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Species concepts in *Calonectria* (*Cylindrocladium*)

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Abstract: Species of *Calonectria* and their *Cylindrocladium* anamorphs are important plant pathogens worldwide. At present 52 *Cylindrocladium* spp. and 37 *Calonectria* spp. are recognised based on sexual compatibility, morphology and phylogenetic inference. The polyphasic approach of integrating Biological, Morphological and Phylogenetic Species Concepts has revolutionised the taxonomy of fungi. This review aims to present an overview of published research on the genera *Calonectria* and *Cylindrocladium* as they pertain to their taxonomic history. The nomenclature as well as future research necessary for this group of fungi are also briefly discussed.

Key words: *Calonectria*, *Cylindrocladium*, species concepts, nomenclature, pathogenicity.

INTRODUCTION

The genus *Calonectria* (*Ca.*) was erected in 1867 by De Notaris, based on *Ca. daldiniana* collected on leaves of *Magnolia grandiflora* (*Magnoliaceae*), in Daldini, Italy (Rossman 1979a). Rossman (1979a) later reduced *Ca. daldiniana* to synonymy under *Ca. pyrochroa*, and defined this nectrioid fungus as having an ascocarp wall structure that is brightly coloured, changing to blood-red in 3 % KOH solution, warty to scaly and with a *Cylindrocladium* (*Cy.*) anamorph (Rossman 1993, Rossman *et al.* 1999). However, due to the restricted morphological characteristics of the teleomorph (Rossman 1979b, 1983), specimens can in many cases only be identified to species level if the anamorph is present (Schoch *et al.* 2000b, Crous 2002).

The anamorph genus *Cylindrocladium*, which is based on *Cy. scoparium,* was first described by Morgan (1892) in the U.S.A., where it was found growing as saprobe on a pod of *Gleditsia triacanthos*. Although Morgan (1892) failed to mention the stipe extension terminating in a vesicle of characteristic shape, he defined the genus as having branched conidiophores producing cylindrical conidia. This fungus has a wide distribution in sub-tropical and tropical regions of the world, and species are pathogenic to numerous plants (Crous 2002).

The aim of this review is to present an overview of published research on the genus *Calonectria* and their *Cylindrocladium* anamorphs. More specifically, the application of three types of species concepts is considered as they pertain to the taxonomic history of this genus. Although several species concepts (Mayden 1997) have been proposed, only the Morphological Species Concept (MSC), the Biological Species Concept (BSC) and the Phylogenetic Species Concept (PSC) are treated, as these have been most widely applied to *Calonectria*. Several reviews (Rossman 1996, Brasier 1997, Harrington & Rizzo 1999, Taylor *et al.* 1999, 2000, Seifert *et al.* 2000, Kohn 2005) have treated the various species concepts applied to the taxonomy of fungi and this topic is not treated other than in the manner in which it applies to *Calonectria.*

TAXONOMIC HISTORY

Calonectria resides in the *Nectriaceae*, one of three families in *Hypocreales*, an order that has been reviewed extensively (Rogerson 1970, Rossman 1983, Rossman *et al.* 1996, 1999). The *Nectriaceae* is circumscribed as having uniloculate ascomata that are orange to purple and not immersed in well-developed stromata (Rossman *et al.* 1999). The family includes approximately 20 genera of socio-economic importance and of these, *Calonectria* is most clearly distinguished from the others by its *Cylindrocladium* anamorphs and relevance as plant pathogens.

The first monograph of *Cylindrocladium* by Boedijn & Reitsma (1950), introduced seven *Cylindrocladium* species with one *Calonectria* connection. Later, in her treatment of *Calonectria*, Rossman (1983) recognised five species including the novel *Ca. ophiospora*. However, this species description did not include the anamorph state. The circumscribed type, *Ca. pyrochoa*, was also incorrectly reduced to synonymy with several other species based only on the teleomorph morphology. Peerally (1991a) highlighted this in a monograph of *Cylindrocladium*, where he regarded the anamorph morphology as important in distinguishing species of *Calonectria*. He subsequently recognised 10 *Calonectria* species with their *Cylindrocladium* anamorphs, including an additional 16 *Cylindrocladium* species not associated with a teleomorph. However, he mistakenly reduced *Cylindrocladiella*, a genus that accommodates *Cylindrocladium*-like species with small conidia (Boesewinkel 1982) and *Nectricladiella* teleomorphs, to synonymy with *Cylindrocladium* (Schoch *et al*. 2000b).

The monograph of *Cylindrocladium* by Crous & Wingfield (1994) entrenched the importance of anamorph characteristics in the taxonomy of *Calonectria* spp. In this monograph, 22

Cylindrocladium species and one variety were recognised, associated with 16 *Calonectria* species. Five species were assigned to the genus *Cylindrocladiella* based on morphological characters of the holomorph. The focus on anamorph characteristics is perpetuated in the most recent monograph (Crous 2002), which recognised 28 *Calonectria* species, all associated with *Cylindrocladium* anamorphs and an additional 18 *Cylindrocladium* species for which teleomorph states were not known. Of the latter group, seven taxa were of doubtful authenticity. Presently, 37 *Calonectria* and 52 *Cylindrocladium* species are recognised (Table 1; Crous 2002, Crous *et al.* 2004b, 2006a; Gadgil & Dick 2004, Lombard *et al.* 2009, 2010).

A general search on MycoBank (www.mycobank.org; Crous *et al.* 2004a, Robert *et al.* 2005) and Index Fungorum (www.indexfungorum.org) resulted in a total of 291 and 261 name records respectively for *Calonectria*. A similar search for *Cylindrocladium* species on both electronic databases indicated a total of 98 and 93 names respectively.

Table 1. List of recognised *Calonectria* species and their respective *Cylindrocladium* anamorphs.

Teleomorph	Reference	Anamorph	Reference
Calonectria acicola Gadgil & M.A. Dick	Gadgil & Dick 2004	*Cylindrocladium acicola* Gadgil & M.A. Dick	Gadgil & Dick 2004
Calonectria asiatica Crous & Hywel-Jones	Crous *et al*. 2004b	*Cylindrocladium asiaticum* Crous & Hywel-Jones	Crous *et al*. 2004b
Calonectria avesiculata T.S. Schub., Ell-Gholl, Alfieri & Schoult.	Schubert *et al.* 1989	*Cylindrocladium avesiculatum* D.L. Gill, Alfieri & Sobers	Gill *et al.* 1971
Calonectria brassicae (Panwar & Bohra) L. Lombard, M.J. Wingf. & Crous	Lombard *et al*. 2009		
Calonectria brachiatica L. Lombard, M.J. Wingf. & Crous	Lombard *et al*. 2009		
Calonectria cerciana L. Lombard, M.J. Wingf. & Crous	Lombard *et al*. 2010		
Calonectria clavata Alfieri, El-Gholl & E.L. Barnard	El-Gholl *et al*. 1993b	*Cylindrocladium flexuosum* Crous	Crous *et al*. 1995
Calonectria colhounii Peerally	Peerally 1973	*Cylindrocladium colhounii* Peerally	Peerally 1973
Calonectria colombiensis Crous	Crous *et al*. 2004b	*Cylindrocladium colombiense* Crous	Crous *et al*. 2004b
Calonectria gracilipes Crous & Mchau	Crous *et al*. 1997a	*Cylindrocladium graciloideum* Crous & Mchau	Crous *et al*. 1997a
Calonectria gracilis Crous, M.J. Wingf. & Alfenas	Crous *et al*. 1997b	*Cylindrocladium pseudogracile* Crous	Crous *et al*. 1997b
Calonectria hederae G. Arnaud ex C. Booth	Booth & Murray 1960	*Cylindrocladium hederae* G. Arnaud ex Peerally	Peerally 1991a
Calonectria hongkongensis Crous	Crous *et al*. 2004b	*Cylindrocladium hongkongense* Crous	Crous *et al*. 2004b
Calonectria ilicicola Boedijn & Reitsma	Boedijn & Reitsma 1950	*Cylindrocladium parasiticum* Crous, M.J. Wingf. & Alfenas	Crous *et al*. 1993d
Calonectria indusiata (Seaver) Crous	Crous 2002	*Cylindrocladium theae* (Petch) Subram	Alfieri *et al*. 1972
Calonectria insularis C.L. Schoch & Crous	Schoch *et al.* 1999	*Cylindrocladium insulare* C.L. Schoch & Crous	Schoch *et al.* 1999
Calonectria kyotensis Terash.	Terashita 1968	*Cylindrocladium floridanum* Sobers & C.P. Seym.	Sobers & Seymour 1967
Calonectria leguminum (Rehm) Crous	Crous 2002	*Cylindrocladium leguminum* Crous	Crous 2002
Calonectria macroconidialis (Crous, M.J. Wingf. & Alfenas) Crous	Crous *et al.* 1999	*Cylindrocladium macroconidiale* (Crous, M.J. Wingf. & Alfenas) Crous	Crous *et al.* 1999
Calonectria madagascariensis Crous	Crous 2002	*Cylindrocladium madagascariense* Crous	Crous 2002
Calonectria mexicana C.L. Schoch & Crous	Schoch *et al.* 1999	*Cylindrocladium mexicanum* C.L. Schoch & Crous	Schoch *et al.* 1999
Calonectria morganii Crous, Alfenas & M.J. Wingf.	Crous *et al*. 1993a	*Cylindrocladium scoparium* Morgan	Morgan 1892
Calonectria multiseptata Crous & M.J. Wingf.	Crous *et al*. 1998b	*Cylindrocladium multiseptatum* Crous & M.J. Wingf.	Crous *et al*. 1998b
Calonectria naviculata Crous & M.J. Wingf.	Crous *et al*. 1994	*Cylindrocladium naviculatum* Crous & M.J. Wingf.	Crous *et al*. 1994
Calonectria ovata D. Victor & Crous	Victor *et al.* 1997	*Cylindrocladium ovatum* El-Gholl , Alfenas, Crous & T.S. Schub.	El-Gholl *et al.* 1993a
Calonectria pauciramosa C.L. Schoch & Crous	Schoch *et al*. 1999	*Cylindrocladium pauciramosum* C.L. Schoch & Crous	Schoch *et al*. 1999
Calonectria pseudoreteaudii L. Lombard, M.J. Wingf. & Crous	Lombard *et al*. 2010		
Calonectria pseudospathiphylli J.C. Kang, Crous & C.L. Schoch	Kang *et al*. 2001b	*Cylindrocladium pseudospathiphylli* J.C. Kang, Crous & C.L. Schoch	Kang *et al*. 2001b
Calonectria pteridis Crous, M.J. Wingf. & Alfenas	Crous *et al*. 1993c	*Cylindrocladium pteridis* F.A. Wolf	Wolf 1926
Calonectria pyrochroa (Desm.) Sacc.	Rossman 1979a	*Cylindrocladium ilicicola* (Hawley) Boedijn & Reitsma	Boedjin & Reitsma 1950
Calonectria queenslandica L. Lombard, M.J. Wingf. & Crous	Lombard *et al*. 2010		
Calonectria reteaudii (Bugnic.) C. Booth	Booth 1966	*Cylindrocladium reteaudii* (Bugnic.) Boesew.	Boesewinkel 1982

Table 1. (Continued).

Teleomorph	Reference	Anamorph	Reference
Calonectria rumohrae El-Gholl & Alfenas	El-Gholl *et al.* 1997	*Cylindrocladium rumohrae* El-Gholl & Alfenas	El-Gholl *et al.* 1997
Calonectria scoparia Ribeiro & Matsuoka ex Peerally	Peerally 1991a	*Cylindrocladium candelabrum* Viégas	Crous 2002
Calonectria spathiphylli El-Gholl, J.Y. Uchida, Alfenas, T.S. Schub., Alfieri & A.R. Chase	El-Gholl *et al.* 1992	*Cylindrocladium spathiphylli* Schoult., El-Gholl & Alfieri	Schoulties *et al.* 1982
Calonectria spathulata El-Gholl, Kimbr., E.L. Barnard, Alfieri & Schoult.	Crous & Wingfield 1994	*Cylindrocladium spathulatum* El-Gholl, Kimbr., E.L. Barnard, Alfieri & Schoult.	Crous & Wingfield 1994
Calonectria terrae-reginae L. Lombard, M.J. Wingf. & Crous	Lombard *et al.* 2010		
Calonectria variabilis Crous, B.J.H. Janse, D. Victor, G.F. Marais & Alfenas	Crous *et al.* 1993b	*Cylindrocladium variabile* Crous, B.J.H. Janse, D. Victor, G.F. Marais & Alfenas	Crous *et al.* 1993b
		Cylindrocladium angustatum Crous & El-Gholl	Crous *et al.* 2000
		Cylindrocladium australiense Crous & K.D. Hyde	Crous *et al.* 2006a
		Cylindrocladium canadense J.C. Kang, Crous & C.L. Schoch	Kang *et al.* 2001b
		Cylindrocladium chinense Crous	Crous *et al.* 2004b
		Cylindrocladium citri (H.S. Fawc. & Klotz) Boedijn & Reitsma	Boedjin & Reitsma 1950
		Cylindrocladium curvatum Boedijn & Reitsma	Boedjin & Reitsma 1950
		Cylindrocladium curvisporum Crous & D. Victor	Victor *et al.* 1997
		Cylindrocladium ecuadoriae Crous & M.J. Wingf.	Crous *et al.* 2006a
		Cylindrocladium gordoniae Leahy, T.S. Schub. & El-Gholl	Leahy *et al.* 2000
		Cylindrocladium hawksworthii Peerally	Peerally 1991b
		Cylindrocladium hurae (Linder & Whetzel) Crous	Crous 2002
		Cylindrocladium indonesiae Crous	Crous *et al.* 2004b
		Cylindrocladium leucothoës El-Gholl, Leahy & T.S. Schub.	El-Gholl *et al.* 1989
		Cylindrocladium malesianum Crous	Crous *et al.* 2004b
		Cylindrocladium multiphialidicum Crous, Simoneau & Risède	Crous *et al.* 2004b
		Cylindrocladium pacificum J.C. Kang, Crous & C.L. Schoch	Kang *et al.* 2001b
		Cylindrocladium penicilloides (Tubaki) Tubaki	Tubaki 1958
		Cylindrocladium pseudonaviculatum Crous, J.Z. Groenew. & C.F. Hill	Crous *et al.* 2002
		Cylindrocladium sumatrense Crous	Crous *et al.* 2004b

NOMENCLATURE OF *CALONECTRIA*

The nomenclature of pleomorphic fungi has been a topic of substantial debate during the course of the past two decades (Gams 1991, Cannon & Kirk 2000, Hawksworth 2004, 2005). The separate naming of anamorphs (mitotic morphs) and teleomorphs (meiotic morphs) has resulted in confusion, especially for non-taxonomists (Cannon & Kirk 2000). This is especially evident where teleomorph species epithets are different to those of their anamorphs and also where more than one anamorph (synanamorph) is found. The naming of fungal morphs based on the International Code of Botanical Nomenclature (ICBN; McNeill *et al.* 2005) and in particular following strict interpretation of Article 59 of the Code has now been unsatisfactory for many fungal groups due to our ability to connect morphs using molecular evidence, and there are increasing calls for further changes to be made.

Recent alterations to the Code at the ICBN meeting in Vienna allows for anamorphic fungi to be named in teleomorph genera, but these are vulnerable to be superseded by a connected teleomorph name in the future (Hawksworth 2004, McNeill *et al.* 2005, P. Cannon pers. comm.). Although there are several *Cylindrocladium* species without *Calonectria* connections (Crous 2002, Crous *et al.* 2004b, 2006a), we believe that new species should be described in *Calonectria* irrespective of whether a teleomorph is known or not. This follows a clear view based on phylogenetic inference that *Cylindrocladium* spp. all have *Calonectria* states (Schoch *et al.* 1999, 2000a, 2000b, Crous 2002, Crous *et al.* 2004b, 2006a). Following the approach of Crous *et al.* (2006b, 2008, 2009a, b) with other fungal groups, Lombard *et al.* (2009, 2010) recently described five new species in the genus *Calonectria*, irrespective whether the teleomorph was observed or not. Thus, for taxonomic purposes, *Cylindrocladium* species with known teleomorph states are referred to as *Calonectria* in this review.

IMPORTANCE OF *CALONECTRIA*

The genus *Calonectria* was initially regarded as a saprobe as no disease symptoms could be induced by inoculating a suspected host (Graves 1915). The first proof of pathogenicity of these fungi was provided by Massey (1917), and subsequently by Anderson (1919), who proved pathogenicity of *Ca. morganii* (as *Cy. scoparium*). Subsequently, *Calonectria* species have been associated with a wide range of disease symptoms on a large number of hosts worldwide (Crous 2002; Table 2; Figs 1–2). In the past, several authors have indicated that *Calonectria* species cause disease on plants residing in approximately 30 plant families (Booth & Gibson 1973, French & Menge 1978, Peerally 1991a, Wiapara *et al.* 1996, Schoch *et al.* 1999). Upon closer inspection, the number of plant families is actually closer to 100 (Table 2) and approximately 335 plant host species (Crous 2002). The plant hosts include important forestry, agricultural and horticultural crops and the impact of these plant pathogens has likely been underestimated.

The majority of disease reports associated with *Calonectria* species in forestry include hosts in five plant families, of which the most important are associated with *Fabaceae* (*Acacia* spp.), *Myrtaceae* (*Eucalyptus* spp.) and *Pinaceae* (*Pinus* spp.). Disease symptoms (Figs 1–2) include cutting rot (Crous *et al.* 1991, Crous 2002, Lombard *et al.* 2009, 2010), damping-off (Batista 1951, Cox 1953, Terashita & Itô 1956, Sharma & Mohanan 1982, Sharma *et al.* 1984, Crous *et al.* 1991, Brown & Ferreira 2000, Crous 2002, Taniguchi *et al.* 2008) leaf diseases (Cox 1953, Hodges & May 1972, Barnard 1984, Sharma *et al.* 1984, El-Gholl *et al.* 1986, Peerally *et al.* 1991a, Crous *et al.* 1993b, Crous & Wingfield 1994, Crous *et al.* 1998b, Schoch & Crous 1999, Schoch *et al.* 1999, Booth *et al.* 2000, Park *et al.* 2000, Crous & Kang 2001, Gadgil & Dick 2004), shoot blight (Sharma *et al.* 1984, Crous *et al.* 1991, 1998b, Crous & Kang 2001), stem cankers (Cox 1953, Sharma *et al.* 1984, 1985, Crous *et al.* 1991, Lombard *et al.* 2009) and root rot (Cox 1953, Hodges & May 1972, Cordell & Skilling 1975, Mohanan & Sharma 1985, Crous *et al.* 1991, Lombard *et al.* 2009). The majority of these diseases is associated with seedling and cutting production in forestry nurseries, but in a few cases *Cylindrocladium* species have also been reported from older, established commercial plantations. In these cases the pathogens have been reported to cause leaf diseases and shoot blight resulting in defoliation of trees leading to loss of vigour (Hodges & May 1972, Sharma *et al.* 1985, Booth *et al.* 2000, Park *et al.* 2000, Crous & Kang 2001, Crous 2002, Old *et al.* 2003, Rodas *et al.* 2005).

In agriculture, *Calonectria* species have been reported to cause diseases on several economically important crops. Several plant families of agricultural importance are susceptible to *Calonectria* infections, including *Fabaceae* and *Solanaceae*. Important diseases in these families are Cylindrocladium black rot of *Arachis hypogea* (peanut) and red crown rot of *Glycine max* (soybean) caused by *Ca. ilicicola* and *Ca. pyrochroa* in the USA (Bell & Sobers 1966, Beute & Rowe 1973, Rowe *et al.* 1973, Sobers & Littrell 1974, Rowe & Beute 1975, Phipps *et al.* 1976, Johnson 1985, Dianese *et al.* 1986, Berner *et al.* 1988, 1991, Culbreath *et al.* 1991, Porter *et al.* 1991, de Varon 1991, Hollowell *et al.* 1998, Kim *et al* 1998) and

Table 2. Plant families that are host to *Calonectria* species and number of known plant host species in each family (Crous 2002).

Host Plant family	Host species	Host Plant family	Host species	Host Plant family	Host species	Host Plant family	Host species
Actinidiaceae	2	*Cornaceae*	1	*Malipighiaceae*	2	*Pteridaceae*	1
Altingiaceae	1	*Crassulaceae*	1	*Malvaceae*	6	*Rhamnaceae*	1
Anacardiaceae	3	*Cupressaceae*	4	*Meliaceae*	2	*Rhizophoraceae*	1
Annonaceae	4	*Curcurbitaceae*	3	*Moraceae*	2	*Rosaceae*	10
Aparagaceae	1	*Cycadaceae*	1	*Musaceae*	2	*Rubiaceae*	2
Apiaceae	1	*Davalliaceae*	1	*Myristicaceae*	1	*Ruscaceae*	1
Apocynaceae	2	*Dennstaedtiaceae*	1	*Myrsinaceae*	1	*Rutaceae*	3
Aquifoliaceae	4	*Dilleniaceae*	1	*Myrtaceae*	31	*Salicaceae*	3
Araceae	5	*Dipterocarpaceae*	1	*Nelumbonaceae*	1	*Sapindaceae*	4
Araliaceae	2	*Dryopteridaceae*	2	*Nepenthaceae*	1	*Sapotaceae*	3
Arecaceae	21	*Ebenaceae*	1	*Nothofagaceae*	1	*Sarraceniaceae*	1
Araucariaceae	2	*Ericaceae*	14	*Nymphaeaceae*	1	*Saxifragaceae*	1
Aspleniaceae	1	*Euphorbiaceae*	6	*Oleaceae*	1	*Solanaceae*	4
Asteraceae	5	*Fabaceae*	57	*Onagraceae*	2	*Sterculiaceae*	2
Berberidaceae	2	*Fagaceae*	4	*Orchidaceae*	1	*Strelilziaceae*	2
Betulaceae	1	*Ginkgoaceae*	1	*Phytolaccaceae*	1	*Theaceae*	1
Bixaceae	1	*Juglandaceae*	2	*Pinaceae*	17	*Ulmaceae*	1
Bromeliaceae	3	*Lauraceae*	6	*Piperaceae*	1	*Verbenaceae*	1
Buxaceae	1	*Laxmanniaceae*	1	*Platanaceae*	1	*Vitaceae*	2
Caricaceae	2	*Lecythidaceae*	1	*Plumbaginaceae*	1	*Vochysiaceae*	1
Caryophyllaceae	1	*Leeaceae*	1	*Poaceae*	6	*Xanthorrhoeaceae*	1
Celastraceae	1	*Linaceae*	1	*Polygalaceae*	1	*Zingiberaceae*	1
Chenopodiaceae	1	*Lomariopsidaceae*	1	*Polygonaceae*	3		
Combretaceae	3	*Lythraceae*	1	*Polypodiaceae*	1		
Convolvulaceae	1	*Magnoliaceae*	2	*Proteaceae*	7		

Fig. 1. Disease symptoms associated with *Calonectria* (*Cylindrocladium*). A. Cutting rot of *Vallea stipolaris*. B. Cutting rot of *Eucalyptus* sp. C. Defoliated *Eucalyptus* trees in a plantation. D. Leaf and shoot blight of a *Eucalyptus* sp. E. Cylindrocladium leaf blight of a *Eucalyptus* sp. F. Leaf spots on a *Eucalyptus* sp. G–H. Stem cankers on twigs of a *Eucalyptus* sp. I–J. Root and collar rot of *Pinus* spp. K. Root rot of *Eucalyptus* sp. with conidiophores on the root surface.

Cylindrocladium tuber rot of *Solanum tuberosum* (potato) (Boedijn & Reitsma 1950, Bolkan *et al.* 1980, 1981) by *Ca. brassicae* (as *Cy. gracile*) in Brazil. Other diseases associated with *Calonectria* species on agricultural crops include root rot and leaf diseases of fruit bearing and spice plants (Jauch 1943, Wormald 1944, Sobers & Seymour 1967, Nishijima & Aragaki 1973, Milholland 1974, Krausz & Caldwell 1987, Hutton & Sanewski 1989, Anandaraj & Sarma 1992, Risède 1994, Jayasinghe & Wijesundera 1996, Risède & Simoneau 2001, Vitale & Polizzi 2008), post-harvest diseases of fruits (Fawcett & Klotz 1937, Boedijn & Reitsma 1950, Sepiah 1990, Fitzell & Peak 1992, Vaidya & Roa 1992, Sivapalan *et al.* 1998), root and crown rot of *Medicago sativa* (alfalfa) (Ooka & Uchida 1982, Hwang & Flores 1987), and sheath net blotch of *Oryza sativa* (rice) (Crous 2002).

On horticultural crops, *Calonectria* species have been reported mostly from the Northern Hemisphere, especially in gardens and ornamental commercial nurseries in Europe and Asia (Polizzi & Crous 1999, Polizzi 2000, Crous 2002, Henricot & Culham 2002, Pérez-Sierra *et al.* 2007, Polizzi *et al.* 2007a, b, Hirooka *et al.* 2008, Polizzi *et al.* 2009, Vitale *et al.* 2009). Hosts in this sector include ornamental trees, shrubs and cut-flowers in several plant families, most commonly in *Arecaceae*, *Asteraceae*, *Ericaceae* and *Rosaceae*. A wide range of disease symptoms are recorded including crown-, collar- and root rot, leaf spots, and cutting rot (Massey 1917, Anderson 1919, Aragaki *et al.* 1972, 1988, Peerally 1991b, Uchida & Kadooka 1997, Polizzi & Crous 1999, Polizzi 2000, Crous 2002, Henricot & Culham 2002, Henricot & Beales 2003, Poltronieri *et al.* 2004, Lane *et al.* 2006, Pérez-Sierra *et al.* 2006, 2007, Polizzi *et al.* 2006a, b, 2007a, b, Vitale & Polizzi 2007, Aghajani *et al.* 2008, Hirooka *et al.* 2008, Vitale *et al*. 2008, Polizzi *et al.* 2009, Vitale *et al.* 2009).

MORPHOLOGY

Morphological or phenotypic characters have played a major role in the description of fungal species (Brasier 1997, Taylor *et. al.* 2000) and form the basis of new fungal descriptions as required by the ICBN (McNeill *et al.* 2005). In recent years, the use of morphological characters alone to delimit new species has been set aside to a large extent, with more focus being placed on biological and phylogenetic characters (Rossman 1996, Brasier 1997, Taylor *et al.* 2000). This trend is also evident in recent studies on *Calonectria* species (Crous *et al.* 2004b, 2006a).

The morphology of *Calonectria* and to a greater extent its anamorph, *Cylindrocladium*, has been important in the taxonomic history of these fungi. Prior to the 1990s, identification of species was based on morphological characteristics and to a lesser extent on sexual compatibility using standardised media (Boedijn & Reitsma 1950, Peerally 1991a, Crous *et al.* 1992, Crous & Wingfield 1994, Crous 2002). This resulted in the establishment of several species complexes, as many *Cylindrocladium* species are morphologically very similar. These include the *Ca. scoparia* complex (Schoch *et al.* 1999), *Ca. brassicae* (as *Cy. gracile*) complex (Crous *et al.* 2004b) and *Ca. kyotensis* complex (Crous *et al.* 2006a). Characteristics of the anamorphs that are extensively employed in identifications include vesicle shape, stipe extension length and macroconidial septation and dimensions (Fig. 3) (Boesewinkel 1982, Peerally 1991a, Crous & Wingfield 1994, Crous 2002). The morphological characteristics of the teleomorph (Fig. 4) that are important for identifications are ascospore septation and dimensions, ascospore number within the asci and perithecial colour. Perithecia of *Calonectria* species are morphologically very similar and these are not typically useful in identifications (Crous & Wingfield 1994, Crous 2002).

The use of biochemical techniques can also be used in phenotypic characterisation. These include substrate utilisation and cell wall polysaccharide analysis. The use of aminopeptidase specificity (Stevens *et al*. 1990) and utilisation of nitrogen and carbon (Hunter & Barnett 1978, Sharma *et al*. 1992) have been used successfully to separate several *Cylindrocladium* species. The use of polysaccharides obtained from cell walls of *Cylindrocladium* positively identified linkages between asexual species and their respective *Calonectria* teleomorphs (Ahrazem *et al*. 1997). However, this method has been found to have limited value as some species in complexes could not be distinguished (Crous 2002).

MATING COMPATIBILITY

Mating strategies have been employed in the taxonomy of *Calonectria* and have played an important role in identifying new species of the genus (Schoch *et al.* 1999, Crous 2002). Based on these studies, there are approximately 18 homothallic and 34 heterothallic species of *Calonectria* (Crous 2002, Crous *et al.* 2004b, Gadgil & Dick 2004, Crous *et al.* 2006a), with the heterothallic species showing a biallelic mating system (Schoch *et al.* 1999). Studies in the female fertility of *Cylindrocladium* by Schoch *et al.* (1999, 2000a, 2001a) have also shown that several species are self-sterile hermaphrodites requiring fertilisation from an opposite mating type. This is typical of heterothallic ascomycetes (Leslie & Klein 1996).

Several difficulties associated with applying the BSC have been highlighted (Brasier 1997, Taylor *et al.* 1999, 2000, Kohn 2005). The most relevant underlying problem occurs where genetically isolated fungal strains retain the ancestral ability to recombine to produce viable progeny (Brasier 1997). This phenomenon has also been found with several phylogenetic species that are closely related in *Calonectria*. Crous (2002), for example, showed that *Cy. hawksworthii*, *Ca. insularis* and *Ca. morganii* were capable of recombining, but that the progeny had low levels of fertility. Other mating studies done by Overmeyer *et al.* (1996) and Neubauer & Zinkernagel (1995) have found that induction of fertile perithecia requires the presence of an additional isolate that, however, does not contribute to the genetic make-up of the progeny. This clearly highlights the need for further studies regarding the mechanism of perithecial formation and recombination in *Calonectria*.

PHYLOGENY

Phylogenetic studies on *Calonectria* and its *Cylindrocladium* anamorphs have substantially influenced the taxonomy of these genera. Application of molecular techniques and particularly DNA sequence comparisons to distinguish between species has resulted in the recognition of numerous cryptic species. Several molecular approaches have been employed that include total protein electrophoresis (Crous *et al.* 1993a, El-Gholl *et al.* 1993a), isozyme electrophoresis (El-Gholl *et al.* 1992, 1997, Crous *et al.* 1998a), random amplification of polymorphic DNA (RAPD) (Overmeyer *et al.* 1996, Victor *et al.* 1997, Schoch *et al.* 2000a, Risède & Simoneau 2004) restriction fragment length polymorphisms (RFLP) (Crous *et al.* 1993b, 1995, 1997b, Jeng *et al.* 1997, Victor *et al.* 1997; Risède & Simoneau 2001) and DNA hybridisation (Crous *et al.* 1993b, 1995, 1997a, Victor *et al.* 1997). Although the above-mentioned techniques have been useful, DNA sequence comparisons and associated phylogenetic inference have had the most dramatic impact on the taxonomy of *Calonectria* and are most widely applied today.

In the first study using 5.8S ribosomal RNA gene and flanking internally transcribed spacers (ITS) sequences Jeng *et al.* (1997) were able to distinguish between *Cy. scoparium* and *Cy. floridanum* isolates. Subsequently, it was found that this gene region contains few informative characters (Crous *et al.* 1999, Schoch *et al.* 1999, Risède & Simoneau 2001, Schoch *et al.* 2001b). Therefore, the β-tubulin (Schoch *et al.* 2001b) and histone H3 (Kang *et al.* 2001a) gene regions have been applied in order to allow for improved resolution in separating species.

The first complete DNA sequence-based phylogenetic study using partial β-tubulin gene sequences (Schoch *et al.* 2001b)

Fig. 2. Disease symptoms associated with *Calonectria* (*Cylindrocladium*). A–D. Defoliation and yellowing associated with *Calonectria pseudonaviculata* infection on *Buxus* sp. at Paleis Het Loo in the Netherlands (upper part of hedge in A, arrows). B–D. Leaf yellowing and defoliation (note detaching leaves in D, arrows). E–H. *Calonectria ilicicola* causing Cylindrocladium black rot (CBR) on *Arachis hypogaea* in Georgia, U.S.A. F. Perithecia forming at the basal plant parts. G. Pods infected with tomato spotted wilt virus (left), healthy pods (middle), and pods infected with CBR (right). H. Field symptoms associated with CBR (photos with permission of T. Brenneman). I. Avocado roots infected with *Ca. ilicicola* (photo with permission of L. Forsberg). J. Seeding blight of *Callistemon citrinus* associated with *Ca. morganii* (photo with permission of G. Polizzi). K. Seedling rot of *Drosera* sp. associated with *Ca. pteridis* infection. L. Leaf spots of *Callistemon citrinus* associated with *Ca. pauciramosa* (photo with permission of G. Polizzi). M. *Arbutus unedo* associated with *Ca. pauciramosa* infection (photo with permission of G. Polizzi). N–O. Root rot and petiole lesions of *Spathiphyllum* sp. associated with *Ca. spathiphylli* infection (photo with permission from the late N.E. El-Gholl). P. Potato tuber infected with *Ca. brassicae*. Q–R. Leaf blight of *Eucalyptus* sp. associated with a mixed infection of *Ca. pteridis* and *Ca. ovata*.

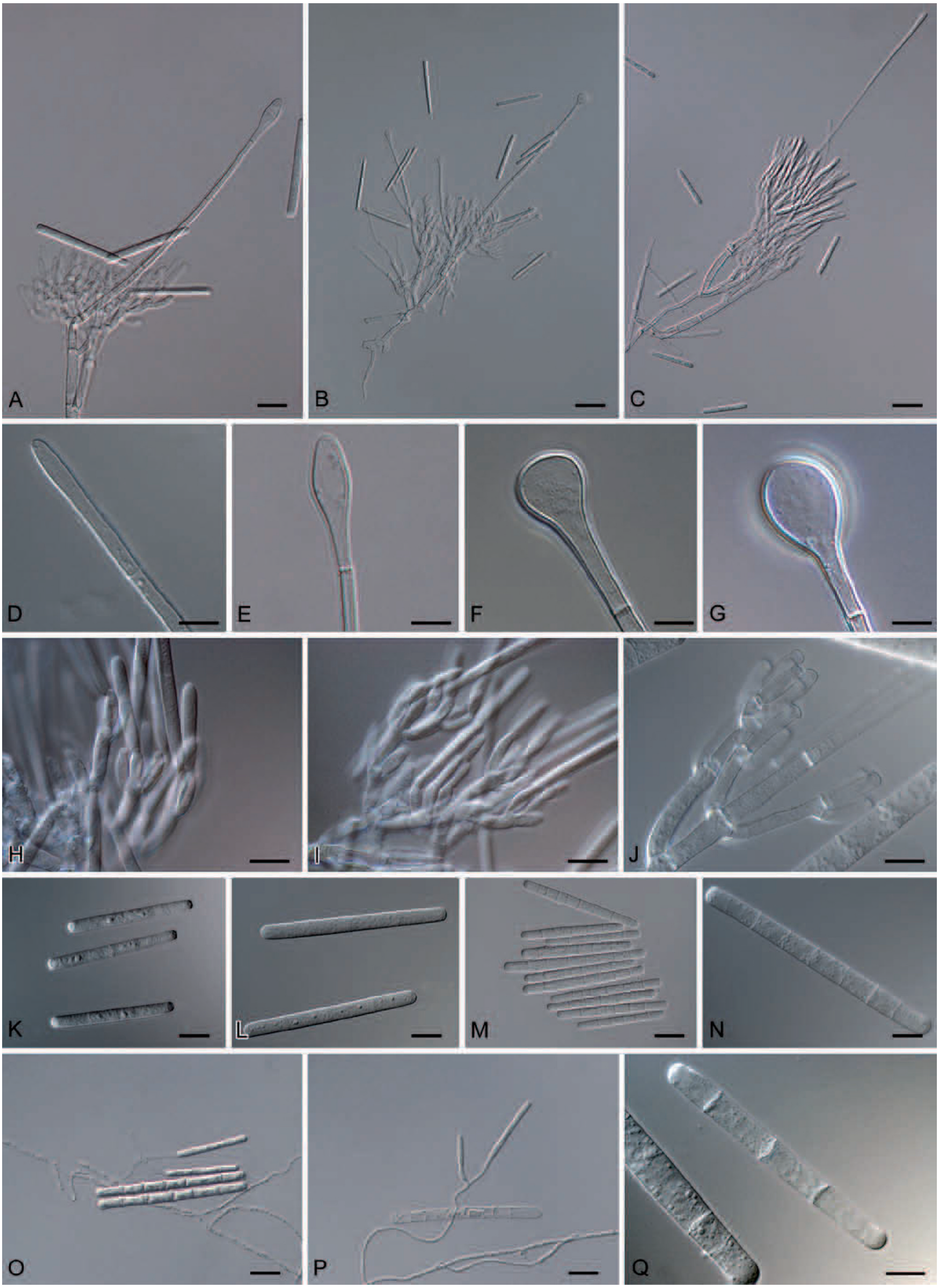

Fig. 3. Anamorph structures of *Calonectria*. A. Macroconidiophore of *Ca. pauciramosa*. B. Macroconidiophore of *Ca. hongkongensis*. C. Macroconidiophore of *Ca. brassicae*. D. Clavate vesicle of *Ca. reteaudii*. E. Obpyriform vesicle of *Ca. pauciramosa*. F. Sphaeropedunculate vesicle of *Ca. hongkongensis*. G. Pyriform vesicle of *Ca. morganii*. H. Fertile branches of *Ca. pauciramosa* with doliiform to reniform phialides. I. Fertile branches of a *Calonectria* sp. with elongate-doliiform to reniform phialides. J. Fertile branches of *Ca. reteaudii* with cylindrical to allantoid phialides. K. One-septate macroconidia of *Ca. pauciramosa*. L. Three-septate macroconidia of *Ca. colhounii*. M–N. Five to eight-septate macroconidia of *Ca. reteaudii*. O–P. Microconidiophores of *Ca. reteaudii*. Q. three-septate microconidium of *Ca. reteaudii.* Scale bars: B–C, M = 50 µm; A, O–P = 20 µm; D–L, N, Q = 10 µm.

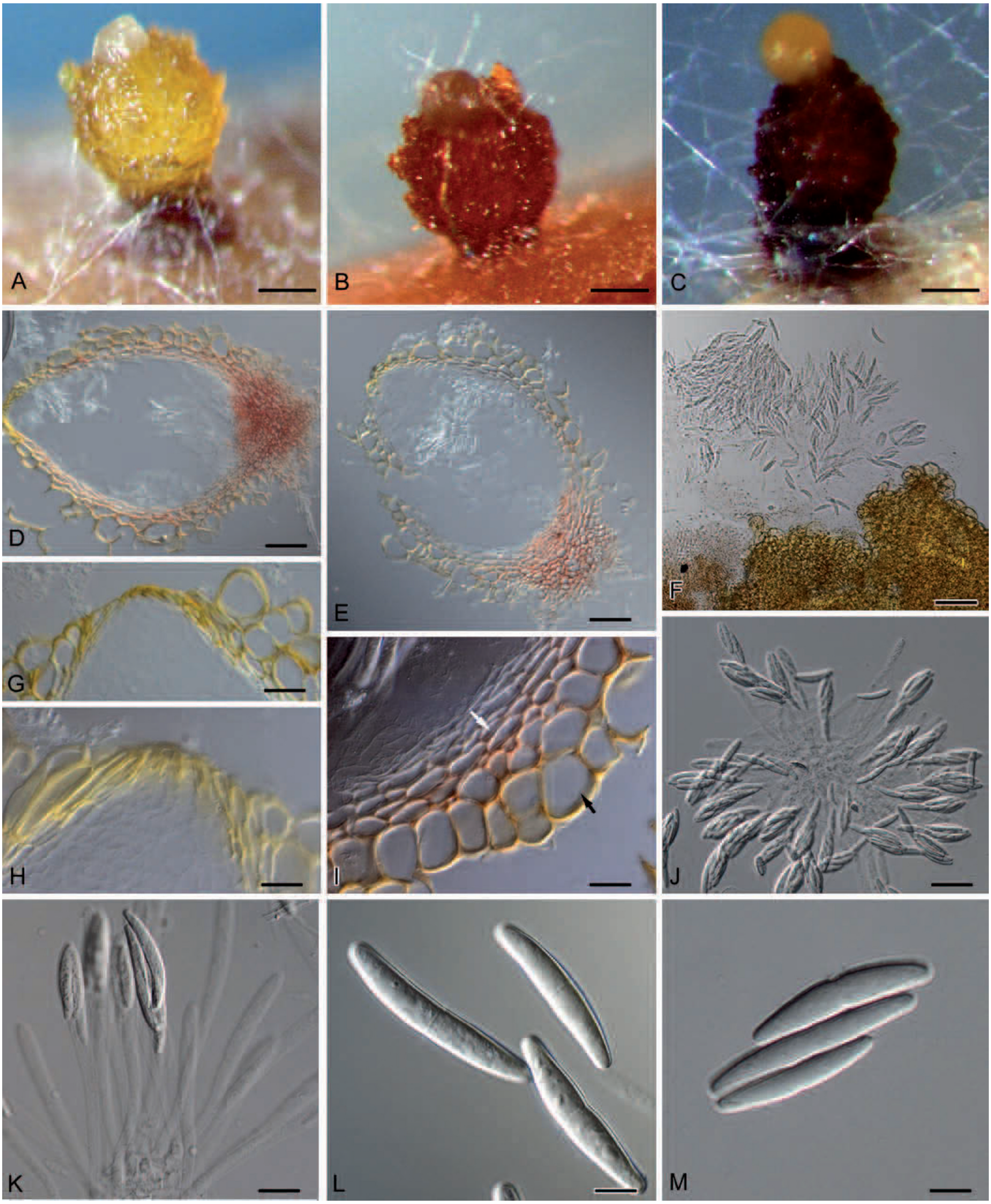

Fig. 4. Teleomorph structures of *Calonectria* spp. A. Yellow perithecium of *Ca. colhounii*. B. Orange to red perithecium of *Ca. pauciramosa*. C. Dark red perithecium of *Calonectria* sp. D–E. Vertical sections through perithecia. F. Squashed perithecium exuding ascospores. G–H. Ostiolar regions of perithecia. I. Vertical section through the wall of a perithecium showing the *textura globulosa* (black arrow) and *textura angularis* (white arrow) wall layers. J. Asci containing eight ascospores. K. Asci containing four ascospores. L–M. One-septate ascospores. Scale bars: A–C = 100 µm; F = 50 µm; J–K = 20 µm; D–E, G–I, L–M = 10 µm.

compared phenotypic, biological and phylogenetic concepts used in the taxonomy of *Cylindrocladium*. This also highlighted the fact that *Calonectria* represents a monophyletic lineage (Schoch *et al*. 2000b, 2001b). Subsequently, combined DNA sequence data for the ITS, β-tubulin and histone H3 gene regions have been widely used in studies relating to taxonomic issues surrounding *Cylindrocladium* and *Calonectria* (Crous *et al.* 1999, Schoch *et al.* 2000a, 2000b, Crous & Kang 2001, Kang *et al.* 2001a, 2001b, Henricot & Culham 2002, Crous *et al.* 2004b, 2006a, Lombard *et al.* 2009, 2010). Other partial gene sequences recently used include translation elongation 1-alpha (TEF-1α) and calmodulin (Crous *et al.* 2004b, Lombard *et al.* 2010). However, insufficient data are currently available for these gene regions on GenBank (www.ncbi.nlm.nih.gov) to make them particularly valuable for comparative analysis.

A recent search in GenBank (March 2010) revealed a total of 734 partial gene sequences for *Calonectria* and *Cylindrocladium*. These include 311 for β-tubulin, 177 for histone H3, 159 for ITS, 39 for calmodulin, 36 for TEF-1α, five for large subunit RNA gene (LSU), three each for the high mobility group (HMG) box and peptidase synthetase and one for the small subunit RNA (SSU) gene. For *Cylindrocladium* and *Calonectria*, there are only six studies (Kang *et al.* 2001a, 2001b; Crous *et al.* 2004b, 2006a, Lombard *et al.* 2009, 2010) that provide files on TreeBase (www.treebase.org).

FUTURE RESEARCH

Population biology

Most studies on *Calonectria* have focused on the taxonomy, phylogeny and pathology of species. There have in contrast been relatively few studies treating the population biology of these fungi. This is unfortunate as population dynamics contributes considerable knowledge to a better understanding of population structure, distribution of genetic diversity, gene flow, centres of origin and mating strategies (McDonald 1997, Linde *et al.* 2002, Grünwald *et al.* 2003). An understanding of the population dynamics of *Calonectria* would contribute in determining the natural spread of these fungi as well as assist in phytosanitary and quarantine regulations. Another important aspect surrounding knowledge of *Calonectria* population dynamics is that this would contribute to plant breeding programmes and thus control of the many diseases that are caused by these fungi (McDonald 1997, Wright *et al.* 2006, 2007).

Limited research has been conducted on the population dynamics of *Calonectria*. To date only two studies (Wright *et al.* 2006, 2007) have reported on the development of polymorphic markers to characterise simple sequence repeats (SSRs) in loci of *Ca. ilicicola* (Wright *et al.* 2006) and *Ca. pauciramosa* (Wright *et al.* 2007). However, no study has yet been published on the population biology of either of these important pathogens using these markers. There is clearly a gap in this area of research concerning *Calonectria* spp. and future research on this topic should be encouraged.

Whole genome sequences

A relatively new and innovative technology employed in fungal genetics is the use of whole genome sequences of filamentous fungi. Whole genome sequencing has become relatively inexpensive and thus common in recent years. This revolutionary technology will promote our understanding of the mechanisms of gene function, conidiation, pathogenesis and sexual reproduction at the genotype level (Kupfer *et al.* 1997, Prade 1998, Yoder & Turgeon 2001, Foster *et al.* 2006, Cuomo *et al.* 2007). It is estimated that most filamentous fungi have a genome size of 30 to 40 Mb, containing approximately 8000 to 9000 genes (Kupfer *et al.* 1997, Prade 1998, Foster *et al.* 2006). There are currently several completed fungal genome sequences (http://www.broad.mit.edu/annotation/fungi/fgi/, Foster *et al.* 2006, Baker *et al.* 2008), including the model yeast *Saccharomyces cerevisiae* (Goffeau *et al.* 1996), plant pathogens and spoilage fungi such as *Aspergillus flavus* (Payne *et al.* 2006), *Fusarium graminearum* (http://www.broad.mit.edu, Cuomo *et al.* 2007), *Magnaporthe grisea* (Dean *et al.* 2005) and the model filamentous fungus *Neurospora crassa* (Galagan *et al.* 2003). Although there are currently over 300 ongoing filamentous fungal genome sequencing projects (http://www.genomesonline.org, Baker *et al.* 2008, Liolios *et al.* 2008), none include species of *Calonectria*.

The most closely related plant pathogen to *Calonectria* species currently being sequenced is *Haematonectria haematococca* (http://www.ncbi.nlm.gov). When the first *Calonectria* species is selected for whole genome sequencing, comparisons with *H. haematococca* could help to identify important genes in pathogenesis and sexual reproduction. Some *Calonectria* species that could be considered for genome sequencing include *Ca. pauciramosa*, based on its pathogenicity and importance on several plant hosts worldwide (Crous 2002), and *Ca. reteaudii*, one of the most important forest pathogens of South East Asia (Booth *et al.* 2000, Old *et al.* 2003).

CONCLUSIONS

Early studies on the taxonomy of *Calonectria* and *Cylindrocladium* focused on the use of MSC in combination with BSC. More recently, the wide availability of molecular techniques and particularly DNA sequence data have revolutionised the taxonomy of *Calonectria* and *Cylindrocladium.* Today, it is well accepted that the morphology of the *Cylindrocladium* state contributes most information to naming species and that these fungi all reside in *Calonectria*.

The first study to combine MSC, BSC and PSC concepts by Schoch *et al.* (1999) resulted in the identification of four species within a single species complex. Subsequently, several studies including the MSC, BSC and PSC have elucidated cryptic species in the genus (Kang *et al.* 2001a, 2001b, Henricot & Culham 2002, Crous *et al.* 2004b, 2006a, Lombard *et al.* 2009, 2010). Application of the BSC in the taxonomy of *Calonectria* has been found to be unreliable in some instances (Crous 2002). However, the implementation of MSC and PSC in combination provides powerful tool for taxonomic studies of these genera and it is likely that this will continue in future studies. Although several species complexes have been identified in *Calonectria*, more research is needed on the population level in order to study the gene flow between populations. Additional to this, more gene regions need to be identified and widely used in PSC. With the identification of several new species since 2002, an updated monograph is required to facilitate ease of identification.

REFERENCES

Aghajani MA, Alizadeh A, Rahimian H (2008). First report of brown patch on bristle basket grass in Iran. *Plant Pathology* **57**: 384.

Ahrazem O, Prieto A, Leal JA, Gomez-Miranda B, Domenech J, Jimenez-Barbero J, Bernabe M (1997). Structural elucidation of acidic fungal polysaccharides isolated from the cell-wall of genera *Cylindrocladium* and *Calonectria*. *Carbohydrate Research* **303**: 67–72.

Alfieri SA, Linderman RG, Morrison RH, Sobers EK (1972). Comparative pathogenicity of *Calonectria theae* and *Cylindrocladium scoparium* to leaves and roots of azalea. *Phytopathology* **62**: 647–650.

Anandaraj M, Sarma YR (1992). A new leaf rot in *Pimenta dioica*. *Indian Phytopathology* **45**: 276–277.

Anderson PJ (1919). Rose canker and its control. *Massachusetts Agricultural Experiment Station Bulletin* **183**: 11–46.

Aragaki M, Laemmlen FF, Nishijima WT (1972). Collar rot of Koa caused by *Calonectria crotalariae*. *Plant Disease Reporter* **56**: 73–74.

Aragaki M, Yahata PS, Uchida JY (1988). Heliconia root rot caused by *Cylindrocladium spathiphylli* f. sp. *heliconiae*. *Phytopathology* **78**: 1614.

Baker SE, Thykaer J, Adney WS, Brettin TS, Brockman FJ, D'Haeseleer P, Martinez AD, Miller RM, Rokhsar DS, Schadt CW, Torok T, Tuskan G, Bennett J, Berka RM, Briggs SP, Heitman J, Taylor J, Turgeon BG, Werner-Washburne M, Himmel ME (2008). Fungal genome sequencing and bioenergy. *Fungal Biology Reviews* **22**: 1–5.

Barnard EL (1984). Occurrence, impact and fungicide control of girdling stem cankers caused by *Cylindrocladium scoparium* on *Eucalyptus* seedlings in a south Florida nursery. *Plant Disease* **68**: 471–473.

Batista AC (1951). *Cylindrocladium scoparium* Morgan var. *brasiliensis* Batista & Ciferri, a new fungus on *Eucalyptus*. *Boletim da Secretaria de Agricultura, Industria e Comercio do Estado de Pernambuco* **18**: 188–191.

Bell DK, Sobers EK (1966). A peg, pod and root necrosis of peanuts caused by a species of *Calonectria*. *Phytopathology* **56**: 1361–1364.

Berner DK, Berggren GT, Snow JP, White EP (1988). Distribution and management of red crown rot of soybean in Louisiana, U.S.A. *Applied Agricultural Research* **3**: 160–166.

Berner DK, Berggren GT, Snow JP (1991). Effects of glyphosate on *Calonectria crotalariae* and red crown rot of soybean. *Plant Disease* **75**: 809–813.

Beute MK, Rowe RC (1973). Studies on the biology and control of Cylindrocladium black rot (CBR) of peanut. *Journal of the American Peanut Research Educational Associations* **5**: 197.

Boedijn KB, Reitsma J (1950). Notes on the genus *Cylindrocladium*. *Reinwardtia* **1**: 51–60.

Boesewinkel HJ (1982). Heterogeneity within *Cylindrocladium* and its teleomorphs. *Transactions of the British Mycological Society* **78**: 553–556.

Bolkan HA, Dianese JC, Ribeiro WRC, Almeida OC de (1980). Disease caused by *Cylindrocladium* on potato tubers in Brazil. *Plant Disease* **64**: 225.

Bolkan HA, Ribeiro WRC, Almeida OC de (1981). Pathogenicity of *Cylindrocladium clavatum* causing potato tuber rot. *Plant Disease* **65**: 47–49.

Booth C (1966). The genus *Cylindrocarpon*. *Mycological Papers* **104**: 1–56.

Booth C, Gibson IAS (1973). *Cylindrocladium scoparium*. *CMI Descriptions of Pathogenic Fungi and Bacteria* No. 362.

Booth TH, Jovanovic T, Old KM, Dubzinski MJ (2000). Climatic mapping to identify high – risk areas for *Cylindrocladium quinqueseptatum* leaf blight on eucalypts in mainland South East Asia and around the world. *Environmental Pollution* **108**: 365–372.

Booth C, Murray JS (1960). *Calonectria hederae* Arnaud and its *Cylindrocladium* conidial state. *Transactions of the British Mycological Society* **43**: 69–72.

Brasier CM (1997). Fungal species in practice: identifying species units in fungi. In: *Species: The units of Biodiversity* (Claridge MF, Dawah HA, Wilson MR, eds). Chapman & Hall, U.K.: 135–170.

Brown BB, Ferreira FA (2000). Disease during propagation of eucalypts. In: *Diseases and pathogens of eucalypts.* (Keane PJ, Kile GA, Podger FD, Brown BN, eds). CSIRO publishing, Australia: 119–151.

Cannon PF, Kirk PM (2000). The philosophy and practicalities of amalgamating anamorph and teleomorph concepts. *Studies in Mycology* **45**: 19–25.

Cordell CE, Skilling DD (1975). Forest nursery diseases in the U.S.A. 7. *Cylindrocladium* root rot. *U.S.D.A. Forest Service Agricultural Handbook No.* **470**: 23–26.

Cox RS (1953). Etiology and control of a serious complex of diseases of conifer seedlings. *Phytopathology* **43**: 469.

Crous PW (2002). *Taxonomy and pathology of Cylindrocladium (Calonectria) and allied genera*. APS Press, St. Paul, Minnesota, U.S.A.

Crous PW, Alfenas AC, Junghans TG (1998a). Variability within *Calonectria ovata* and its anamorph *Cylindrocladium ovatum* from Brazil. *Sydowia* **50**: 1–13.

Crous PW, Alfenas AC, Wingfield MJ (1993a). *Calonectria scoparia* and *Calonectria morganii* sp. nov., and variation among isolates of their *Cylindrocladium* anamorphs. *Mycological Research* **97**: 701–708.

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

Crous PW, Groenewald JZ, Hill CF (2002) *Cylindrocladium pseudonaviculatum* sp. nov. from New Zealand, and new *Cylindrocladium* records from Vietnam. *Sydowia* **54**: 23–33.

Crous PW, Groenewald JZ, Risède J-M, Simoneau P, Hyde KD (2006a). *Calonectria* species and their *Cylindrocladium* anamorphs: species with clavate vesicles. *Studies in Mycology* **55**: 213–226.

Crous PW, Groenewald JZ, Risède J-M, Simoneau P, Hywel-Jones NL (2004b). *Calonectria* species and their *Cylindrocladium* anamorphs: species with sphaeropedunculate vesicles. *Studies in Mycology* **50**: 415–430.

Crous PW, Janse BJH, Victor D, Marais GF, Alfenas AC (1993b). Molecular characterization of *Cylindrocladium* spp. with three-septate conidia and ovoid-like vesicles. *Systematic and Applied Microbiology* **16**: 266–273.

Crous PW, Kang JC (2001). Phylogenetic confirmation of *Calonectria spathulata* and *Cylindrocladium leucothoes* based on morphology, and sequence data of the β-tubulin and ITS rRNA genes. *Mycoscience* **42**: 51–57.

Crous PW, Kang JC, Schoch CL, Mchau GRA (1999). Phylogenetic relationships of *Cylindrocladium pseudogracile* and *Cylindrocladium rumohrae* with morphologically similar taxa, based on morphology and DNA sequences of internal transcribed spacers and β-tubulin. *Canadian Journal of Botany* **77**: 1813–1820.

Crous PW, Krof A, Zyl WH van (1995). Nuclear DNA polymorphisms of *Cylindrocladium* species with 1-septate conidia and clavate vesicles. *Systematic and Applied Microbiology* **18**: 224–250.

Crous PW, Mchau GRA, Zyl WH van, Wingfield MJ (1997a). New species of *Calonectria* and *Cylindrocladium* isolated from soil in the tropics. *Mycologia* **89**: 653–660.

Crous PW, Phillips AJL, Wingfield MJ (1991). The genera *Cylindrocladium* and *Cylindrocladiella* in South Africa, with special reference to forestry nurseries. *South African Forestry Journal* **157**: 69–85.

Crous PW, Phillips AJL, Wingfield MJ (1992). Effects of cultural conditions on vesicle and conidium morphology in species of *Cylindrocladium* and *Cylindrocladiella*. *Mycologia* **84**: 497–504.

Crous PW, Schoch CL, El-Gholl NE, Schubert TS, Leahy RM (2000). *Cylindrocladium angustatum* sp. nov., a new leaf spot pathogen of *Tillandsia capitata* from Florida U.S.A. *Mycosience* **41**: 521–526.

Crous PW, Slippers B, Wingfield MJ, Rheeder J, Marasas WFO, Phillips AJL, Alves A, Burgess T, Barber P, Groenewald JZ (2006b). Phylogenetic lineages in the *Botryosphaeriaceae*. *Studies in Mycology* **55**: 235–253.

Crous PW, Summerell BA, Carnegie AJ, Wingfield MJ, Groenewald JZ (2009a). Novel species of *Mycosphaerellaceae* and *Teratosphaeriaceae*. *Persoonia* **23**: 119–146.

Crous PW, Summerell BA, Carnegie AJ, Wingfield MJ, Hunter GC, Burgess TI, Andjic V, Barber PA, Groenewald JZ (2009b). Unravelling *Mycosphaerella*: do you believe in genera? *Persoonia* **23**: 99–118.

Crous PW, Theron L, Zyl WH van (1997b). Delineation of *Cylindrocladium* species with 1–3-septate conidia and clavate vesicles based on morphology and rDNA RFLPs. *Mycological Research* **101**: 210 – 214.

Crous PW, Wingfield MJ (1994). A monograph of *Cylindrocladium*, including anamorphs of *Calonectria*. *Mycotaxon* **51**: 341–435.

Crous PW, Wingfield MJ, Alfenas A (1993c). Additions to *Calonectria*. *Mycotaxon* **46**: 217–234.

Crous PW, Wingfield MJ, Alfenas AC (1993d). *Cylindrocladium parasiticum* sp. nov., a new name for *C. crotalariae*. *Mycological Research* **97**: 889–896.

Crous PW, Wingfield MJ, Alfenas AC, Silveira SF (1994). *Cylindrocladium naviculatum* sp. nov., and two new vesciculate hyphomycete genera, *Falcocladium* and *Vesiculomyces*. *Mycotaxon* **50**: 441–458.

Crous PW, Wingfield MJ, Mohammed C, Yuan ZQ (1998b). New foliar pathogens of *Eucalyptus* from Australia and Indonesia. *Mycological Research* **102**: 527–532.

Crous PW, Wood AR, Okada G, Groenewald JZ (2008). Foliicolous microfungi occurring on *Encephalartos*. *Persoonia* **21**: 135–146.

Culbreath AK, Beute MK, Campbell CL (1991). Spatial and temporal aspects of epidemics of Cylindrocladium black rot in resistant and susceptible peanut genotypes. *Phytopathology* **81**: 144–150.

Cuomo CA, Güldener U, Xu J-R, Trial F, Turgeon BG, *et al.* (2007). The *Fusarium graminearum* genome reveals a link between localized polymorphism and pathogen specialization. *Science* **317**: 1400–1402.

Dean RA, Talbot NJ, Ebbole DJ, Farman ML, Mitchell TK, *et al.* (2005). The genome sequence of the rice blast fungus *Magnaporthe grisea*. *Nature* **434**: 980–986.

Dianese JC, Ribeiro WRC, Urben AF (1986). Root rot of soybean caused by *Cylindrocladium clavatum* in central Brazil. *Plant Disease* **70**: 977–980.

El-Gholl NE, Alfenas AC, Crous PW, Schubert TS (1993a). Description and pathogenicity of *Cylindrocladium ovatum* sp. nov. *Canadian Journal of Botany* **71**: 466–470.

El-Gholl NE, Alfenas AC, Junghans, DT, Schubert TS, Miller JW, Leahy EM (1997). Description of *Calonectria rumohrae* sp. nov. (anamorph = *Cylindrocladium rumohrae* sp. nov.) *Mycotaxon* **64**: 467–484.

El-Gholl NE, Alfieri SA, Barnard EL (1993b). Description and pathogenicity of *Calonectria clavata* sp. nov. *Mycotaxon* **48**: 201–216.

El-Gholl NE, Kimbrough JW, Barnard EL, Alfieri SA, Schoulties CL (1986). *Calonectria spathulata* sp. nov. *Mycotaxon* **26**: 151–164.

El-Gholl NE, Leahy RM, Schubert TS (1989). *Cylindrocladium leucothoeae* sp. nov. *Canadian Journal of Botany* **67**: 2529–2532.

El-Gholl NE, Uchida JY, Alfenas AC, Schubert T S, Alfieri SA, Chase AR (1992). Induction and description of perithecia of *Calonectria spathiphylli* sp. nov. *Mycotaxon* **45**: 285–300.

Fawcett HS, Klotz LJ (1937). A new species of *Candelospora* causing decay of citrus fruit. *Mycologia* **29**: 207–215.

Fitzell RD, Peak CM (1992). Field evaluation of benomyl to control *Cylindrocladium* fruit spot of custard apple. *Australasian Plant Pathology* **21**: 16–17.

Foster SJ, Monahan BJ, Bradshaw RE (2006). Genomics of the filamentous fungi – moving from the shadow of the baker's yeast. *Mycologist* **20**: 10–14.

French DW, Menge JA (1978). Survival of *Cylindrocladium floridanum* in naturally and artificially infested forest tree nurseries. *Plant Disease Reporter* **62**: 806–810.

Gadgil PD, Dick MA (2004). Fungi silvicolae novazelandiae: 5. *New Zealand Journal of Forestry Science* **34**: 316–323.

Galagan JE, Calvo SE, Borkovich KA, Selker EU, Read ND, *et al.* (2003). The genome sequence of the filamentous fungus *Neurospora crassa*. *Nature* **422**: 859–868.

Gams W (1991). What are names in current use? *Mycotaxon* **40**: 319–322.

Gill DL, Alfieri SA, Sobers EK (1971). A new leaf disease of *Ilex* spp. caused by *Cylindrocladium avesiculatum* sp. nov. *Phytopathology* **61**: 58–60.

Goffeau A, Barrell BG, Bussey H, Davis RW, Dujon B, *et al.* (1996). Life with 6000 genes. *Science* **274**: 546–567.

Graves AH (1915). Root rot of coniferous seedlings. *Phytopathology* **5**: 213–217.

Grünwald NJ, Goodwinj SB, Milgroom MG, Fry WE (2003). Analysis of genotypic diversity data for populations of microorganisms. *Phytopathology* **93**: 738–746.

Harrington TC, Rizzo DM (1999). Defining species in the fungi. In: *Structure and Dynamics of Fungal Populations.* (Worrall JJ, ed.). Kluwer Academic Press, Dordrecht: 43–70.

Hawksworth DL (2004). Limitation of dual nomenclature for pleomorphic fungi. *Taxon* **53**: 596–598.

Hawksworth DL (2005). Two major changes in fungal nomenclature enacted in Vienna. *Mycological Research* **109**: 1061–1062.

Henricot B, Beales P (2003). First record of *Cylindrocladium pauciramosum* on myrtle (*Myrtus communis*) in Portugal. *Plant Pathology* **52**: 420.

Henricot B, Culham A (2002). *Cylindrocladium buxicola*, a new species affecting *Buxus* spp., and its phylogenetic status. *Mycologia* **94**: 980–997.

Hirooka Y, Takeuchi J, Horie H, Natsuaki KT (2008). *Cylindrocladium* brown leaf spot on *Howea belmoreana* caused by *Calonectria ilicicola* (anamorph: *Cylindrocladium parasiticum*) in Japan. *Journal of General Plant Pathology* **74**: 66–70.

Hodges CS, May LC (1972). A root disease of pine, *Araucaria*, and *Eucalyptus* in Brazil caused by a new species of *Cylindrocladium*. *Phytopathology* **62**: 898–901.

Hollowell JE, Shew BB, Beute MK, Abad ZG (1998). Occurrence of pod rot pathogens in peanuts grown in North Carolina. *Plant Disease* **82**: 1345–1349.

Hunter BB, Barnett HL (1978). Growth and sporulation of species and isolates of *Cylindrocladium* in culture. *Mycologia* **70**: 614–635.

Hutton DG, Sanewski GM (1989). *Cylindrocladium* leaf and fruit spot of custard apple in Queensland. *Australasian Plant Pathology* **18**: 15–16.

Hwang SF, Flores G (1987). Effects of *Cylindrocladium gracile*, *Fusarium roseum* and *Plenodomus meliloti* on crown and root rot, foliage yield and winterkill of alfalfa in north-eastern Alberta. *Canadian Plant Disease Survey* **67**: 31–33.

Jauch C (1943). The presence of *Cylindrocladium scoparium* in Argentina. *Revista Argentina de Agronomia* **10**: 355–360.

Jayasinghe CK, Wijesundera RLC (1996). Morphological, cultural and pathogenic variation among the clove isolates of *Cylindrocladium quinqueseptatum*. *Journal of Plantation Crops* **24**: 34–42.

Jeng RS, Dumas M, Liu FH, Wang CL, Hubbes M (1997). DNA analysis of *Cylindrocladium floridanum* isolates from selected forest nurseries. *Mycological Research* **101**: 285–291.

Johnson GI (1985). Occurrence of *Cylindrocladium crotalariae* on peanut (*Arachis hypogaea*) seed. *Plant Disease* **69**: 434–436.

Kang JC, Crous PW, Old KM, Dubzinski MJ (2001a). Non-conspecificity of *Cylindrocladium quinqueseptatum* and *Calonectria quinqueseptata* based on a β-tubulin gene phylogeny and morphology. *Canadian Journal of Botany* **79**: 1241–1247.

Kang JC, Crous PW, Schoch CL (2001b). Species concepts in the *Cylindrocladium floridanum* and *Cy. spathiphylli* complexes (*Hypocreaceae*) based on multi-allelic sequence data, sexual compatibility and morphology. *Systematic and Applied Microbiology* **24**: 206–217.

Kim KD, Russin JS, Snow JP (1998). Susceptibility to *Calonectria ilicicola* in soybean grown in greenhouse and field. *Korean Journal of Crop Science* **43**: 239–244.

Kohn LM (2005). Mechanisms of fungal speciation. *Annual Review of Phytopathology* **43**: 279–308.

Krausz JP, Caldwell JD (1987). *Cylindrocladium* root rot of kiwifruit. *Plant Disease* **71**: 374–375.

Kupfer DM, Reece CA, Clifton SW, Roe BA, Prade RA (1997). Multicellular ascomycetous fungal genomes contain more than 8000 genes. *Fungal Genetics and Biology* **21**: 364–372.

Lane CR, Beales PA, Henricot B, Holden A (2006). First record of *Cylindrocladium pauciramosum* on *Ceanothus* in the UK. *Plant Pathology* **55**: 582.

Leahy RM, Schubert TS, El-Gholl NE (2000). *Cylindrocladium gordoniae* sp. nov. *Mycotaxon* **76**: 77–83.

Leslie JF, Klein KK (1996). Female fertility and mating type effects on effective population size and evolution in filamentous fungi. *Genetics* **144**: 557–567.

Liolios K, Mavromatis K, Tavernarakis N, Kyrpides NC (2008). The Genome On Line Database (GOLD) in 2007: status of genomic and metagenomic projects and their associated metadata. *Nucleic Acids Research* **36**: D475–D479.

Linde CC, Zhan J, McDonald BA (2002). Population structure of *Mycosphaerella graminicola*: from lesions to continents. *Phytopathology* **92**: 946–955.

Lombard L, Rodas CA, Crous PW, Wingfield BD, Wingfield MJ (2009). *Calonectria* (*Cylindrocladium*) species associated with dying *Pinus* cuttings. *Persoonia* **23**: 41–47.

Lombard L, Zhou XD, Crous PW, Wingfield BD, Wingfield MJ (2010). *Calonectria* species associated with cutting rot of *Eucalyptus*. *Persoonia* **24**: 1–11.

Massey LM (1917). The crown canker disease of rose. *Phytopathology* **7**: 408–417.

Mayden RL (1997). A hierarchy of species concepts: the denouement in the saga of the species problem. In: *Species: The units of Biodiversity* (Claridge MF, Dawah HA, Wilson MR, eds).Chapman & Hall, U.K.: 381–424.

McDonald BA (1997). The population genetics of fungi: tools and techniques. *Phytopathology* **87**: 448–453.

McNeill J, Stuessy TF, Turland NJ, Hörandl E (2005). XVII International Botanical Congress: preliminary mail vote and report of Congress action on nomenclature proposals. *Taxon* **54**: 1057–1064.

Milholland RD (1974). Stem and root rot of blueberry caused by *Calonectria crotalariae*. *Phytopathology* **64**: 831–834.

Mohanan C, Sharma JK (1985). *Cylindrocladium* causing seedling diseases of Eucalyptus in Kerala, India. *Transactions of the British Mycological Society* **84**: 538–539.

Morgan AP (1892). Two new genera of hyphomycetes. *Botanical Gazette* **17**: 190–192.

Neubauer C, Zinkernagel V (1995). *Calonectria morganii* (Crous, Alfenas and Wingfield), the sexual stage of *Cylindrocladium scoparium* Morgan. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* **102**: 323–325.

Nishijima WT, Aragaki M (1973). Pathogenicity and further characterization of *Calonectria crotalariae* causing collar rot of papaya. *Phytopathology* **63**: 553–558.

Old KM, Wingfield MJ, Yuan ZQ (2003). A manual of diseass of eucalypts in South – East Asia. Center for International Forestry Research, Jakarta, Indonesia. Pp. 98.

Ooka JJ, Uchida JY (1982). *Cylindrocladium* root and crown rot of alfalfa in Hawaii. *Plant Disease* **66**: 947–948.

Overmeyer C, Lünneman S, Wallburnn C von, Meinhardt F (1996). Genetic variability among isolates and sexual offspring of the plant pathogenic fungus *Calonectria morganii* on the basis of random amplification of polymorphic DNA (RAPD) and restriction fragment length polymorphism (RFLP). *Current Microbiology* **33**: 249–255.

Park RF, Keane PJ, Wingfield MJ, Crous PW (2000). Fungal diseases of eucalypt foliage. In: *Diseases and pathogens of eucalypts*. (Keane PJ, Kile GA, Podger FD, Brown BN, eds). CSIRO publishing, Australia: 153–239.

Payne GA, Nierman WC, Wortman JR, Pritchard BL, Brown D, *et al.* (2006). Whole genome comparison of *Aspergillus flavus* and *A. oryzae*. *Medical Mycology* **44**: S9–S11.

Peerally A (1973). *Calonectria colhounii* sp. nov., a common parasite of tea in Mauritius. *Transactions of the British Mycological Society* **61**: 89–93.

Peerally A (1991a). The classification and phytopathology of *Cylindrocladium* species. *Mycotaxon* **40**: 323–366.

Peerally A (1991b). *Cylindrocladium hawksworthii* sp. nov. pathogenic to water-lilies in Mauritius. *Mycotaxon* **40**: 367–376.

Pérez-Sierra A, Alvarez LA, Henricot B, Garcia-Jimenez J, Armengol J (2006). *Cylindrocladium pauciramosum* causes root and collar rot of *Polygala myrtifolia* in Spain. *Plant Pathology* **55**: 298.

Pérez-Sierra A, Alvarez LA, Leon M, Abad-Campos P, Armengol J, Garcia-Jimenez J (2007). First report of leaf spot, blight and stem lesions caused by *Cylindrocladium pauciramosum* on *Callistemon* in Spain. *Plant Disease* **91**: 1057.

Phipps PM, Beute MK, Barker KR (1976). An elutriation method for quantitative isolation of *Cylindrocladium crotalariae* microsclerotia from peanut field soil. *Phytopathology* **66**: 1255–1259.

Polizzi G (2000). Prime esperience di lotta chimica nei confrontidel marciume del colletto e delle radici di *Polygala myrtifolia* causato da *Cylindrocladium pauciramosum*. *Informatore Fitopatologico* **11**: 39–47.

Polizzi G, Crous PW (1999). Root and collar of milkwort caused by *Cylindrocladium pauciromosum*, a new record for Europe. *European Journal of Plant Pathology* **105**: 407–411.

Polizzi G, Grasso FM, Vitale A, Aiello D (2007b). First occurrence of *Calonectria* leaf spot on mexican blue palm in Italy. *Plant Disease* **91**: 1057.

Polizzi G, Vitale A, Aiello D, Castello I, Guarnaccia V, Parlavecchio G (2009). First record of crown and root rot caused by *Cylindrocladium pauciramosum* on brush cherry in Italy. *Plant Disease* **93**: 547.

Polizzi G, Vitale A, Aiello D, Dimartino MA, Parlavecchio G (2007a). First report of damping-off and leaf spot caused by *Cylindrocladium scoparium* on different accessions of bottlebrush cuttings in Italy. *Plant Disease* **91**: 769.

Polizzi G, Vitale A, Aiello D, Parlavecchio G (2006a). First record of crown and root rot caused by *Cylindrocladium pauciramosum* on California lilac in Italy. *Plant Disease* **90**: 1459.

Polizzi G, Vitale A, Castello I, Groenewald JZ, Crous PW (2006b). Cylindrocladium leaf spot, blight and crown rot, new diseases of mastic tree seedlings caused by *Cylindrocladium scoparium*. *Plant Disease* **90**: 1110.

Poltronieri LS, Silva JF da, Alfenas AC, Zauza EAV, Trindade DR (2004). *Eugenia brachypoda*, new host of *Cylindrocladium pteridis* in the State of Pará, Brazil. *Fitopatologia Brasileira* **29**: 102–103.

Porter DM, Wright FS, Taber RA, Smith DH (1991). Colonization of peanut seed by *Cylindrocladium crotalariae. Phytopathology* **81**: 896–900.

Prade RA (1998). Fungal genomics – one per week. *Fungal Genetics and Biology* **25**: 76–78.

Risède J-M (1994). Partial characterization of *Cylindrocladium* sp., a root pathogen of banana in Martinique. *Fruits* (Paris) **49**: 167–178.

Risède J-M, Simoneau P (2001). Typing *Cylindrocladium* species by analysis of ribosomal DNA spacers polymorphism: application to field isolates from the banana rhizosphere. *Mycologia* **93**: 494–504.

Risède J-M, Simoneau P (2004). Pathogenic and genetic diversity of soilborne isolates of *Cylindrocladium* from banana cropping systems. *European Journal of Plant Pathology* **110**: 139–154.

Robert V, Stegehuis G, Stalpers J (2005). The MycoBank engine and related databases. http://www.mycobank.org

Rodas CA, Lombard L, Gryzenhout M, Slippers B, Wingfield MJ (2005). Cylindrocladium blight of *Eucalyptus grandis* in Colombia. *Australasian Plant Pathology* **34**: 134–149.

Rogerson CT (1970). The Hypocrealean fungi (*Ascomycetes, Hypocreales*). *Mycologia* **62**: 865–910.

Rossman AY (1979a). *Calonectria* and its type species, *C. daldiniana*, a later synonym of *C. pyrochroa*. *Mycotaxon* **8**: 321–328.

Rossman AY (1979b). A preliminary account of the taxa described in *Calonectria*. *Mycotaxon* **8**: 485–558.

Rossman AY (1983). The phragmosporous species of *Nectria* and related genera. *Mycological Papers* **150**: 1–164.

Rossman AY (1993). Holomorphic hypocrealean fungi: Nectria sensu stricto and telemorphs of *Fusarium*. In: *The fungal holomorph: mitotic, meiotic and pleomorphic speciation in fungal systematics.* (Reynolds DR, Taylor JW, eds.). CAB International, Wallingford, U.K.: 149–160.

Rossman AY (1996). Morphological and molecular perspectives on systematics of the *Hypocreales*. *Mycologia* **88**: 1–19.

Rossman AY, Samuels GJ, Rogerson CT, Lowen R (1999). Genera of *Bionectriaceae, Hypocreaceae* and *Nectriaceae* (*Hypocreales, Ascomycetes*). *Studies in Mycology* **42**: 1–248.

Rowe RC, Beute MK (1975). Variability in virulence of *Cylindrocladium crotalariae* isolates on peanut. *Phytopathology* **65**: 422–425.

Rowe RC, Beute MK, Wells JC (1973). *Cylindrocladium* black rot of peanuts in North Carolina – 1972. *Plant Disease Reporter* **57**: 387–389.

Schoch CL, Crous PW (1999). First report of *Cylindrocladium* root and petiole rot on *Spathiphyllum* in South Africa. *South African Journal of Botany* **65**: 67–72.

Schoch CL, Crous PW, Polizzi G, Koike ST (2001a). Female fertility and single nucleotide polymorphism comparisons in *Cylindrocladium pauciramosum*. *Plant Disease* **85**: 941–946.

Schoch CL, Crous PW, Wingfield BD, Wingfield MJ (1999). The *Cylindrocladium candelabrum* species complex includes four distinct mating populations. *Mycologia* **91**: 286–298.

Schoch CL, Crous PW, Wingfield BD, Wingfield MJ (2001b). Phylogeny of *Calonectria* based on comparisons of β-tubulin DNA sequences. *Mycological Research* **105**: 1045–1052.

Schoch CL, Crous PW, Cronwright G, Witthuhn RC, El-Gholl NE, Wingfield BD (2000a). Recombination in *Calonectria morganii* and phylogeny with other heterothallic small-spored *Calonectria* species. *Mycologia* **92**: 665–673.

Schoch CL, Crous PW, Wingfield MJ, Wingfield BD (2000b). Phylogeny of *Calonectria* and selected hypocrealean genera with cylindrical macroconidia. *Studies in Mycology* **45**: 45–62.

Schoulties CL, El-Gholl NE, Alfieri SA (1982). *Cylindrocladium spathiphylli* sp. nov. *Mycotaxon* **16**: 265–272.

Schubert TS, El-Gholl NE, Alfieri SA, Schoulties CL (1989). *Calonectria avesiculata* sp. nov. *Canadian Journal of Botany* **67**: 2414–2419.

Seifert KA, Gams W, Crous PW, Samuels GJ (2000). Molecules, morphology and classification: Towards monophyletic genera in the Ascomycetes. *Studies in Mycology* **45**: 1–4.

Sepiah M (1990). New storage disease of guava fruit caused by *Cylindrocladium scoparium*. *Plant Disease* **74**: 253.

Sharma JK, Mohanan C (1982). *Cylindrocladium* spp. associated with various diseases of *Eucalyptus* in Kerala. *European Journal of Forest Pathology* **12**: 129–136.

Sharma JK, Mohanan C, Maria Florence EJ (1984). Nursery diseases of *Eucalyptus* in Kerala. *European Journal of Forest Pathology* **14**: 77–89.

Sharma JK, Mohanan C, Maria Florence EJ (1985). Disease survey in nurseries and plantations of forest tree species grown in Kerala. Kerala *Forest Research Institute, Research Report* **36**: 1–268.

Sharma JK, Mohanan C, Rugimini P (1992). Cultural characters and growth of *Cylindrocladium quinqueseptatum* isolates. *European Journal of Forest Pathology* **22**: 217–226.

Sivapalan A, Metussin R, Hamdan F, Zain RM (1998). Fungi associated with postharvest fruit rots of *Durio graveolens* and *D. kutejensis* in Brunei Darussalam. *Australasian Plant Pathology* **27**: 274–277.

Sobers EK, Littrell RH (1974). Pathogenicity of three species of *Cylindrocladium* to select hosts. *Plant Disease Reporter* **58**: 1017–1019.

Sobers EK, Seymour CP (1967). *Cylindrocladium floridanum* sp. nov. associated with decline of peach trees in Florida. *Phytopathology* **57**: 389–393.

Stevens C, Palmer MA, McRoberts RE (1990). Use of aminopeptidase substrate specificities to identify species of *Cylindrocladium* in Wisconsin nurseries. *Mycologia* **82**: 436–443.

Taniguchi T, Tanaka C, Tamai S, Yamanaka N, Futai K (2008). Identification of *Cylindrocladium* sp. causing damping-off disease of Japanese black pine (*Pinus thunbergii*) and factor affecting the disease severity in a black locust (*Robinia pseudoacacia*)-dominated area. *Journal of Forest Research* **13**: 233–240.

Taylor JW, Jacobson DJ, Fisher MC (1999). The evolution of asexual fungi: Reproduction, speciation and classification. *Annual Review of Phytopathology* **37**: 197–246.

Taylor JW, Jacobson DJ, Kroken SM, Kasuga T, Geiser DM, Hibbett DS, Fisher MC (2000). Phylogenetic species recognition and species concepts in fungi. *Fungal Genetics and Biology* **31**: 21–32.

Terashita T (1968). A new species of *Calonectria* and its conidial state. *Transactions of the Mycological Society of Japan* **8**: 124–129.

Terashita T, Itô K (1956). Some notes on *Cylindrocladium scoparium* in Japan. *Bulletin of the Forestry Experiment Station Tokyo* **87**: 33–47.

Tubaki K (1958). Studies on Japanese Hyphomycetes. 5. Leaf & stem group with a discussion of the classification of Hyphomycetes and their perfect stages. *Journal of Hattori Botanical Laboratory* **20**: 142–144.

Uchida JY, Kadooka CY (1997). Blight of leatherfern caused by *Calonectria theae*, and *Cylindrocladium* spp. *Phytopathology* **87**: S98–S99.

Vaidya P, Rao VG (1992). Three undescribed post-harvest diseases of fruits from Maharashtra. *Journal of Economic and Taxonomic Botany* **16**: 241–244.

Varon AF de (1991). *Cylindrocladium scoparium* associated with drying up and early death of soybean plants. *Fitopatologia Colombiana* **15**: 2–7.

Victor D, Crous PW, Janse BJH, Wingfield MJ (1997). Genetic variation in *Cylindrocladium floridanum* and other morphologically similar *Cylindrocladium* species. *Systemic and Applied Microbiology* **20**: 268–285.

Vitale A, Aiello D, Castello I, Dimartino MA, Parlavecchio G, Polizzi G (2009). Severe outbreak of crown rot and root rot caused by *Cylindrocladium pauciramosum* on strawberry tree in Italy. *Plant Disease* **93**: 842.

Vitale A, Aiello D, Castello I, Parlavecchio G, Polizzi G (2008). First report of crown rot and root rot caused by *Cylindrocladium pauciramosum* on Feijoa (*Feijoa settowiana*) in Italy. *Plant Disease* **92**: 1590.

Vitale A, Polizzi G (2007). First record of the perfect stage *Calonectria pauciramosa* on mastic tree in Italy. *Plant Disease* **91**: 328.

Vitale A, Polizzi G (2008). First record of leaf spots and stem lesions on *Pistacia lentiscus* caused by *Cylindrocladium pauciramosum* and *C. scoparium* in Italy. *Plant Pathology* **57**: 384.

Wiapara NW, Di Menna ME, Cole ALJ, Skipp RA (1996). Pathogenicity of *Cylindrocladium scoparium* to pasture clover and grass species. *Australasian Plant Pathology* **25**: 205–211.

Wolf FA (1926). Brown leaf spot of leather fern. *Journal of the Elisha Mitchell Scientific Society* **42**: 55–62.

Wormald H (1944). A *Cylindrocladium* as the cause of a shoot wilt of varieties of plum and cherry used for rootstocks. *Transactions of the British Mycological Society* **27**: 71–80.

Wright LP, Wingfield BD, Crous PW, Brenneman T, Wingfield MJ (2006). Isolation and characterization of microsatellite loci in *Cylindrocladium parasiticum*. *Molecular Ecology Notes* **6**: 110–112.

Wright LP, Wingfield BD, Crous PW, Wingfield MJ (2007). Isolation and characterization of microsatellite loci in *Cylindrocladium pauciramosum. Molecular Ecology Notes* **7**: 343–345.

Yoder OC, Turgeon BG (2001). Fungal genomics and pathogenicity. *Current Opinion in Plant Biology* **4**: 315–321.