.0)×(5.0)6.5–6.9 (8.6) µm (av. = 30.6×6.7 µm), with a length:width ratio of 3.5–6.0. *Microconidia* 0–1-septate, ellipsoid to ovoid, more or less straight, without a visible hilum; aseptate microconidia sometimes curved towards one end, (3.0) 8.5–9.8(17.0)×(1.7)3.3–3.5(5.0) µm (av. = 9.1×3.4 µm), with a length:width ratio of 1.5–3.4; 1-septate, (9.2)13.4–14.6(18.9)×(3.0)4.0–4.4(5.9) µm (av. = 14.0×4.2 µm), with a length:width ratio 2.6–4.0. *Conidia* formed in heads or on simple conidiophores as white (OA) or unpigmented (SNA) masses. *Chlamydospores* globose to subglobose, 9–14×7–14 µm, smooth, but often appearing rough due to deposits, thick-walled, terminal on short or long lateral branches or intercalary, single, in chains or in clumps, golden-brown.

Holotype: Portugal, Vidigueira, at basal end of a 2-year-old *Vitis vinifera* plant; scion Petit Verdot, rootstock 110R, 2008, coll./isol. C. Rego, holotype CBS H-20558, culture ex-type CBS 129078=Cy241=CPC 19165.

Culture characteristics: Mycelium felty with average density. Surface on OA chestnut, with saffron aerial mycelium. Sienna to saffron on PDA, with luteous aerial mycelium. Concentric zonation, with homogeneous transparency, margins predominantly even. Reverse similar to surface, except in the colour; sepia on OA, and chestnut to umber on PDA. Colonies on PDA grow poorly, 1–5 mm diam at 4°C after 7 days. Optimum temperature for growth is 22°C, when colonies reach 43–57 mm diam, after 7 days. Colony diam was 37–47 mm at 25°C, after 7 days. No growth was observed at 30°C.

Isolates studied: Cy131; Cy155; CBS 537.92; CBS 102892; CBS 129078 (Table 1).

Hosts and distribution: *Actinidia chinensis* 'Hayward' (internal lesion of stem) (France), *Aesculus hippocastanum* (wood) (Belgium), *Phragmites australis* (stem) (Germany), *Vitis vinifera* (Portugal).

Ilyonectria gamsii *A. Cabral & Crous, sp. nov. (Fig. 6)*

MycoBank 560112.

Etymology: Named after Prof. dr. Walter Gams, who has made a major contribution to our knowledge of Hypocrealean soil fungi.

Ilyonectriae panacis morphologice similis, sed longitudine media macroconidiorum breviore, 34.3–38.5 µm, distinguitur.

Conidiophores simple or complex to sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched, bearing up to two phialides, 1–3-septate, 50–150 µm long; phialides monophialidic, cylindrical to subulate, 30–60 µm long, 2.5–3.5 µm wide at the base, 1.5–2.0 µm near the aperture. *Sporodochial conidiophores* irregularly branched; phialides cylindrical, mostly widest near the base. *Macroconidia* predominating, formed on simple conidiophores, on SNA formed in flat domes of slimy masses, 1–3-septate, straight, cylindrical with both ends broadly rounded, with mostly visible, centrally located hilum; 1-septate, (22.0)25.7–27.9(33.0)×(4.0)5.1–5.5(6.0) µm (av. = 26.8×5.3 µm), with a length:width ratio of 4.3–6.2; 2-septate, (25.0)28.2–31.7(39.0)×(5.0)5.5–5.9(6.5) µm (av. = 29.9×5.7 µm), with a length:width ratio of 4.2–7.1; 3-septate, (24.0)34.3–38.5(44.0)×(5.0)5.9–6.3(7.0) µm (av. = 36.4×6.1 µm), with a length:width ratio of 4.3–7.3. *Microconidia* 0–1-septate, ellipsoid to subcylindrical, more or less straight, mostly with a visible hilum; aseptate microconidia (4.0)6.9–8.0(10.0)×(3.0)4.0–4.5(5.0) µm (av. = 7.4×4.3 µm), with a length:width ratio of 1.3–2.9; 1-septate, (8.0)12.9–15.7(18.0)×(4.0)4.2–4.7(5.5) µm (av. = 14.3×4.4 µm), with a length:width ratio 1.8–4.0. *Chlamydospores* globose to subglobose to ellipsoidal, 8–14×7–12 µm, smooth, but often appearing rough due to deposits, thick-walled, mostly intercalary, rarely terminal on short lateral branches, single, in chains or in clumps, hyaline, becoming medium brown.

Holotype: Netherlands, Lelystad, soil, June 1997, coll./isol. J.T. Poll, iden. W. Gams, holotype CBS H-20559, culture ex-type CBS 940.97.

Culture characteristics: Mycelium cottony, dense. Surface on OA cinnamon, with sparse, buff aerial mycelium, on PDA umber to chestnut, with buff to saffron aerial mycelium; zonation absent, transparency homogeneous, margin even; reverse similar to surface, but chestnut on PDA. Colonies on PDA grow 6–7 mm diam at 4°C after 7 days. Optimum temperature at 22°C when colonies reach

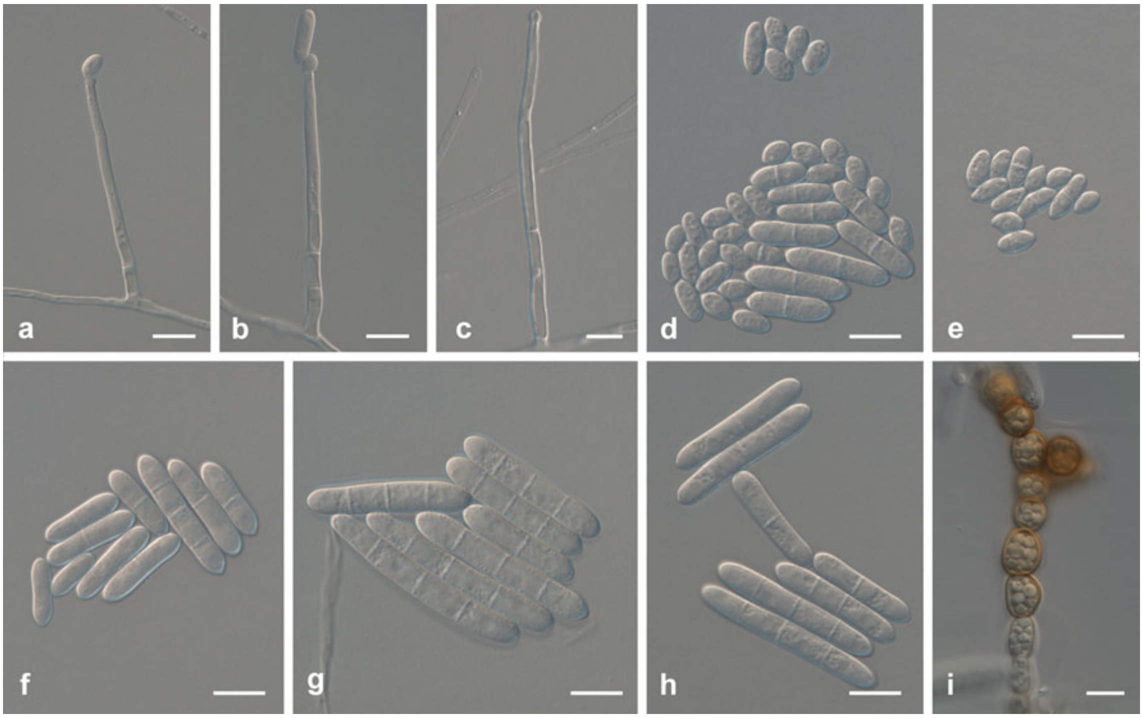


Fig. 6 *Ilyonectria gamsii* (CBS 940.97). **a**–**c** Simple conidiophores on aerial mycelium. **d**–**h** Micro- and macroconidia. **i** Chlamydospores on mycelium. *Bars* 10 µm

44–45 mm diam, after 7 days. Colony diam is 22–24 mm at 25°C, after 7 days. No growth observed at 30°C.

Isolate studied: CBS 940.97 (Table 1).

Habitat and distribution: Soil (Netherlands).

Ilyonectria liliigena *A. Cabral & Crous, sp. nov. (Fig. 7)*

MycoBank 560114.

Etymology: Named after its host, *Lilium regale*.

Ilyonectriae panacis morphologice similis, sed longitudine media macroconidiorum 3-septatorum breviore, 27.9–29.8 µm, distinguitur.

Conidiophores simple or complex or sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched, bearing up to two phialides, 1–4-septate, 50–170 µm long; phialides monophialidic, cylindrical to subulate, 30–65 µm long, 2.0–3.5 µm wide at the base, 1.5–2.0 µm near the apex. *Sporodochial conidiophores* irregularly branched; phialides cylindrical, mostly widest near the base. *Macroconidia* predominating, formed on simple conidiophores, on SNA formed in flat domes of slimy masses, 1(−3)-septate, straight or frequently minutely curved, cylindrical or sometimes typically minutely widening towards the tip, therefore appearing somewhat clavate, mostly without a visible hilum; 1-septate, (19.0)22.9–24.6 (30.0)×(3.3)4.2–4.5(5.2) µm (av. = 23.8×4.3 µm), with a length:width ratio of 4.0–7.0; 2-septate, (21.0)26.1–27.7 (32.1)×(4.0)4.7–5(5.7) µm (av. = 26.9×4.9 µm)with a length:width ratio of 3.8–7.0; 3-septate, (23.9)27.9–29.8 (35.0)×(3.9)4.7–5.1(6.0) µm (av. = 28.9×4.9 µm), with a length:width ratio of 4.0–8.3. *Microconidia* 0–1-septate, ellipsoidal to subcylindrical, more or less straight, mostly with a visible hilum; aseptate, microconidia (5.9)8.9–10.3 (17.0)×(2.5)3.0–3.2(4.4) µm (av. = 9.6×3.1 µm), with a length:width ratio of 2.0–4.6; 1-septate, (10.0)12.9–14.3 (18.0)×(2.5)3.3–3.6(4.5) µm (av. = 13.6×3.4 µm), with a length:width ratio 2.8–5.6. *Conidia* formed in heads on simple conidiophores or as white (OA) or unpigmented (SNA) masses. *Chlamydospores* globose to subglobose, 6–14×5–12 µm, smooth but often appearing rough due to deposits, thick-walled, mostly in terminal on short lateral branches or rarely intercalary, single, in chains or in clumps, hyaline, becoming slightly brown at margins.

Holotype: Netherlands, Hoorn, bulb rot of *Lilium regale*, 1949, coll./isol. M.A.A. Schipper, holotype CBS H-20560, culture ex-type CBS 189.49.

Culture characteristics: Mycelium felty, with an average to strong density. Surface on OA sienna, with sparse, saffron, aerial mycelium. Surface on PDA sepia to cinnamon, with saffron to buff aerial mycelium. Zonation absent or concentric, with homogeneous transparency. Margins were even, or sometimes slightly uneven. Reverse similar to surface, except in colour; on OA pale vinaceous

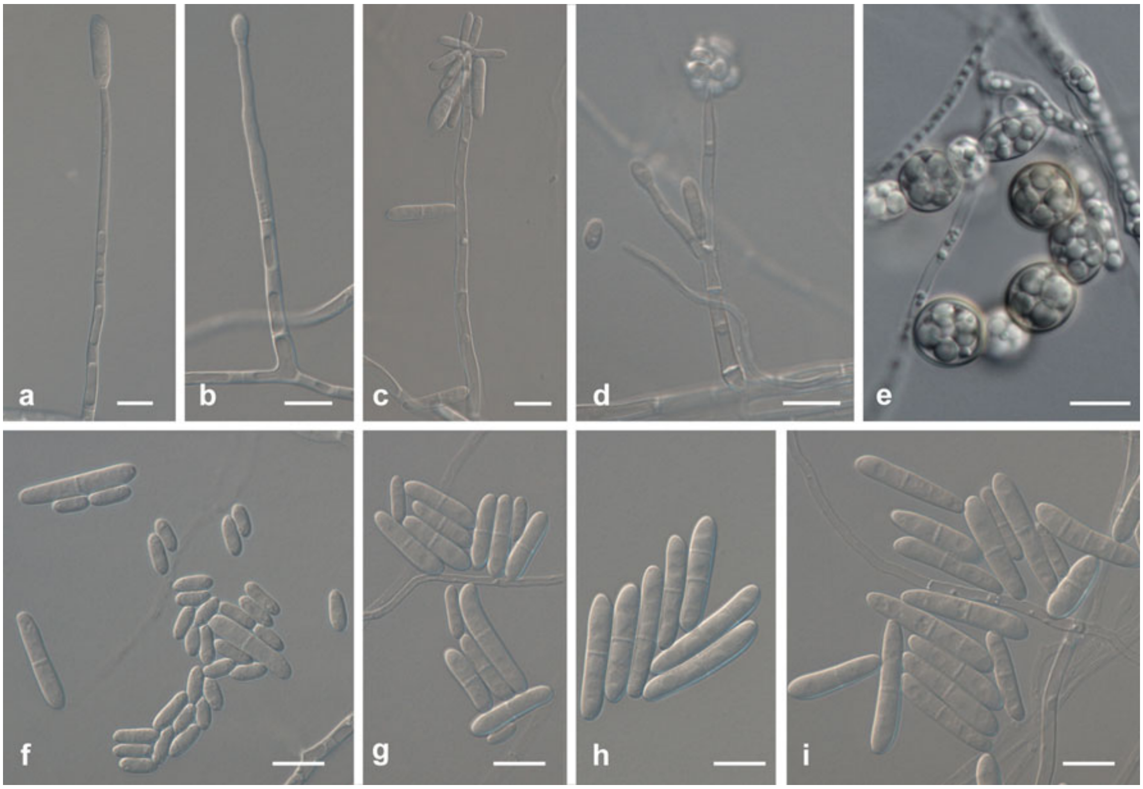


Fig. 7 *Ilyonectria liliigena* (CBS 189.49). **a**–**d** Simple conidiophores on aerial mycelium. **e** Chlamydospores on mycelium. **f**–**i** Micro- and macroconidia. *Bars* 10 µm

to cinnamon; on PDA buff to saffron to chestnut. Colonies on PDA grew poorly (1–4 mm diam) at 4°C after 7 days. Optimum temperature at 22°C, when colonies reach 34–45 mm diam, after 7 days. Colony diam was 16–29 mm at 25°C, after 7 days. No growth was observed at 30°C.

Isolates studied: CBS 189.49; CBS 732.74; CBS 304.85; CBS 305.85 (Table 1).

Host and distribution: *Lilium regale* bulbs (Netherlands).

Ilyonectria lusitanica *A. Cabral, Rego & Crous, sp. nov. (Fig. 8)*

MycoBank 560105.

Etymology: Named after the Latin name for the country from where it was collected, Portugal.

Ilyonectriae europaeae morphologice similis, sed longitudine media macroconidiorum breviore, 25–28.4 µm, distinguitur.

Conidiophores simple or complex, sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched, bearing up to two phialides, 1–4-septate, 60–220 µm long; phialides monophialidic, cylindrical to subulate, 20–70 µm long, 2.5–3.5 µm wide at the base, 1.5–2.5 µm near the aperture. *Complex conidiophores* aggregated in small sporodochia, repeatedly and irregularly branched. *Macroconidia* predominating, formed by both type of conidiophores, on SNA formed in flat domes of slimy masses, 1(−3)-septate, straight or minutely curved, cylindrical with both ends more or less broadly rounded, but may narrow towards the tip, without a visible hilum, and may have a constriction on the septa in older cultures; 1-septate, (14.0) 17.3–18.8(21.0)×(4.0)4.6–5(5.5) µm (av. = 18.1×4.8 µm), with a length:width ratio of 2.8–4.8; 2-septate, (18.0)20.5–22.1(27.0)×(4.0)4.9–5.2(6.0) µm (av. = 21.3×5.1 µm), with a length:width ratio of 3.5–5.4; 3-septate, (18.0)25.0–28.4 (38.0)×(4.5)5.2–5.5(6.0) µm (av. = 26.7×5.4 µm), with a length:width ratio of 3.6–6.8. *Microconidia* 0–1-septate, ellipsoid to ovoid, more or less straight, without a visible hilum, and may have a constriction at the septum; aseptate, (5.0)6.9–8.2(10.0)×(2.5)3.0–3.3(4.0) µm (av. = 7.6×3.2 µm), with a length:width ratio of 1.7–3.3; 1-septate, (8.0)10.0–11.0 (14.0)×(3.0)3.4–3.7(4.0) µm (av. = 10.5×3.6 µm), with a length:width ratio 2.0–3.7. *Conidia* formed in heads on simple conidiophores or as white (OA) or unpigmented (SNA) masses. *Chlamydospores* rarely observed, globose to subglobose to cylindrical, 9–13×7–11 µm, smooth, but often appearing rough due to deposits, thick-walled, intercalary, hyaline, becoming slightly brown at the margin.

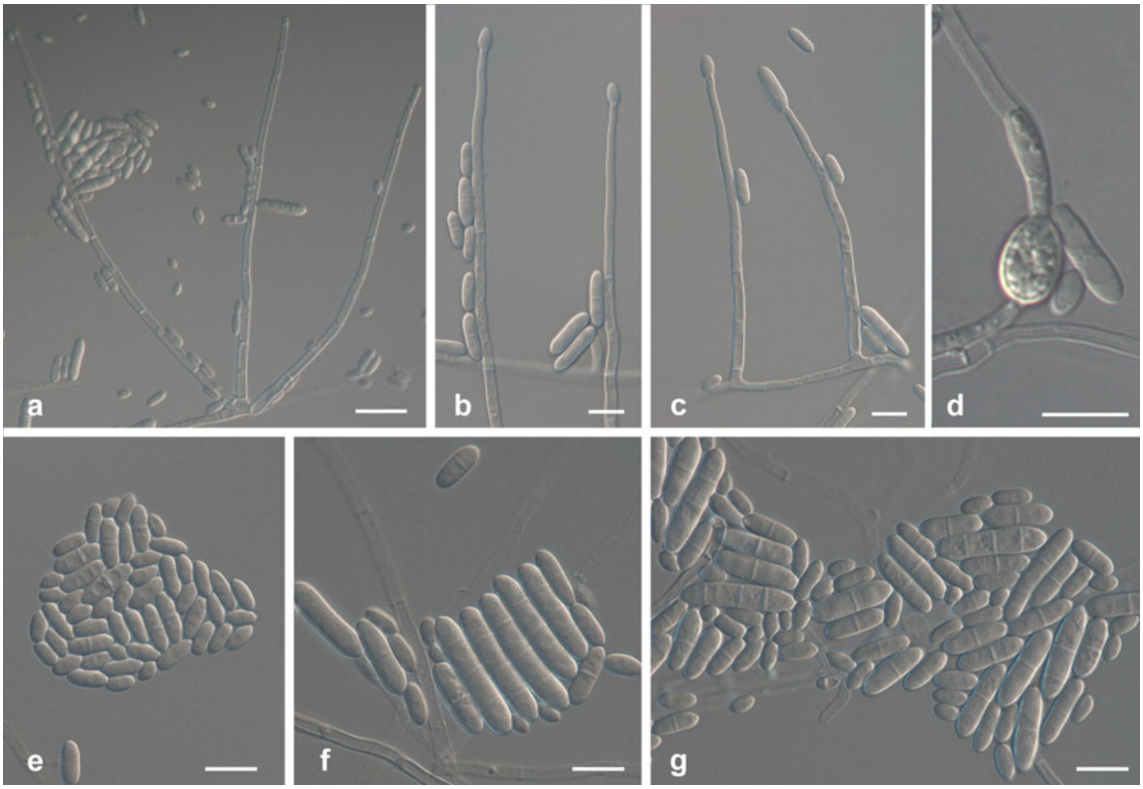


Fig. 8 *Ilyonectria lusitanica* (CBS 129080). **a**–**c** Simple conidiophores of the aerial mycelium. **d** Chlamydospores on mycelium. **e**–**g** Micro- and macroconidia. *Bars* (**a**) 20 µm, (**b**–**g**) 10 µm

Holotype: Portugal, Melgaço, Alvaredo, on *Vitis vinifera,* below grafting zone, 6–year-old plant; scion Alvarinho on rootstock 196–17, 2005, coll./isol. N. Cruz, holotype CBS H-20563, culture ex-type CBS 129080=Cy197=CPC 19166.

Culture characteristics: Mycelium felty with average density. Surface on OA cinnamon, with aerial mycelium sparse, buff. Surface on PDA, cinnamon, with sparse, ochreous to buff aerial mycelium. Zonation absent, transparency homogeneous, margin even. Reverse similar to surface but buff to cinnamon on OA, and chestnut to cinnamon on PDA. Colonies on PDA grow 5–6 mm at 4°C after 7 days. Optimum temperature between 20 and 22°C, with colonies reaching 42–46 mm and 43–46 mm, respectively, after 7 days. Colony diam was 31–32 mm at 25°C, after 7 days. No growth observed at 30°C.

Isolate studied: CBS 129080 (Table 1).

Host and distribution: *Vitis vinifera* (Portugal).

Ilyonectria mors-panacis *(A.A. Hildebr.) A. Cabral & Crous, comb. nov. (Fig. 9)*

MycoBank 560115.

Basionym: *Ramularia mors-panacis* A.A. Hildebr., Can. J. Res. 12: 101. 1935.

= *Cylindrocarpon panacis* Matuo & Miyaz., Trans. Mycol. Soc. Japan 9: 111. 1969.

≡ *Cylindrocarpon destructans* f.sp. *panacis* Matuo & Miyaz., Ann. Phytopath. Soc. Japan 50: 390. 1984.

Conidiophores simple or complex, sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched, rarely consisting only of phialides, 1–3-septate, 45–170 µm long; phialides monophialidic, cylindrical to subulate, 23–55 µm long, 2.0–3.0 µm wide at the base, 1.5–3.0 µm near the apex. *Complex conidiophores* aggregated in small sporodochia, repeatedly and irregularly branched. *Macroconidia* predominating, formed on simple conidiophores, on SNA formed in flat domes of slimy masses, 1(−3)-septate, straight, cylindrical with both ends more or less broadly rounded, mostly without a hilum; 1-septate, (21.0)28.2–31.6(40.0)×(5.0)5.8–6.3(7.5) µm (av. = 29.9×6.1 µm), with a length:width ratio of 3.3–7.0; 2-septate, (28.0)30.5–38.4(42.0)×(5.0)5.9–6.4–7.0(7.1) µm (av. = 34.4×6.4 µm), with a length:width ratio of 4.0–6.0; 3-septate, (37.8)39.0–44.2(45.0)×(6.9)7.0–7.5(7.5) µm (av. = 41.0×7.2 µm), with a length:width ratio of 5.3–6.0. *Microconidia* 0–1-septate, ellipsoid to subcylindrical, more or less straight, without a visible hilum; aseptate, (5.0)8.9–10.4(17.0)×(2.5)3.6–3.9(5.0) µm (av. = 9.6×3.8 µm), with a length:width ratio of 1.3–3.4; 1-septate, (9.0)12.5–14.1(19.0)×(3.5)4.4–4.8(5.5) µm (av. = 13.3×4.6 µm), with a length:width ratio 2.0–4.0. *Conidia*

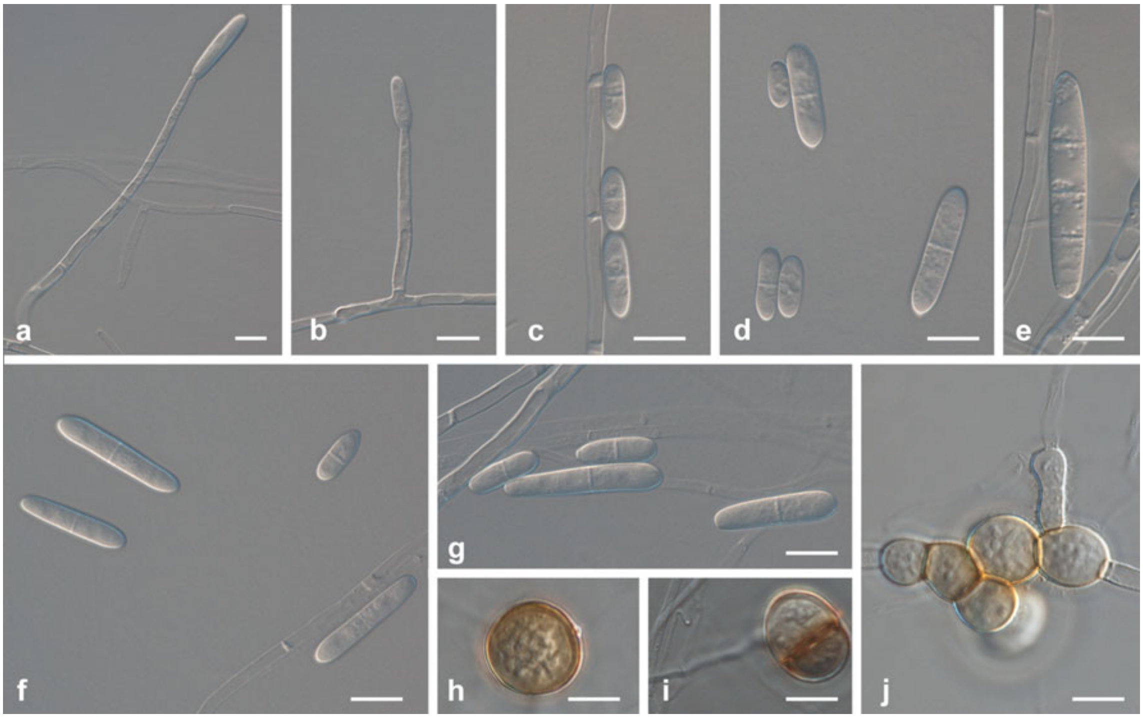


Fig. 9 *Ilyonectria mors-panacis* (CBS120363). **a**, **b** Simple conidiophores on aerial mycelium. **c**–**g** Micro- and macroconidia. **h**–**j** Chlamydospores on mycelium. *Bars* 10 µm

formed in heads on simple conidiophores or as white, creamy (OA) or hyaline (SNA) masses. *Chlamydospores* globose to subglobose, 8–16×7–15 µm, smooth, but often appearing rough due to deposits, thick-walled, terminal on short lateral branches or intercalary, single, in chains or in clumps, hyaline, becoming medium brown.

Lectotype: Canada, Ontario, on living roots of *Panax quinquefolium,* June 1935, A.A. Hildebrand, lectotype designated here CBS H-20561, culture ex-lectotype CBS 306.35.

Culture characteristics: Mycelium felty with an average density. Surface on OA and PDA chestnut, with sparse, buff to rosy-buff to cinnamon or saffron aerial mycelium. Concentric zonation, with homogeneous transparency, and even margins. Reverse similar to surface, ochreous to fulvous, or sepia to dark vinaceous on OA, and chestnut to sienna on PDA. Colonies on PDA grow 3–9 mm diam at 4°C after 7 days. Optimum temperature for growth is 18°C, when colonies reach 22–40 mm diam, after 7 days. Colony diam was 31–40 mm at 25°C after 7 days. No growth was observed at 30°C.

Isolates studied: CBS 306.35; CBS 307.35; CBS 120359; CBS 120360; CBS 120361; CBS 120362; CBS 120363; CBS 120364; CBS 120365; CBS 120366; CBS 120367; CBS 120368; CBS 120369; CBS 124662; CPC 13535; CPC 13537 (Table 1).

Hosts and distribution: *Panax ginseng* (Japan), *P. quinquefolium* (Canada).

Notes: *Ilyonectria mors-panacis* is distinct from "*C.*" *destructans* (anamorph: "*C*". *destructans*, neotype CUP-011985, conidia (18.0)23.0–30.0(35.0) × (6.0)6.5(7.0) µm) in having larger conidia, and indistinct hila (being prominent, flat, 2 µm diam in *I. radicicola*; see also Samuels and Brayford 1990, Fig. 1). "*Ramularia" panacicola* is distinct by also having shorter conidia than *I. mors-panacis*, 5.5–34.2 × 2.5–7.2 µm (Zinssmeister 1918), and appears to be another potential synonym of "*C.*" *destructans*. However, no authentic material could be located of "*R.*" *panacicola*, and the only isolate deposited under this name was a Canadian strain collected by Hildebrand (1935), which in fact represented *I. mors-panacis* (Fig. 1). The oldest name for the species on *Panax* treated here, therefore, is *R. mors-panacis* (CBS 306.35), with the Japanese collections ("*C.*" *panacis* ≡ "*C.*" *destructans* f.sp. *panacis*, CBS 124662= NBRC 31881) being later synonyms (see Fig. 1).

Ilyonectria panacis *A. Cabral & Crous, sp. nov. (Fig. 10)*

MycoBank 560104.

Etymology: Named after its host, *Panax quinquefolium*.

Ilyonectriae liliigenae morphologice similis, sed longitudine media macroconidiorum longiore, 31–35 µm, distinguitur.

Conidiophores simple or complex, sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched bearing up to three phialides, 1–5-septate, 60–220 µm long; phialides monophialidic, cylindrical to

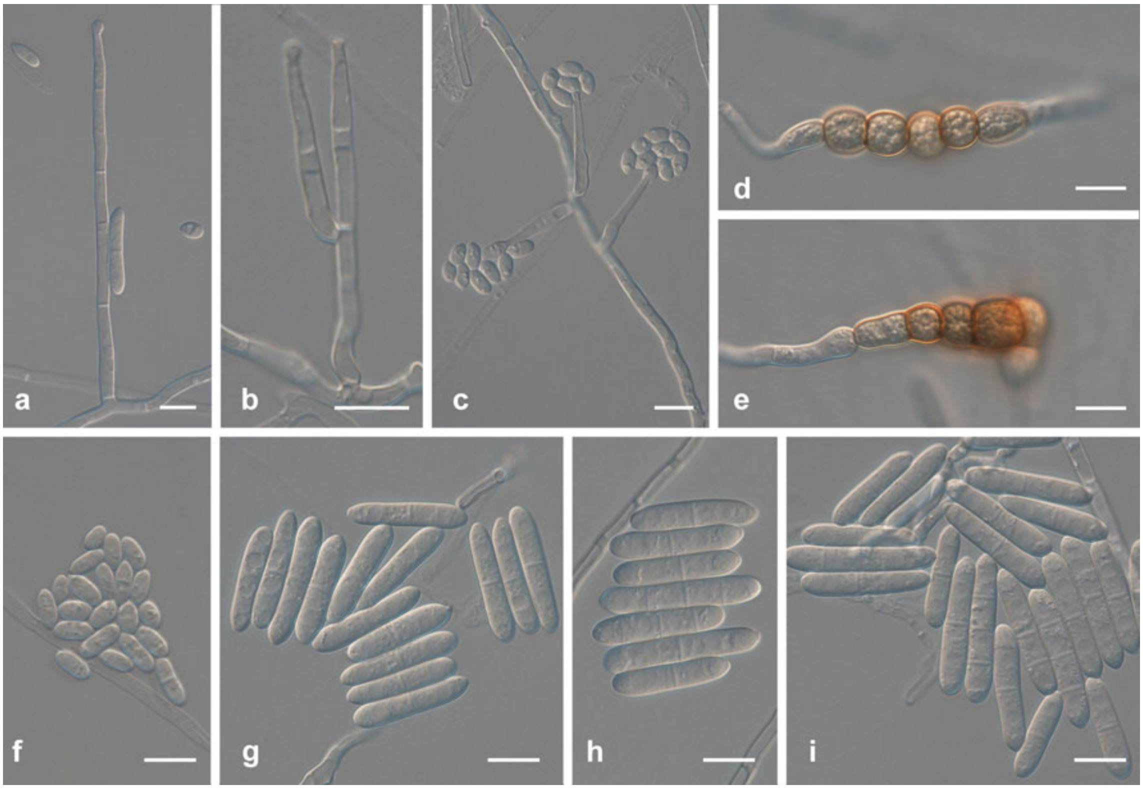


Fig. 10 *Ilyonectria panacis* (CBS 129079). **a**–**c** Simple, unbranched or sparsely branched conidiophores on aerial mycelium. **d**, **e** Chlamydospores on mycelium. **f**–**i** Micro- and macroconidia. *Bars* 10 μm

subulate, 20–65 μm long, 2.5–3.0 μm wide at the base, 1.5–2.0 μm near the aperture. *Complex conidiophores* aggregated in small sporodochia, repeatedly and irregularly branched. *Macroconidia* predominating, formed on both type of conidiophores, on SNA formed in flat domes of slimy masses, 1(−3)-septate, straight, cylindrical with both ends more or less broadly rounded, mostly with a visible centrally located hilum; 1-septate, (20.0)23.7–25.9(32.0)×(4.0)4.7–5.0(5.5) μm (av. = 24.8×4.8 μm), with a length:width ratio of 4.0–6.0; 2-septate, (23.0)27.0–30.3(37.0)×(4.8)5.0–5.4(6.0) μm (av. = 28.7×5.2 μm), with a length:width ratio of 4.6–6.7; 3-septate, (27.0)31.2–35.0(49.0)×(5.0)5.4–5.8(6.0) μm (av. = 33.1×5.6 μm), with a length:width ratio of 4.9–8.2. *Microconidia* 0–1-septate, ellipsoid to ovoid to subcylindrical, more or less straight, mostly with a visible hilum; aseptate, (6.0)8.0–9.8(13.0)×(3.5)3.7–3.9(4.0) μm (av. = 8.9×3.8 μm), with a length:width ratio of 1.7–3.3; 1-septate, (8.0)11.3–13.7(16.0)×(3.5)3.8–4.2(4.5) μm (av. = 12.5×4.0 μm), with a length:width ratio 1.8–4.3. *Conidia* formed in heads on simple conidiophores or as white (OA) or unpigmented (SNA) masses. *Chlamydospores* globose to subglobose to ellipsoidal, 8–14×6–10 μm, smooth, but often appearing rough due to deposits, thick-walled, terminal on short lateral branches or intercalary, single, in chains or in clumps, hyaline, becoming medium brown.

Holotype: Canada, Alberta, *Panax quinquefolium*, 1998, coll./isol. K. F. Chang, holotype CBS H-20562, culture ex-type CBS 129079=CDC-N-9A=CPC 19167.

Culture characteristics: Mycelium felty with strong density. Surface on OA chestnut to sienna, with aerial mycelium sparse, vinaceous-buff. Surface on PDA chestnut to cinnamon, with aerial mycelium sparse, buff to saffron. No zonation was observed, and transparency was homogeneous; margins predominantly even. Reverse similar to surface, except in the colour, fawn to cinnamon on OA, and chestnut on PDA. Colonies on PDA grow 5 mm diam at 4°C after 7 days. Optimum temperature at 20°C, with colonies reaching 40–42 mm diam, after 7 days. Colony diam was 15 mm at 25°C after 7 days. No growth observed at 30°C.

Isolate studied: CBS 129079 (Table 1).

Host and distribution: *Panax quinquefolium* (Canada).

Notes: Several species have in the past been described on *Panax* in the genera *Ramularia* and *Cylindrocarpon*. The only unresolved species is *"C." destructans* (and its potential synonym, "*Ramularia" panacicola,* see above). *"Cylindrocarpon" destructans* is clearly different from *I.*

panacis, which has larger conidia, (27.0)31.2–33.1–35.0 (49.0)×(5.0)5.4–5.6–5.8(6.0) µm.

Ilyonectria pseudodestructans *A. Cabral, Rego & Crous, sp. nov. (Fig. 11)*

MycoBank 560106.

Etymology: Named after its morphological similarity to "*Cylindrocarpon" destructans*.

Ilyonectriae crassae morphologice similis, sed macroconidiis clavatis distinguitur.

Conidiophores simple or complex, sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched, bearing up to two phialides, 1–3-septate, 50–180 µm long; phialides monophialidic, cylindrical to subulate, 30–58 µm long, 2.5–3.5 µm wide at the base, 1.5–2.0 µm near the aperture. *Complex conidiophores* aggregated in small sporodochia, repeatedly and irregularly branched. *Macroconidia* predominating, formed by simple conidiophores, on SNA formed in flat domes of slimy masses, 1–3(−4)-septate, straight, typically clavate, mostly centrally located hilum; 1-septate, (19.0)25.8–27.5(35.0)× (4.0)5.0–5.3(6.5) µm (av. = 26.7×5.2 µm), with a length: width ratio of 3.8–6.6; 2-septate, (23.0)30.0–31.7(38.0)× (5.0)5.3–5.5(6.0) µm (av. = 30.9×5.4 µm), with a length: width ratio of 4.3–7.4; 3-septate, (28.0)34.2–36.2(48.0)× (5.0)5.9–6.2(7.0) µm (av. = 35.2×6.0 µm), with a length: width ratio of 4.6–7.4. *Microconidia* 0–1-septate, ellipsoid to ovoid to subcylindrical, more or less straight, with a visible, centrally located hilum; aseptate (6.0)10.5–11.8 (15.0)×(3.0)3.6–3.8(4.5) µm (av. = 11.2×3.7 µm), with a length:width ratio of 1.5–4.3; 1-septate, (10.0)14.6–15.6 (18.0)×(3.0)4.1–4.4(5.0) µm (av. = 15.1×4.2 µm), with a length:width ratio of 2.4–5.0. *Conidia* formed in heads on simple conidiophores or as white (OA) or unpigmented (SNA) masses. *Chlamydospores* globose to subglobose to ellipsoid, 9–18×8–14 µm, smooth but often appearing rough due to deposits, thick-walled, terminal on short lateral branches or intercalary, in chains or in clumps, and also in the cells of macroconidia, hyaline, becoming medium brown.

Holotype: Portugal, São Paio, Gouveia, *Vitis vinifera,* 4-year-old, showing decline symptoms, scion Malvasia fina; rootstock 1103P, 1996, coll./isol. C. Rego, holotype CBS H-20564, culture ex-type CBS 129081=Cy20=CPC 19164.

Culture characteristics: Mycelium felty, with average to strong density. Surface on OA cinnamon, with sparse, buff

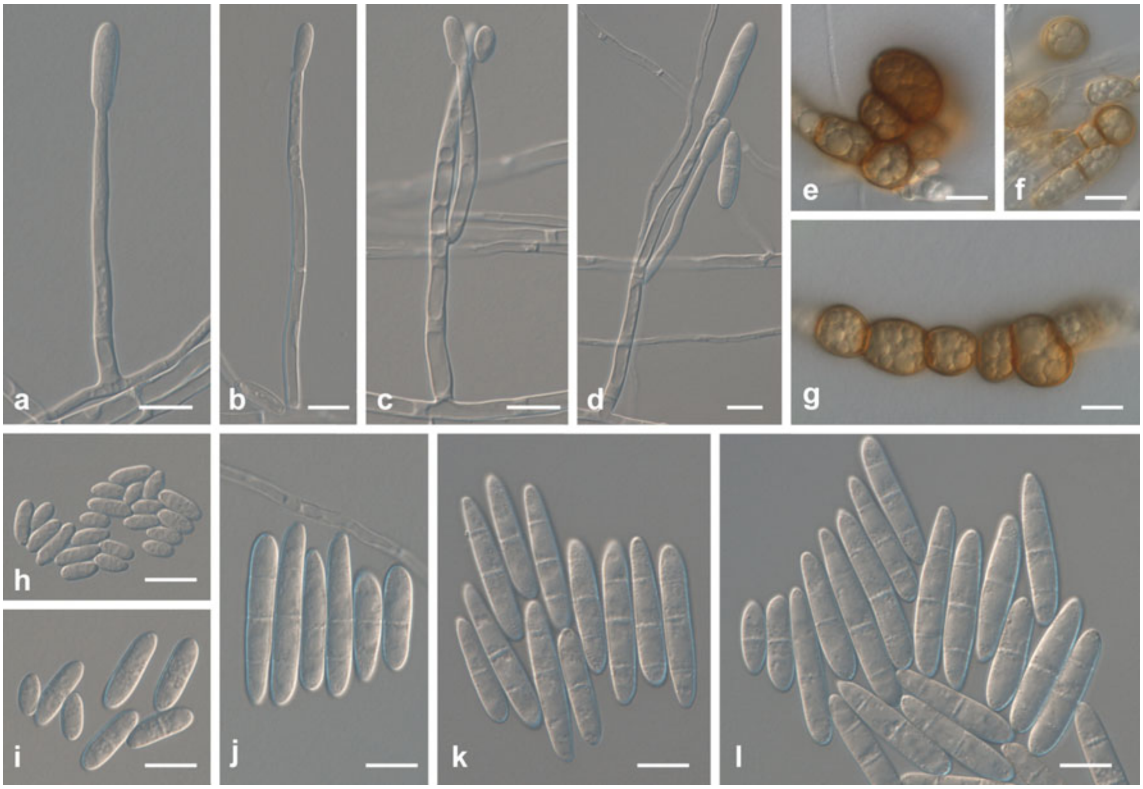


Fig. 11 *Ilyonectria pseudodestructans* (all from CBS 129081, except **g** and **e** from CBS117824). **a**–**d** Simple, unbranched or sparsely branched conidiophores on aerial mycelium. **e**–**g** Chlamydospores on mycelium and macroconidia. **h**–**l** Micro- and macroconidia. *Bars* 10 µm

to saffron or chestnut to sienna aerial mycelium. Surface on PDA cinnamon to vinaceous, with sparse, saffron to buff or chestnut to sienna aerial mycelium. Zonation absent, with homogeneous transparency; margins even. Reverse similar to surface, except in colour, sepia to cinnamon on OA and chestnut to cinnamon on PDA. Colonies on PDA grow poorly (4–6 mm diam), at 4°C after 7 days. Optimum temperature between 20–22°C, when colonies reach 32–44 mm and 37–41 mm diam, respectively, after 7 days. Colony diam was 22–29 mm at 25°C after 7 days. No growth was observed at 30°C.

Isolates studied: CPC 13534; CBS 117812; CBS 117824; CBS 129081; Cy22 (Table 1).

Hosts and distribution: *Poa pratensis* (Canada), *Quercus* sp. (Austria), *Vitis vinifera* (Portugal).

Notes: *Ilyonectria pseudodestructans* is reminiscent of "*Cylindrocarpon" destructans,* in having a similar conidial morphology (3-septate, with central, truncate hilum). However, conidia of *I. pseudodestructans* are somewhat longer than those of *I. radicicola*.

Ilyonectria robusta *(A.A. Hildebr.) A. Cabral & Crous, comb. nov. (Figs. 12 and 13)*

MycoBank 560113.

Basionym: *Ramularia robusta* A.A. Hildebr. Can. J. Res. 12: 102. 1935.

Perithecia formed heterothallically in vitro, disposed solitarily or in groups, developing directly on the agar surface or on sterile pieces of birch wood, ovoid to obpyriform, with a flattened apex, up to 70 µm wide, orange to red, becoming purple-red in 3 % KOH (positive colour reaction), smooth to warted, up to 250 µm diam and high; *perithecial wall* consisting of two regions; outer region 11–36 µm thick, composed of 1–3 layers of angular to subglobose cells, 10–30 × 6–24 µm; cell walls up to 1 µm thick; inner region 8–14 µm thick, composed of cells that are flat in transverse optical section and angular to oval in subsurface optical face view, 5–11 × 2.5–5 µm; *Asci* narrowly clavate to cylindrical, 40–50 × 4.5–6 µm, 8-spored; apex subtruncate, with a minutely visible ring.

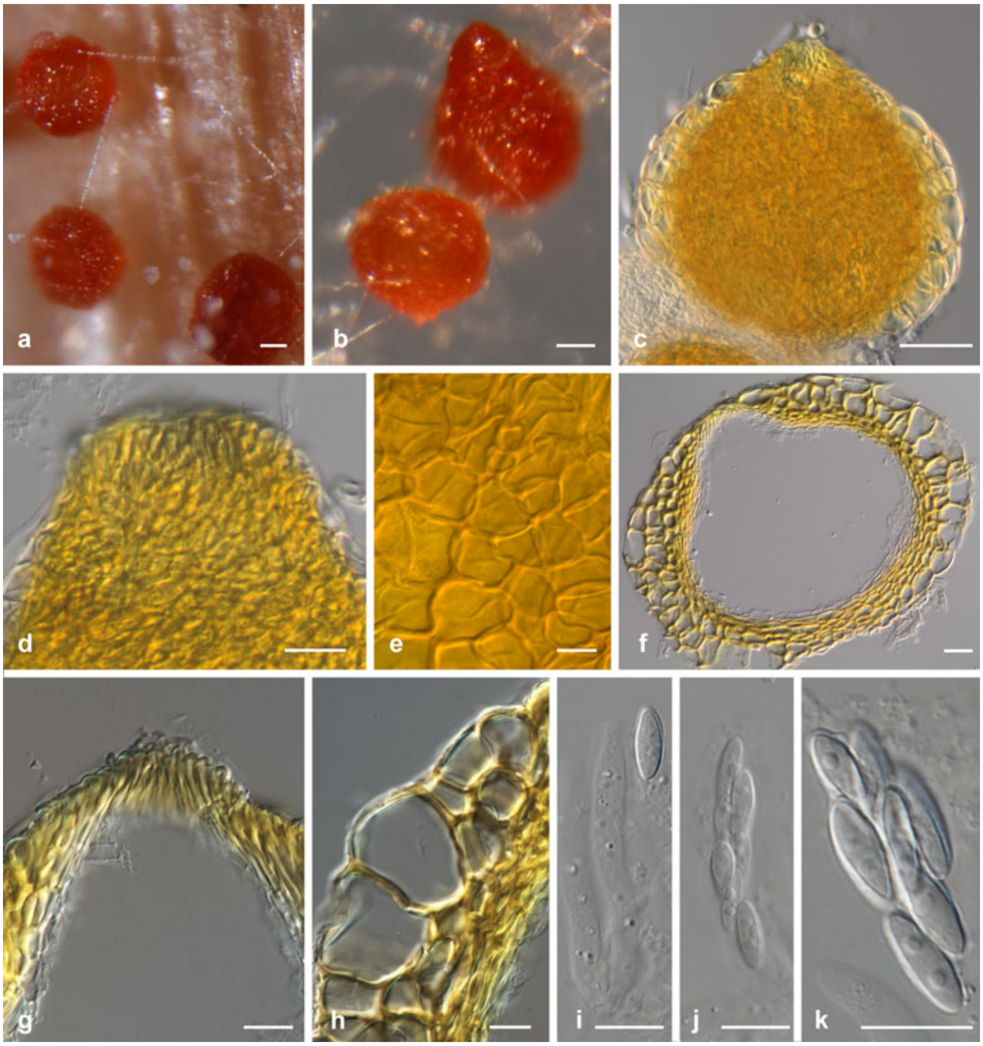


Fig. 12 *Ilyonectria robusta* (**a**, **b** from CPC 13532 × CBS 308.35; **c**–**k** from CPC 13532 × CBS 117813). **a**, **b** Development of perithecia on the surface of a birch toothpick or agar. **c**–**e** Perithecium mounted in lactic acid. **d** Ostiolar area. **e** Surface view of perithecium wall region. **f**–**h** Longitudinal sections of perithecia showing details of ostiole and wall. **i**–**k** Asci and ascospores. *Bars* (**a**–**c**) 50 µm; (**d**, **f**) 20 µm; (**e**, **g**–**k**) 10 µm

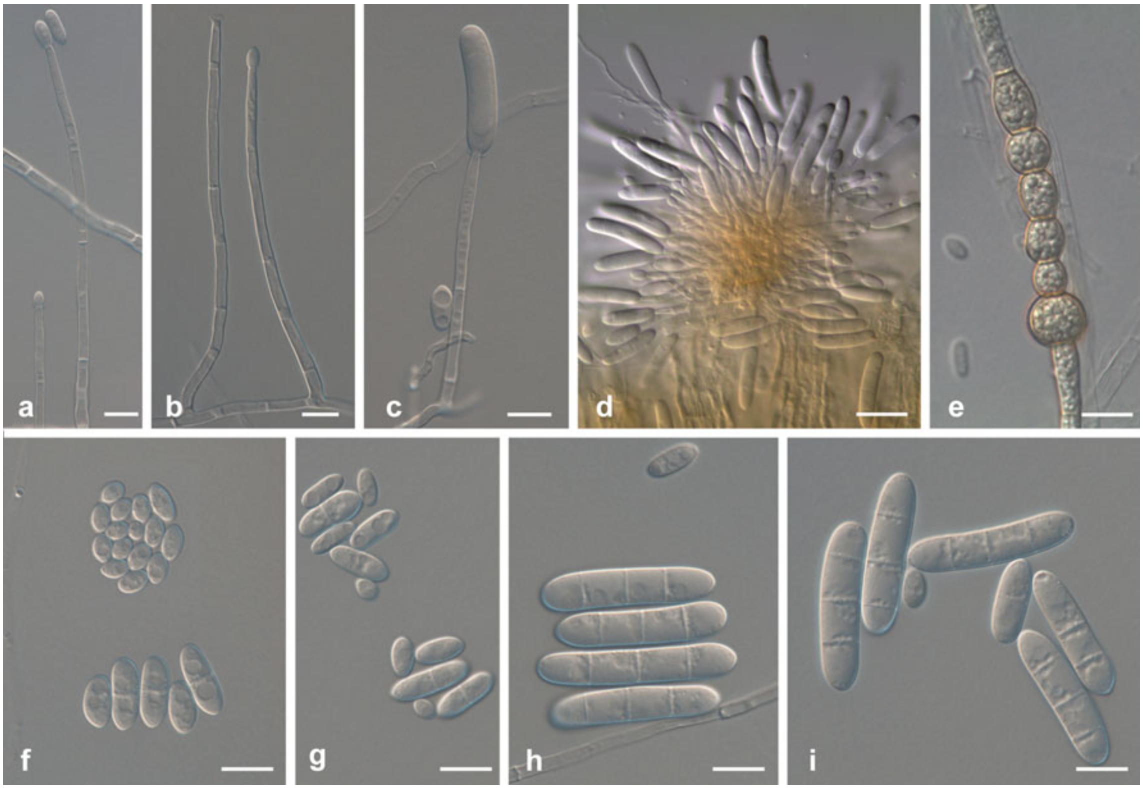


Fig. 13 *Ilyonectria robusta* (All from CBS 129084, except **f** from CBS 605.92). **a**–**c** Simple conidiophores on aerial mycelium. **d** Sporodochial conidiophore on carnation leaf agar. **e** Chlamydospores on mycelium **f**–**i** Micro- and macroconidia. *Bars* 10 µm

Ascospores medianly 1-septate, ellipsoid to oblong-ellipsoid, somewhat tapering towards both ends, smooth to finely warted, frequently guttulate, hyaline, (8.2)9.4–9.7–10.0(11.5)×(2.5)2.9–3.0–3.1(3.7) µm. *Conidiophores* simple or complex or sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched, bearing up to three phialides, 1–4-septate, 55–160 µm long; phialides monophialidic, cylindrical to subulate, 20–60 µm long, 2.0–3.0 µm wide at the base, 1.5–2.0 µm near the apex. *Complex conidiophores* aggregated in small sporodochia (on carnation leaf agar; Crous et al. 2009b), repeatedly and irregularly branched; phialides more or less cylindrical, but tapering slightly in the upper part towards the apex, or narrowly flask-shaped, mostly with widest point near the middle, 15–20 µm long, 2.5–3.5 µm wide at the base, 3.0–4.0 µm at the widest point, and 1.0–2.0 µm wide near the apex. *Macroconidia* predominating, formed on simple conidiophores, on SNA formed in flat domes of slimy masses, 1–3-septate, straight, minutely curved or sometimes distorted, cylindrical with both ends more or less broadly rounded, but may narrow towards the tip, mostly without a visible hilum; 1-septate, (15.0)22.8–24.6(35.0)×(4.5)6.3–6.7(8.0) µm (av. = 23.7×6.5 µm), with a length:width ratio of 2.7–5.2; 2-septate, (20.0)26.2–28.1(38.0)×(5.0)6.9–7.2(8.0) µm (av. = 27.2×7.0 µm), with a length:width ratio of 2.9–5.2; 3-septate, (24)32.3–34.7(58)×(6.0)7.2–7.5(9.0) µm (av. = 33.5×7.4 µm), with a length:width ratio of 3.1–7.3. *Microconidia* 0–1-septate, ellipsoid to ovoid to subcylindrical, more or less straight, without a visible hilum; aseptate, (4.0)8.0–9.3(14.0)×(2.5)3.6–4.0(5.5) µm (av. = 8.7×3.8 µm), with a length:width ratio of 1.3–4.0; 1-septate, (9.0)13.5–14.7(18.0)×(3.5)4.7–5.1(6.0) µm (av. = 14.1×4.9 µm), with a length:width ratio 1.5–4.5. *Conidia* formed in heads on simple conidiophores or as white (OA) or unpigmented (SNA) masses. *Chlamydospores* globose to subglobose, 7–14×6–13 µm, smooth, but often appearing rough due to deposits, thick-walled, mostly occurring intercalary in chains, hyaline, becoming golden-brown.

Lecto- and teleotype: Canada, Ontario, on living roots of *Panax quinquefolium,* 1935, A.A. Hildebrand, lectotype designated here CBS H-20565, as dried culture of CBS 308.35; teleotype designated here CBS H-20566, including fertile perithecia of the teleomorph (CPC 13532×CBS 308.35), culture ex-lectotype CBS 308.35.

Fertile matings: Perithecia observed after 4 wk in crossings of strains: CPC 13532×CBS 308.35, CPC 13532×CBS 773.83, CPC 13532×CBS 605.92, CPC 13532×CBS 117813, CBS 129084×CBS 308.35, CBS 129084×CBS 605.92, CBS 129084×CBS 117813.

Culture characteristics: Mycelium felty with an average density. Surface on OA sienna to sepia with aerial mycelium sparse, buff. Surface on PDA cinnamon, with aerial mycelium buff to cinnamon, or rosy buff on PDA. Zonation absent to concentric, with homogeneous transparency; margins predominantly even, but sometimes uneven. Reverse similar to surface, except in the colour, sienna on OA and chestnut at the centre, and sienna to orange towards the margin on PDA. Colonies on PDA grow 4–7 mm at 4°C after 7 days. Optimum temperature at 22°C when colonies reach 40–52 mm diam, after 7 days. Colony diam was 35–48 mm at 25°C after 7 days. No growth to slight growth (0–2 mm) was observed at 30°C.

Isolates studied: CBS 321.34; CBS 308.35; CBS 773.83; CBS 605.92; CBS 117813; CBS 117814; CBS 117815; CBS 117817; CBS 117818; CBS 117819; CBS 117820; CBS 117821; CBS 117822; CBS 117823; CBS 129084; CD1666; CPC 13532; Cy23; Cy158; Cy231 (Table 1).

Hosts and distribution: *Loroglossum hircinum* (root) (Tunisia), *Panax quinquefolium* (root) (Canada), *Prunus cerasus, Thymus* sp., *Vitis vinifera* (basal end of rootstock) (Portugal), *Quercus robur* (root), *Quercus* sp. (root) (Austria), *Tilia petiolaris* (rootstock) (Germany), water (in aquarium with *Anodonta* sp.) (Netherlands).

Notes: When Hildebrand (1935) described *Ramularia robusta* from living roots of *Panax quinquefolium* in Ontario, Canada, he did not indicate a type specimen. However, he deposited an original culture in the CBS. A sporulating, dried-down culture is thus herewith designated as lectotype, and a new name proposed in *Ilyonectria*, with a teleotype represented by a fertile mating between CPC 13532×CBS 308.35.

Ilyonectria rufa *A. Cabral & Crous, sp. nov. (Fig. 14)*

MycoBank 560116.

Etymology: The epithet "*rufa*" referring to "*Coleomyces rufus*", a provisional name proposed for this species by Moreau and Moreau (1937).

Ilyonectriae crassae morphologice similis, sed macroconidiis brevioribus, 28–31.2 μm longis, distinguitur.

Conidiophores simple or complex, sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched, bearing up to two phialides, 1–5-septate, 55–210 μm long; phialides monophialidic, cylindrical to subulate, 20–57 μm long, 2.5–3.5 μm wide at the base, 1.5–2.0 μm near the aperture. *Complex conidiophores* aggregated in small sporodochia, repeatedly and irregularly branched. *Macroconidia* predominating, formed on both types of conidiophores, on SNA formed in flat domes of slimy masses, 1(−3)-septate, straight, cylindrical with both

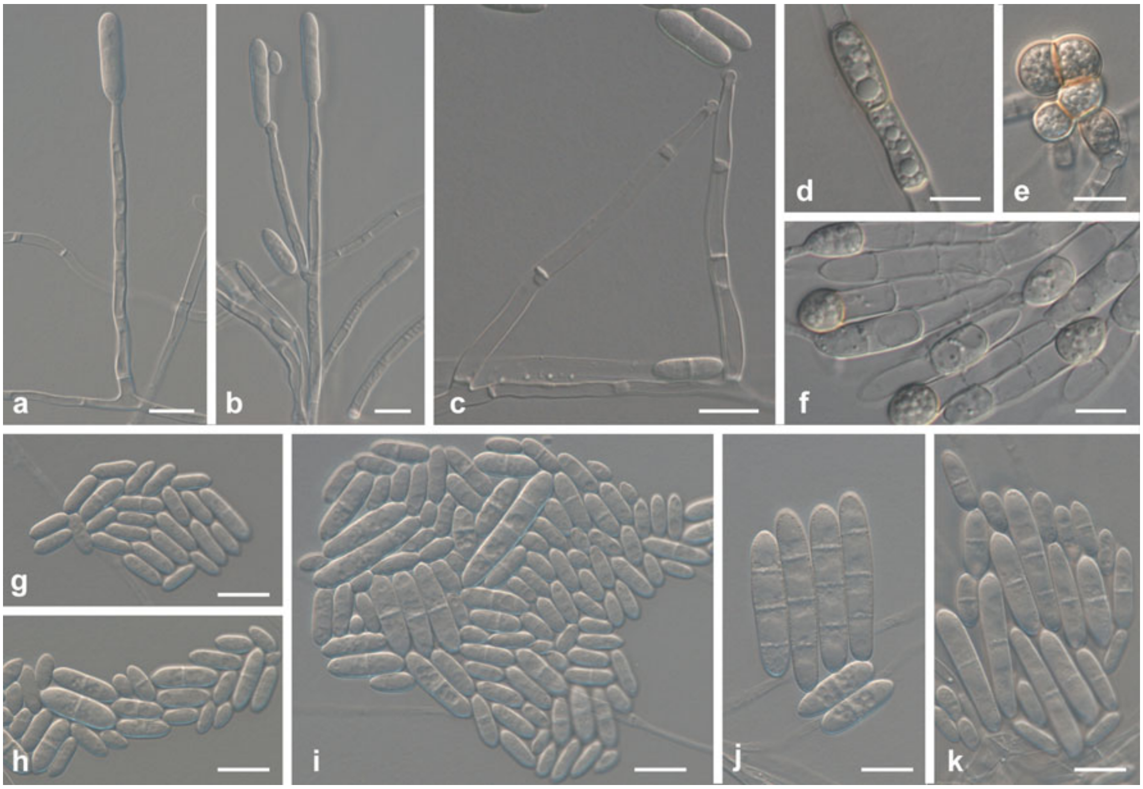


Fig. 14 *Ilyonectria rufa* (All from CBS 156.47, except **c** from CBS 120372). **a**–**c** Simple, sparsely branched conidiophores on aerial mycelium. **d**–**f** Chlamydospores in mycelium and in macroconidia. **g**–**k** Micro- and macroconidia. *Bars* 10 μm

ends broadly round, mostly centrally located hilum; 1-septate, (17.0)22.3–23.8(29.0)×(4.0)5.1–5.4(6.0) µm (av. = 23.1×5.3 µm), with a length:width ratio of 3.1–5.6; 2-septate, (19.0)24.5–26.6(32.0)×(4.0)5.2–5.5(6.5) µm (av. = 25.5×5.4 µm), with a length:width ratio of 3.4–6.0; 3-septate, (23.0)28.6–31.2(37.0)×(5.0)5.5—5.9(7.0) µm (av. = 29.9×5.7 µm), with a length:width ratio of 3.4–7.2. *Microconidia* 0–1-septate, ellipsoid to subcylindrical, more or less straight, with a visible, centrally located hilum; aseptate, (4.0)8.4–9.8(15.0)×(3.0)3.5–3.8(5.0) µm (av. = 9.1×3.6 µm), with a length:width ratio of 1.3–4.0; 1-septate, (9.0)12.1–13.3(17.0)×(3.0)4.2–4.6(5.5) µm (av. = 12.7×4.4 µm), with a length:width ratio 2.2–3.8. *Conidia* formed in heads on simple conidiophores or as white (OA) or unpigmented (SNA) masses. *Chlamydospores* globose to subglobose to cylindrical, 7–12×6–9 µm, smooth, but often appearing rough due to deposits, thick-walled, terminal on short, lateral branches, or intercalary, single, in chains or in clumps, and also in the cells of the macroconidia, hyaline, becoming slightly brown in the outer wall.

Holotype: France, dune sand, Feb. 1937, coll./isol. F. Moreau, holotype CBS H-20567, culture ex-type CBS 153.37.

Culture characteristics: For CBS 153.37, CBS 156.47, CPC 13536 and 94–1628: Mycelium felty with average to strong density. Surface on OA buff to saffron, aerial mycelium sparse, buff. On PDA rosy-buff to cinnamon, with aerial mycelium sparse, buff to rosy-buff or pale luteus in the centre. For CBS 640.77, CBS 120371 and CBS 120372: Mycelium felty, with low to average density. Surface on OA cinnamon to sienna, aerial mycelium sparse, saffron to cinnamon. On PDA saffron to cinnamon, with aerial mycelium cinnamon to rust. Zonation absent or concentric, with homogeneous transparency; margins even or sometimes uneven. Reverse similar, except in colour, saffron on OA, and cinnamon to rosy-buff on PDA, or sienna with pigments, pale vinaceous in OA and umber to chestnut on PDA. Colonies on PDA grow poorly, (2–7 mm diam) at 4°C, after 7 days. Optimum temperature between 20–22°C, when colonies reach 28–42 mm, 31–46 mm diam, respectively, after 7 days. Colony diam was 19–24 mm at 25°C after 7 days. No growth observed at 30°C.

Isolates studied: CBS 153.37; CBS 156.47; CBS 640.77; CBS 120371; CBS 120372; CPC 13536; 94–1628 (Table 1).

Hosts and distribution: *Azalea indica* (Belgium), dune sand (France), *Picea glauca*, *Pseudotsuga menziesii* (Canada).

Notes: The genus *Coleomyces* represents a later synonym of *Cylindrocarpon* (Booth 1966). However, *Coleomyces*, which is based on *C. rufus* (Moreau and Moreau 1937), was published as "*ad interim*", suggesting that Moreau and Moreau were planning to validate the name later, which was not the case. Based on the International Code of Botanical Nomenclature (Art. 34.1, Ex. 6), Chaverri et al. (2011) correctly chose to ignore the name. However, an original strain of *C. rufus* was deposited in the CBS (CBS 153.37), and the species epithet is herewith validated for the species.

Ilyonectria venezuelensis *A. Cabral & Crous, sp. nov.* *(Fig. 15)*

MycoBank 560117.

Etymology: Named after the country from where it was collected, Venezuela.

Ilyonectriae robustae morphologice similis, sed conidiophoris cum verticillo terminali phialidum distinguitur.

Conidiophores simple or complex, sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium or from agar surface, solitary to loosely aggregated, unbranched, or bearing terminal, penicillate phialides, 1–4-septate, 35–200 µm long; phialides monophialidic, cylindrical to subulate, 40–60 µm long, 2.5–3.5 µm wide at the base, 1.5–2.5 µm near the apex, or narrowly flask-shaped, 16–40 µm long, 2.0–3.0 µm wide at the base, 3.0–4.0 µm at the widest point, 1.5–2.5 µm near the apex. *Complex conidiophores* aggregated in small sporodochia, repeatedly and irregularly branched. *Macroconidia* predominating, formed by both types of conidiophores, on SNA formed in flat domes of slimy masses, 1–3-septate, straight or minutely curved, cylindrical with both ends more or less broadly rounded, but may narrow towards the tip, mostly without a visible hilum; 1-septate, (22.0)24.6–27.3(35.0)×(5.0)5.3–5.7(6.5) µm (av. = 26.0×5.5 µm), with a length:width ratio of 3.8–7.0; 2-septate, (25.0)26.3–37.4(44.0)×(5.9)6.0–6.6(7.0) µm (av. = 31.9×6.3 µm), with a length:width ratio of 4.2–6.8; 3-septate, (28.0)36.5–41.7(50.0)×(6.0)6.9–7.5(8.0) µm (av. = 39.1×7.2 µm), with a length:width ratio of 4.0–6.7. *Microconidia* 0–1-septate, ellipsoid to ovoid, more or less straight, without a visible hilum; aseptate, (5.0)8.4–10.5(13.0)×(3.0)3.3–3.7(4.0) µm (av. = 9.5×3.5 µm), with a length:width ratio of 1.7–3.4; 1-septate, (11.0)14.5–16.3(19.0)×(3.5)3.9–4.3(5.0) µm (av. = 15.4×4.1 µm), with a length:width ratio 2.8–4.8. *Conidia* formed in heads on simple conidiophores or as white (OA) or unpigmented (SNA) masses. *Chlamydospores* ovoid to ellipsoidal, 6–13×5–7 µm, smooth, but often appearing rough due to deposits, thick-walled, terminal on short lateral branches or intercalary, single, in chains or in clumps, hyaline, becoming slightly brown at the margin.

Holotype: Venezuela, Amazonas, Cerro de la Neblina, tree bark, 1985, coll./isol. A. Rossman, holotype CBS H-20568, culture ex-type CBS 102032.

Culture characteristics: Mycelium cottony with average to strong density. Surface on OA saffron, with aerial

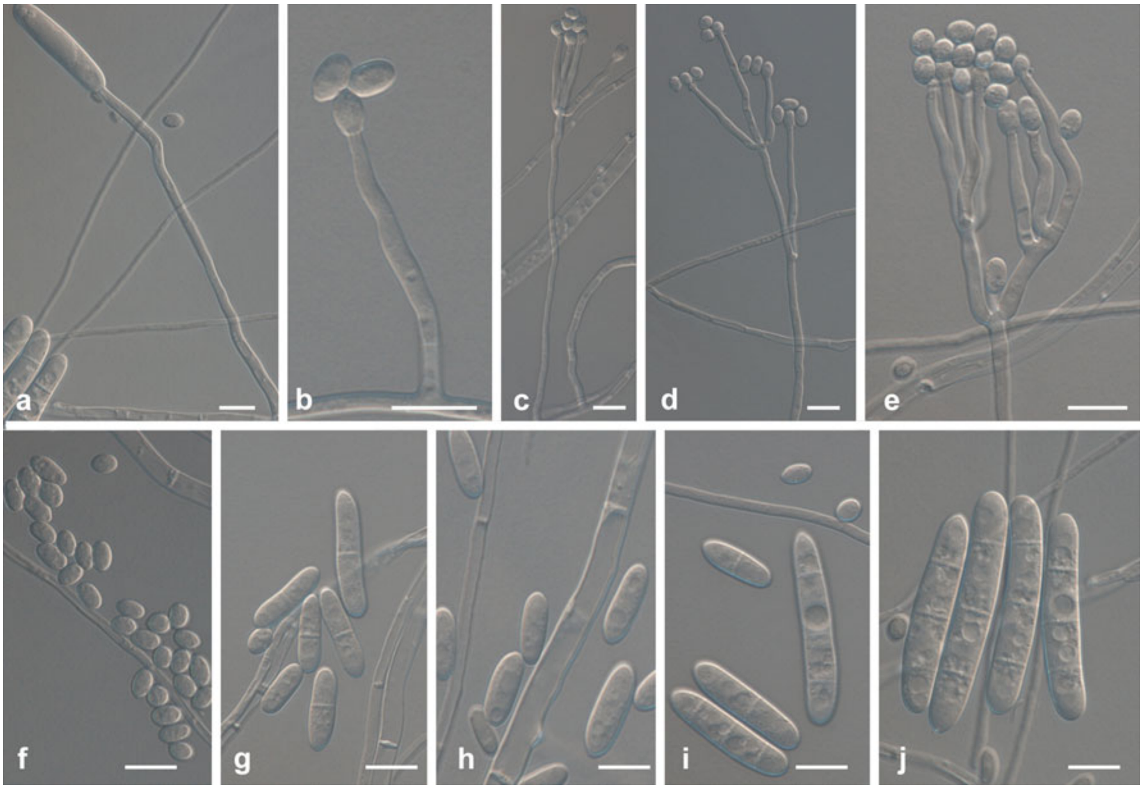


Fig. 15 *Ilyonectria venezuelensis* (CBS 102032). **a**, **b** Simple conidiophores on aerial mycelium. **c**–**e** Conidiophores bearing terminal, penicillate phialides. **f**–**j** Micro- and macroconidia. *Bars* 10 μm

mycelium sparse, buff, on PDA buff to saffron, with aerial mycelium saffron to pale luteous; zonation absent, transparency homogeneous, margin even; reverse similar to surface, but saffron to cinnamon on PDA. Colonies on PDA grow poorly (2–3 mm) at 4°C, after 7 days. Optimum temperature at 20°C, with colonies reaching 49 mm diam, after 7 days. Colony diam was 35–36 mm at 25°C after 7 days. No growth was observed at 30°C.

Isolate studied: CBS 102032 (Table 1).

Host and distribution: Tree bark (Venezuela).

Ilyonectria vitis *A. Cabral, Rego & Crous, sp. nov. (Fig. 16)*

MycoBank 560107.

Etymology: Named after the host from which it was collected, *Vitis vinifera*.

Ilyonectriae anthuriicolae morphologice similis, sed longitudine media macroconidiorum longiore, 41.6–43.5 μm, distinguitur.

Conidiophores simple or complex or sporodochial. *Simple conidiophores* arising laterally or terminally from aerial mycelium, solitary to loosely aggregated, unbranched or sparsely branched, bearing up to three phialides, 1–3 septate, 30–70 μm long; monophialides more or less cylindrical, but tapering slightly towards the tip, 11–21 μm long, 2.0–3.0 μm wide at the base, 3.0–4.5 μm at widest point, 1.5–2.5 μm near the apex. Conidiophores forming microconidia arising from mycelium at agar surface, reduced to monophialides, or a stipe with a terminal arrangement of phialides, ranging from 2 to a dense cluster; sparsely branched or penicillate; monophialides narrowly flask-shaped, typically with widest point near the middle, 10–17 μm long, 1.5–3.0 μm wide at the base, 2.5–4.0 μm at widest point, 1.0–2.0 μm near the apex. *Sporodochial conidiophores* irregularly branched; phialides more or less cylindrical but slightly tapering towards the tip, or narrowly flask-shaped, with widest point near the middle, 14–20 μm long, 2.5–3.5 μm wide at the base, 3.0–4.5 μm at widest point, 1.5–2.5 μm near the apex. *Macroconidia* formed in flat domes of slimy masses, predominantly 3-septate, rarely 1–2- or 4-septate, straight or minutely curved, cylindrical with both ends more or less broadly rounded, mostly without a visible hilum; 3-septate conidia (34.9)41.6–43.5(51.6)×(6.2)7.9–8.2(9.5) μm (av. =42.5×8.0 μm), with a length:width ratio of 3.9–6.7. *Microconidia* on SNA formed in heads, aseptate, subglobose to ovoid, rarely ellipsoid, mostly with a visible, centrally located or slightly laterally displaced hilum, (3.7)4.9–5.4(6.7)×(3.2)3.7–4.0(4.6) μm (av. = 5.1×3.9 μm), with a length:width ratio of 1.1–1.7. *Chlamydospores* globose to subglobose to ellipsoid, 9–18×6–13 μm, smooth, but often appearing

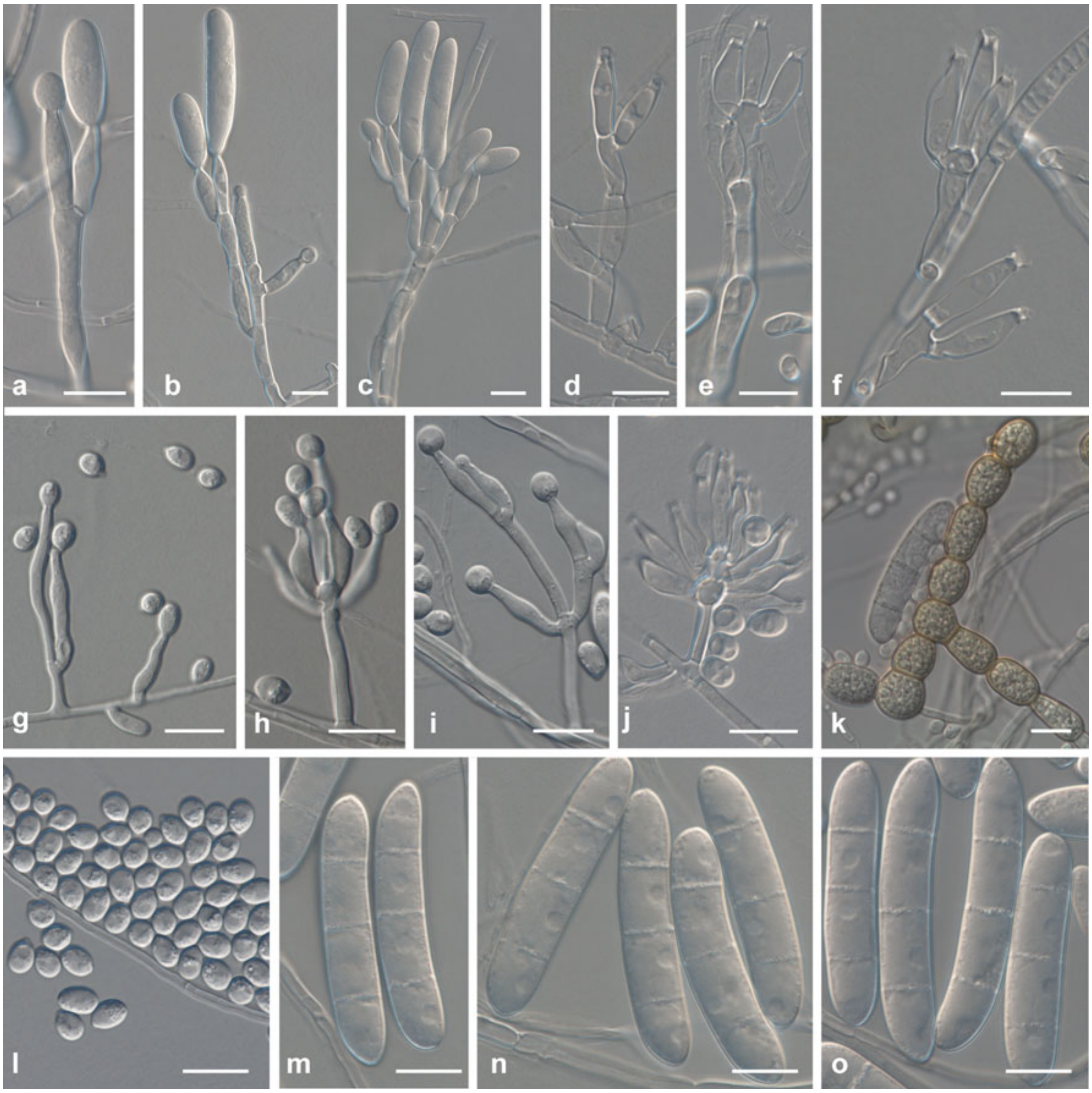


Fig. 16 *Ilyonectria vitis* (CBS 129082). **a**–**c** Simple conidiophores on aerial mycelium. **d**–**g** Conidiophores forming microconidia arising from mycelium at agar surface, reduced to a stipe with a terminal arrangement of phialides, ranging from 2 to a dense cluster; sparsely branched or penicillate. **i**–**l** Micro- and macroconidia. **m** Chlamydospores on mycelium. *Bars* 10 µm

rough due to deposits, thick-walled, formed intercalary in chains or in clumps, and also in the cells of macroconidia, hyaline, becoming golden-brown.

Holotype: Portugal, Vidigueira, *Vitis vinifera,* basal end of a 2-year-old plant; scion Touriga Nacional; rootstock 110R, 2008, coll./isol. C. Rego, holotype CBS H-20569, culture ex-type CBS 129082=Cy233=CPC 19168.

Culture characteristics: Mycelium felty with density low to average. Surface on OA sienna, with sparse, saffron aerial mycelium, and luteous growth at margin. Surface on PDA chestnut, with sienna aerial mycelium, with luteous margin. Zonation was absent (OA) or concentric (PDA), transparency was homogeneous (PDA) or not (OA). Growth at margin even to uneven. Reverse similar to surface, except in colour, sienna to saffron on OA, and chestnut to umber on PDA. Colonies on PDA do not grow at 4°C after 7 days. Optimum temperature at 20°C, when colonies reach 29–30 mm diam, after 7 days. Colony diam was 39–40 mm at 25°C and 8–9 mm at 30°C after 7 days. No growth was observed at 35°C.

Isolate studied: CBS 129082 (Table 1).

Host and distribution: *Vitis vinifera* (Portugal).

Key to species treated

1 Growth at margin on OA after 14 days at 20°C, lacking yellow pigmentation

2 Colony diameter on PDA after 7 days at 25°C<30 mm

3 Macroconidia forming chlamydospores

4 Macroconidia 1–3-septate, 3-septate macroconidia mean range 34.1–36.2 μm long

5 Macroconidia cylindrical, with the base appearing somewhat acute *I. crassa*

5* Macroconidia clavate *I. pseudodestructans*

4* Macroconidia predominantly 1-septate; 3-septate macroconidia smaller, mean range 28–31.2 μm long *I. rufa*

3* Macroconidia lacking chlamydospores

6 Macroconidia predominantly curved *I. liliigena*

6* Macroconidia straight

7 Macroconidia lacking visible hilum *I. mors-panacis*

7* Macroconidia with a visible, centrally located hilum

8 Three-septate macroconidia mean range 31.0–35.0 μm long *I. panacis*

8* Three-septate macroconidia mean range 34.3–38.5 μm long *I. gamsii*

2* Colony diameter after 7 days at 25°C>30 mm

9 Colony diameter after 7 days at 25°C, >50 mm *I. cyclaminicola*

9* Colony diameter after 7 days at 25°C, 30–50 mm

10 Conidiophores bearing a terminal whorl of phialides *I. venezuelensis*

10* Conidiophores unbranched, or different from above

11 Teleomorph known, and can be induced in culture

12 Three-septate macroconidia mean range 32.3–34.7 μm long; ascospores mean range 9.4–10.0 μm long *I. robusta*

12* Three-septate macroconidia mean range 30.0–36.0 μm long; ascospores mean range longer, 10–13 μm long *I. radicicola*[a]

11* Teleomorph unknown

13 Mean range of 3-septate macroconidia, 29.7–31.5 × 6.5–6.9 μm *I. europaea*

13* Mean range of 3-septate macroconidia smaller, 25.0–28.4 × 5.2–5.5 μm *I. lusitanica*

1* Yellow pigmentation present at margin

14 Macroconidia 3-septate, mean range 29.5–32.2 μm long *I. anthuriicola*

14* Macroconidia 3-septate, mean range 41.6–43.5 μm long *I. vitis*

[a] No authentic cultures of *"C." destructans*, conidia (18.0–)23.0–30.0(−35.0) × (6.0–)6.5(−7.0) μm, are presently available.

Discussion

"Cylindrocarpon" destructans is a cosmopolitan soil-borne pathogen causing disease on a wide number of herbaceous and woody plant species (Samuels and Brayford 1990). The wide morphological and pathogenic amplitude of *"C." destructans* makes it a commonly identified species, with many diseases from the *Cylindrocarpon*-complex being attributed to it, and ranking at the top of all "*Cylindrocarpon" spp. deposited in the NCBI nucleotide database.*

In this study, *"C." destructans* isolates from the CBS culture collection (deposited under the wider concept of the species) were analysed using a multigene approach in order to clarify taxonomic aspects of this species complex. Molecular analyses show that these isolates cluster in various clades supported by high bootstrap support values. A previous study (Seifert et al. 2003) included a subset of the strains used here, and already highlighted the existence of unexpected divergence in "*C.*" *destructans*, as opposed to a large homogeneity in e.g. *Neonectria ditissima*. Several species have in recent years been separated from the "*C.*" *destructans* complex, including "*C.*" *macroconidialis*, "*C.*" *coprosmae* and "*C.*" *austroradicicola* based on morphological (Samuels and Brayford 1990) and molecular characters (Schroers et al. 2008; Seifert et al. 2003). Furthermore, several isolates causing black foot disease of grapevine, previously considered as "*C.*" *destructans*, were recently identified as *I. liriodendri* (Chaverri et al. 2011; Halleen et al. 2006), along with the ex-type strain from *Liriodendron tulipifera* (CBS 110.81) and a strain from *Cyclamen* (CBS 301.93). In this study, two further strains isolated from young *Malus domestica* and *Quercus suber* trees showing decline symptoms were also identified as *I. liriodendri*.

Altogether, we analysed 68 strains putatively belonging to "*C.*" *destructans*, but none of them clustered together with the ex-type culture of *I. radicicola* (CBS 264.65), suggesting that this species may not be as common as previously accepted. Halleen et al. (2006) identified a single strain (IMI 313237, isolated from arecoid palm) clustering with CBS 264.65. This also raises questions relating to the correlation between the anamorph, "*C.*" *destructans,* and its purported teleomorph, *I. radicicola*.

"Nectria" radicicola was described by Gerlach and Nilson (1963) from decayed leaves, flowers stalks and corms of *Cyclamen persicum* collected in Sweden, with a "*Cylindrocarpon"* anamorph they identified as *"C." radicicola*.

In 1924, Wollenweber introduced "*C.*" *radicicola* (McAlpine) Wollenw. as a new combination, based on *Septocylindrium radicicola* McAlpine (1899), described from *Citrus* trees in Australia. Later, Wollenweber (1928) noted that *Septocylindrium radicicola*, with catenulate conidia, was different from "*C.*" *radicicola*, and the name was therefore based on Wollenweber's (1928) description. Because of this confusion in names, Booth (1966) suggested that "*C.*" *radicicola* should be dropped, and that the name to be used as anamorph for *I. radicicola* should be "*C.*" *destructans* [originally described by Zinssmeister (1918) on *Panax quinquefolia* from Wisconsin, USA].

Furthermore, Booth (1966) designated a neotype for "*C.*" *destructans*, obtained from *P. quinquefolia* in USA, KY, Washington Co., Springfield; collected by W.B. Edwards in 1922, available as herbarium material in Cornell Plant Pathology Herbarium, CUP-011985. This specimen was re-examined in the present study [conidia (18.0)23.0–30.0(35.0) × (6.0)6.5(7.0) μm] [original description by Zinssmeister (1918), 9.0–32.4×3.2–8.1 μm], thus revealing conidia to be smaller than those formed by *I. radicicola,* which are (24.0)33.1(47.0) × (4.9)6.4(7.8) μm. From these observations, we conclude that "*C.*" *destructans*, which occurs on *P. quinquefolia* in the USA, represents yet another species distinct from *I. radicicola*, which is not yet represented in our phylogenetic tree (Fig. 1).

A strain deposited in CBS culture collection by Hildebrand in 1935, as "*Ramularia" mors-panacis,* was found to represent original material (ex-type CBS 306.35), collected from living roots of *Panax quinquefolium* in Ontario, Canada. The epithet "*mors-panacis"* is therefore resurrected for this clade, while the Japanese collection identified as "*Cylindrocarpon destructans"* f. sp. *panacis* (ex-type CBS 124662=NBRC 31881), isolated from *Panax ginseng* in Japan, is treated as synonym.

The ex-type strain of "*Ramularia" robusta* (CBS 308.35), isolated from living roots of *Panax quinquefolium* in Ontario, Canada, can be resurrected for a large clade representing isolates from a range of hosts and continents. Similarly, an authentic strain of "*C.*" *destructans* var. *crassum* (Booth 1966; Wollenweber 1931) is available for a species occurring on *Panax* and *Pseudotsuga* in Canada, *Lilium* and *Narcissus* in the Netherlands, and can thus be resurrected as *I. crassa*. Although strain CBS 120370 clustered together with other strains of *I. crassa* for most genes (no nucleotide differences in ITS and TEF, two nucleotide differences in HIS), this strain was not included in that species because of an 8-bp difference in TUB, a slower growth rate (e.g., 21 mm colony diam at 20°C for 7 days, as opposed to 31–46 mm for other isolates), a lower conidial length:width ratio [e.g. for 3-septate conidia 4.0–6.5, as opposed to 4.8–8.9 and smaller conidia (e.g. 3-septate conidia ranging from (26.0)31.2–34.0(40.0)×(6.0)6.6–7.1(8.0) μm (av. 32.6×6.9 μm) , as opposed to (29.0)34.1–36(49.0)×(5.0)5.6–5.8(7.0) μm (av. 35.1×5.7 μm)]. Further studies should thus be conducted in order to clarify the taxonomy of this strain.

Ilyonectria anthuriicola and *I. vitis* are very similar in morphology to "*C.*" *pauciseptatum*. These species all have predominantly 3-septate macroconidia after 10 days in culture. *Ilyonectria anthuriicola* is easier to distinguish than "*C.*" *pauciseptatum* as the 3-septate conidia are smaller and narrower, (25.0)29.5–32.2(38.0)×(6.0)7.5–8.1(9.0) μm, while in "*C.*" *pauciseptatum* they are (37.0)42.0–47.0(54.0)×(7.0)8.5–9.5(10.0) (Schroers et al. 2008). For *I. vitis* 3-septate macroconidia are of similar size to those of "*C.*" *pauciseptatum*, (34.9)41.6–43.5(51.6)×(6.2)7.9–8.2(9.5), making it difficult to distinguish them based on this character. Growth rate at 20°C is slower in *I. vitis* than in "*C.*" *pauciseptatum*, and they also differ regarding colony characteristics and colours. Morphologically, however, they remain difficult to distinguish.

In this study, the genetic structure of the *I. radicicola* complex was analysed using a multi-locus approach along with morphological and culture characters. Three major groups were identified based on this approach, each group containing several species. Although we have been able to clarify several aspects related to the host range and distribution of taxa in the *I. radicicola* species complex, further collections, especially from *Panax* in the USA, will be essential to elucidate the status of *"C." destructans*.

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References

Booth C (1966) The genus *Cylindrocarpon*. Mycol Pap 104:1–56

Brayford D, Honda BM, Mantiri FR, Samuels GJ (2004) *Neonectria* and *Cylindrocarpon*: the *Nectria mammoidea* group and species lacking microconidia. Mycologia 96:572–597

Castlebury LA, Rossman AY, Hyten AS (2006) Phylogenetic relationships of *Neonectria/Cylindrocarpon* on Fagus in North America. Can J Bot 84:1417–1433. doi:10.1139/B06-105

Chaverri P, Salgado C, Hirooka Y, Rossman AY, Samuels GJ (2011) Delimitation of *Neonectria* and *Cylindrocarpon* (*Nectriaceae*, *Hypocreales*, *Ascomycota*) and related genera with *Cylindrocarpon*-like anamorphs. Stud Mycol 68:57–78

Crous PW, Gams W, Stalpers JA, Robert V, Stegehuis G (2004a) MycoBank: an online initiative to launch mycology into the 21st century. Stud Mycol 50:19–22

Crous PW, Groenewald JZ, Risede JM, Hywel-Jones NL (2004b) *Calonectria* species and their *Cylindrocladium* anamorphs: species with sphaeropedunculate vesicles. Stud Mycol 50:415–429

Crous PW, Slippers B, Wingfield MJ, Rheeder J, Marasas WFO, Philips AJL, Alves A, Burgess T, Barber P, Groenewald JZ (2006) Phylogenetic lineages in the *Botryosphaeriaceae*. Stud Mycol 55:235–253. doi:10.3114/sim.55.1.235

Crous PW, Braun U, Groenewald JZ (2007) *Mycosphaerella* is polyphyletic. Stud Mycol 58:1–32. doi:10.3114/sim.2007.58.01

Crous PW, Schoch CL, Hyde KD, Wood AR, Gueidan C, de Hoog GS, Groenewald JZ (2009a) Phylogenetic lineages in the *Capnodiales*. Stud Mycol 64:17–47. doi:10.3114/sim.2009.64.02

Crous PW, Verkleij GJM, Groenewald JZ, Samson RA (eds) (2009b) Fungal Biodiversity. CBS Laboratory Manual Series 1. Centraalbureau voor Schimmelcultures, Utrecht

de Hoog GS, Gerrits van den Ende AHG (1998) Molecular diagnostics of clinical strains of filamentous Basidiomycetes. Mycoses 41:183–189

Domsch KH, Gams W, Anderson TH (2007) Compendium of Soil Fungi, 2nd edn. IHW, Eching

Gerlach W, Nielsson L (1963) Beiträge zur Kenntnis der Gattung *Cylindrocarpon* Wr. V. *Nectria radicicola* n. sp., die bisher unbekannte Hauptfruchtform von *Cylindrocarpon radicicola* Wr. Phytopathol Z 48:251–257

Glass NL, Donaldson G (1995) Development of primer sets designed for use with PCR to amplify conserved genes from filamentous ascomycetes. Appl Environ Microbiol 61:1323–1330

Gräfenhan T, Schroers H-J, Nirenberg HI, Seifert KA (2011) An overview of the taxonomy, phylogeny, and typification of nectriaceous fungi in *Cosmospora*, *Acremonium*, *Fusarium*, *Stilbella*, and *Volutellax*. Stud Mycol 68:79–113

Guerber JC, Correll JC (2001) Morphological description of *Glomerella acutata*, the teleomorph of *Colletotrichum acutatum*. Mycologia 93:216–229

Halleen F, Schroers H-J, Groenewald JZ, Crous PW (2004) Novel species of *Cylindrocarpon* (*Neonectria*) and *Campylocarpon* gen. nov. associated with black foot disease of grapevines (*Vitis* spp.). Stud Mycol 50:431–455. doi:10.3114/sim.55.1.227

Halleen F, Fourie PH, Crous PW (2006) A review of black-foot disease of grapevines. Phytopathol Mediterr 45:S55–S67

Hildebrand AA (1935) Root rot of ginseng in Ontario caused by members of the genus *Ramularia*. Can J Res 12:82–114

Hirooka Y, Kobayashi T, Natsuaki KT (2005) *Neonectria castaneicola* and *Neo. rugulosa* in Japan. Mycologia 97:1058–1066. doi:10.3852/mycologia.97.5.1058

Larkin MA, Blackshields G, Brown NP, Chenna R, McGettigan PA, McWilliam H, Valentin F, Wallace IM, Wilm A, Lopez R, Thompson JD, Gibson TJ, Higgins DG (2007) Clustal W and Clustal X version 2.0. Bioinformatics 23:2947–2948

Lombard L, Crous PW, Wingfield BD, Wingfield MJ (2010) Phylogeny and systematics of the genus *Calonectria*. Stud Mycol 66:31–69. doi:10.3114/sim.2010.66.03

Mantiri FR, Samuels GJ, Rahe GE, Honda B (2001) Phylogenetic relationships in *Neonectria* species having *Cylindrocarpon* anamorphs inferred from mitochondrial ribosomal DNA sequences. Can J Bot 79:334–340

Möller EM, Bahnweg G, Sandermann H, Geiger HH (1992) A simple and efficient protocol for isolation of high molecular weight DNA from filamentous fungi, fruit bodies, and infected plant tissues. Nucleic Acids Res 20:6115–6116

Moreau F, Moreau M (1937) Sur un nouveau champignon a collarette, *Coleomyces rufus*, nov. gen., nov. sp., ad interim. Bull Trimest Soc Mycol Fr 53:33–38

Nirenberg H (1976) Untersuchungen über die morphologische und biologische differenzierung in der Fusarium-Sektion Liseola. Mitt Biol Bundesanst Land- Forstwirtsch 169:1–117

O'Donnell K, Cigelnik E (1997) Two divergent intragenomic rDNA ITS2 types within a monophyletic lineage of the fungus *Fusarium* are nonorthologous. Mol Phylogenet Evol 7:103–116

O'Donnell K, Kistler HC, Cigelnik E, Ploetz RC (1998) Multiple evolutionary origins of the fungus causing Panama disease of banana: concordant evidence from nuclear and mitochondrial gene genealogies. Proc Natl Acad Sci USA 95:2044–2049

Rayner RW (1970) A Mycological Colour Chart. British Mycological Society and CAB International Mycological Institute, Kew

Rossman AY, Samuels GJ, Rogerson CT, Lowen R (1999) The genera of *Bionectriaceae*, *Hypocreaceae* and *Nectriaceae* (*Hypocreales, Ascomycetes*). Stud Mycol 42:1–248

Samuels GJ, Brayford D (1990) Variation in *Nectria radicicola* and its anamorph, *Cylindrocarpon destructans*. Mycol Res 94:433–442

Schroers H-J, Žerjav M, Munda A, Halleen F, Crous PW (2008) *Cylindrocarpon pauciseptatum* sp. nov., with notes on *Cylindrocarpon* species with wide, predominantly 3-septate macroconidia. Mycol Res 112:82–92. doi:10.1016/j.mycres.2007.10.004

Schroers H-J, Gräfenhan T, Nirenberg HI, Seifert KA (2011) A revision of *Cyanonectria* and *Geejayessia* gen. nov., and related species with *Fusarium*-like anamorphs. Stud Mycol 68:115–138

Seifert KA, McMullen CR, Yee D, Reeleder RD, Dobinson KF (2003) Molecular differentiation and detection of ginseng-adapted isolates of the root rot fungus *Cylindrocarpon destructans*. Phytopathology 93:1533–1542

Tewoldemedhin YT, Mazzola M, Mostert L, McLeod A (2010) *Cylindrocarpon* species associated with apple tree roots in South Africa and their quantification using real-time PCR. Eur J Plant Pathol. doi:10.1007/s10658-010-9728-4

White TJ, Bruns T, Lee S, Taylor J (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis MA, Gelfand D, Sninsky JJ, White TJ (eds) PCR protocols: a guide to methods and applications. Academic, San Diego, pp 315–322

Wollenweber HW (1913) *Ramularia*, *Mycosphaerella*, *Nectria,* Calonectria. Eine morphologisch pathologische Studie zur Abgrenzung von Pilzgruppen mit cylindrischen und sichelförmigen Konidienformen. Phytopathology 3:198–242

Wollenweber HW (1924) *Fusaria autographice delineata*. 2nd edn. Berlin

Wollenweber HW (1928) Über Fruchtformen der Krebserregenden Nectriaceen. Z Parasitenk 1:138–173

Wollenweber HW (1931) *Fusarium*-Monographie. Fungi parasitici et saprophytici. Z Parasitenk 3:495

Zinssmeister CL (1918) Ramularia root-rots of ginseng. Phytopathology 8:557