Review paper

The Genera *Cylindrocladium* and *Cylindrocladiella* in South Africa, with Special Reference to Forest Nurseries

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SYNOPSIS

Species of *Cylindrocladium* and *Cylindrocladiella* are widely distributed throughout the world and are known to be important pathogens of numerous angiosperm and gymnosperm hosts. Several species are notorious pathogens in nurseries, and have frequently been found on tree genera such as *Eucalyptus*, *Pinus* and *Acacia*. This paper provides a review of current knowledge, identifies areas of future research, and outlines the importance of *Cylindrocladium* and *Cylindrocladiella* in South African forestry.

INTRODUCTION

The genus *Cylindrocladium* was erected in 1892 by Morgan, with *C. scoparium* Morgan as the type. This species was found on a dead pod of honey locust (*Gleditschia triacanthos* L.) in Ohio (Morgan, 1892). Subsequently, Graves (1915) isolated the same fungus from roots of *Pinus strobus* L., *P. resinosa* Ait. and *Tsuga canadensis* L. but failed to induce symptoms through artificial inoculations. He, therefore, assumed it to be saprophytic. Massey (1917) and Anderson (1919) were the first to show that *C. scoparium* could cause disease. Jackson (1938) associated this fungus with damping-off, root rot and crown canker of several conifer species. The fungus has subsequently been found to be a devastating pathogen of numerous hosts (Cox, 1953; Bugbee and Anderson, 1963a, 1963b; Bertus, 1976a, 1976b). Gibson (1975) concluded that *C. scoparium* is probably one of the most serious nursery pathogens of eucalypts at all growth stages. At that time it had however not been noticed on African *Eucalyptus* stock.

Boesewinkel (1982a) selected several small-spored species in the genus *Cylindrocladium* (*C.*), and placed them in a new genus, *Cylindrocladiella* Boesewinkel (*Ca.*) . This genus currently comprises five species (Boesewinkel, 1982a, 1982b), three of which have been reported as pathogens of *Eucalyptus* (Batista *et al.*, 1965; Sharma and Mohanan, 1982; Mohanan and Sharma, 1985a).

At present, approximately 33 *Cylindrocladium* spp. have been described (Boedijn and Reitsma, 1950; Alfieri *et al.*, 1970; Gill *et al.*, 1971; Panwar and Bohra, 1974; Hunter and Barnett, 1978; Schoulties *et al.*, 1982; El-Gholl *et al.*, 1986, 1989), 12 of which are pathogenic to *Eucalyptus* (Peerally, 1974a, 1974b; Almeida and Bolkan, 1981a; Sharma and Mohanan, 1982; Mohanan and Sharma, 1985a; El-Gholl, *et al.*, 1986). Only one *Cylindrocladium* sp., *C. scoparium*, has been reported from *Eucalyptus* in South Africa (Lundquist and Baxter, 1985). Additional local hosts for *C. scoparium* include *Acacia* spp. (Doidge, 1950; Hagemann and Rose, 1988), *Persea americana* Mill. (Darvas, 1978), *Medicago truncatula* Gaertn. (Lamprecht, 1986) and *Syncarpia glomulifera* (Smith) Niedz. (PREM 45419). Darvas *et al.* (1978) found *C. scoparium* and *Ca. parva* (Anderson) Boesewinkel to be pathogenic on pines. The latter fungus was subsequently found on roots of avocado (Darvas, 1978), *Protea aurea* (N.L. Burm.) Rourke (PREM 45440) and has recently been isolated by us from roots of *Acacia mearnsii* de Wild, *Pinus radiata* D. Don. and forest litter. Although Sharma and Mohanan (1982) reported *Ca. parva* as pathogenic to *Eucalyptus*, we have found it growing saprophytically on *Eucalyptus* leaf litter. These observations support similar findings that, under certain conditions, *Cylindrocladium* spp. can occur as saprophytes (Boedijn and Reitsma, 1950; French and Menge, 1978).

The genera *Cylindrocladium* and *Cylindrocladiella* are hardly known in South Africa. Preliminary surveys have, however, indicated that a number of species occur in this country, and that they are potentially important pathogens of various plants, especially *Eucalyptus* spp. No previous review of information pertaining to the two genera has been published. Therefore, this paper reviews current knowledge of *Cylindrocladium* and *Cylindrocladiella* and considers their importance in forest nurseries in South Africa. Future areas of research on the pathogenic species are also outlined.

TAXONOMY AND MORPHOLOGICAL CHARACTERISTICS

Cylindrocladium, together with other closely related genera such as *Cylindrocladiella*, *Gliocladium* Corda, *Cylindrocarpon* Wollemw. and *Fusarium* Link: Fr. are

grouped in the order *Hypocreales*. *Cylindrocladium* has a *Calonectria* de Not. teleomorph, while the latter genera have *Nectria* Fr. states (Booth, 1966; Rossman, 1979a, 1979b, 1983).

Apart from cultural characteristics, the main criteria on which identifications of *Cylindrocladium* and *Cylindrocladiella* species are based include conidial dimensions and septation, shape and size of the vesicle, characteristics of the stipe, phialides, branching habit and individual branch dimensions. Species differentiation is complicated because of plasticity of the fungus on different media and under various environmental conditions (Zumpetta, 1976; Hunter and Barnett, 1978).

Cylindrocladium is characterised by having species with hyaline, cylindrical conidia, 1–7 (or more) septate, with obtuse ends (Hunter and Barnett, 1978), mostly encased in an irregular mucilaginous matrix. Conidia form on monophialides, which occur singly or in groups of up to five on penicillate branches of the conidiophore. These branches arise laterally from central or lateral specialised hyphae, referred to as the stipe, being septate, branched or unbranched, giving rise to a fertile, terminal, thin-walled structure of characteristic shape, called the vesicle. Chlamydospores occur in clusters and form microclerotia in soil, debris, host tissue and culture media.

Cylindrocladiella is, at present recognised by having small, cylindrical 0–1 septate spores, borne on monophialides. Conidiophores can either be subverticillate or penicillate. In the latter case the branches are usually arranged around a central stipe, which is non-septate, but separated from a basal cell by a septum. A thin-walled vesicle is formed at its apex, and this can develop a septum with age. Chlamydospores are more frequently arranged in chains than in clusters (Boesewinkel, 1982a).

COMMONLY ACCEPTED SPECIES

Both *C. scoparium* and *Ca. parva* occur in forestry regions of the Cape, Transvaal and Natal. Although various other species have been found in South Africa, they will be dealt with in a subsequent study. Species described in *Cylindrocladium* and *Cylindrocladiella* have been found to have a wide geographic distribution and host range (*Tables 1* and *2*).

TABLE 1. Host range, geographic distribution, symptoms and literature pertaining to Cylindrocladium *spp.*

Fungus	Geographic distribution	Hosts	*Eucalyptus* spp.	Symptoms	References on control	General references
Cylindrocladium avesiculatum Gill, Alfieri & Sobers Teleomorph: *Calonectria avesiculata* Schubert, El-Gholl, Alfieri & Schoulties	Georgia, Florida, USA	*Ilex* spp., *Rhododendron obtusum* *Pyranchanta coccinea*		Leaf spot, twig die-back, defoliation		Gill, Alfieri & Sobers, 1971; Schubert, El-Gholl, Alfieri & Schoulties, 1989; Sobers & Alfieri, 1972
Cylindrocladium brassicae Panwar & Bohra	India	*Brassica camprestis*		Not given		Panwar & Bohra, 1974
Cylindrocladium braziliensis (Batista & Ciferri) Peerally Synonym: *C. scoparium* Morgan var. *braziliensis* Batiste & Ciferri	Brazil	*Eucalyptus* spp.	*E. alba*, *E. citriodora*, *E. grandis*, *E. saligna*	Damping-off, die-back of adult trees		Batista, 1951; Peerally, 1974g
Cylindrocladium candelabrum Viegas	Brazil	*Annona* sp., *Luma* sp.		Leaf spot		Viegas, 1946
Cylindrocladium citri (Fawcett & Klotz) Boedijn & Reitsma Synonym: *Candelspora citri* Fawcett & Klotz	Florida, USA	*Citrus sinensis*		Fruit decay		Boedijn & Reitsma, 1950; Fawcett & Klotz, 1937; Schoulties, El-Gholl & Alfieri, 1982

TABLE 1. Host range, geographic distribution, symptoms and literature pertaining to Cylindrocladium *spp.* (Contd)

Fungus	Geographic distribution	Hosts	*Eucalyptus* spp.	Symptoms	References on control	General references
Cylindrocladium clavatum Hodges & May	Brazil, India, Mauritius	*Arachis hypogaea*, *Araucaria agustifolia*, *Capsinum frutescens*, *Cicer arietinum*, *Eucalyptus* spp., *Glycine max*, *Pinus caribaea*, *P. elliottii* *P. insularis*, *P. mochoacana*, *P. montesumae*, *P. oocarpa*, *P. palustris*, *P. patula*, *Pisum sativum*, *Solanum tuberosum*	*E. cloeziana*, *E. grandis*, *E. microcorys*, *E. paniculata*, *E. saligna*, *E. tereticornis*	Root rot, seedling and shoot blight, stem canker, leaf spot	Hodges & May, 1971; Rattan & Dhanda, 1985; Rattan, Dhanda & Rhandhawa, 1983	Almeida & Bolkan 1981b; Bolkan, Dianese, Ribeiro & Almeida, 1980; Bolkan, Ribeiro & Almeida, 1981; Dianese, Ribeiro & Urben, 1986; Dianese, Ribeiro, Sharma, Ferreira & Urban, 1987; Hodges, Reis & May, 1976; Hodges, Reis & May, 1976; Lopes & Reifschneider, 1982; Mohanan & Sharma, 1985a, 1986; Ooka & Uchida, 1982; Peerally, 1974b.
Cylindrocladium colhounii Peerally Teleomorph: *Calonectria colhounii* Peerally	Australia, India Mauritius	*Annona reticulata*, *Callistemon lanceolatus*, *Canavalia ensiformis*, *Camellia sinensis*, *Eucalyptus* sp.	*E. robusta*	Leaf spot, fruit rot		Hutton & Sanewski, 1989; Peerally, 1973; Peerally 1974j; Sidderamaiah, 1988
Cylindrocladium crotalariae (Loos) Bell & Sobers Synonyms: *Candelospora theae* (Petch) Wakefield: Gadd var. *crotalariae* Loos; *Cercosporella theae* Petch Teleomorph: *Calonectria crotalariae* (Loos) Bell & Sobers Synonym: *Calonectria theae* Loos var. *crotalariae* Loos	Brazil, Sri Lanka, Florida, Georgia, Hawaii, USA	*Acacia* sp., *Arachis* sp., *Carica* sp., *Eucalyptus* spp., *Glycine max* *Liriodendron* sp., *Tephrosia* sp. *Vaccinium* sp.	*E. camaldulensis*, *E. citriodora*, *E. grandis*, *E. punctata*, *E. robusta*, *E. rudis*, *E. saligna*, *E. sideroxylon*, *E. tereticornis*	Root rot, leaf spot, blighting	Pataky, Black, Hollowell & Beute, 1984; Porter & Mozingo, 1986; Sidebottom & Beute, 1989a, 1989b	Alfenas, Matsuoka, Ferreira & Hodges, 1979; Aragaki, Laemmlen & Nishijima, 1972; Bell, 1967; Bell & Sobers, 1966; Black, Pataky & Beute, 1984; Diomande, Black, Harris & Beute, 1980; Filer, 1970; Griffin, 1977; Griffin, Roth & Powell, 1978; Hadley, Beute & Leonard, 1979; Harris & Beute, 1982; Hau, Campbell & Beute, 1982; Hwang & Ko, 1975; Johnson, 1985; Krigsvold, 1979; Krigsvold, Griffin & Hale, 1982; Kuhlman, Cordell & Filer, 1980; Milholland, 1974; Nishijima & Aragaki, 1973; Oak & Triplett, 1985; Peerally, 1974i; Phipps, Beute & Barker, 1976; Rowe & Beute, 1975; Rowe, Beute & Wells, 1973; Rowe, Beute, Wells & Wynne, 1974; Sobers & Alfieri, 1972; Sobers & Littrell, 1974; Tomimatsu & Griffin, 1982; Tomimatsu & Griffin, 1988

TABLE 1. Host range, geographic distribution, symptoms and literature pertaining to Cylindrocladium *spp.* (Contd)

Fungus	Geographic distribution	Hosts	*Eucalyptus* spp.	Symptoms	References on control	General references
Cylindrocladium curvatum Boedijn & Reitsma	Bogor, Kerala, India	*Hibiscus* sp., *Eucalyptus* spp.	*E. grandis*, *E. tereticornis*	Leaf spot, root rot		Boedijn & Reitsma, 1950; Sharma, Mohanan & Maria Florence, 1985
Cylindrocladium ellipticum Alfieri, Seymour & Sobers	Florida, USA	*Mahonia bealei*, *Rhododendrom indicum*		Leaf spot		Alfieri, Seymour & Sobers, 1970
Cylindrocladium floridanum Sobers & Seymour Teleomorph: *Calonectria kyotensis* Terashita Synonyms: *C. uniseptata* Gerlach: *C. floridana* Sobers	Brazil, England, Germany, India, Japan, Mauritius, New Zealand, Florida, USA	*Acacia dealbata* *Callistemon* spp., *Crotalaria* sp., *Eucalyptus* spp., *Glycine max*, *Fragariae* sp., *Liriodendrom* sp., *Pinus* spp. and others (see reference	*E. camaldulensis* *E. grandis* *E. robusta* *E. rudis* *E. saligna* *E. tereticornis*	Leaf spot, root rot, wilt	Cordell, Juttner & Stambaugh, 1971; French & Menge, 1978; Menge & French, 1976; Weaver, 1971a, 1971b	Boesewinkel, 1974; Cordell & Skilling, 1975; Ferreira, 1989; Forsberg, 1985; Gerlach, 1968; Kuhlman, Cordell & Filer, 1980; Peerally, 1974a; Sharma & Mohanan, 1982; Sobers, 1969, 1972; Sobers & Seymour, 1967; Terashita, 1968; Truscott, 1934
Cylindrocladium hederae (Arn.) Peerally Synonym: *C. macrosporum* Sherb, var. *hederae* Arn. *Teleomorph: Calonectria hederae* Booth & Murray	England, France	*Hedera* sp.		Leaf spot, root rot		Booth & Murray, 1960; Peerally, 1974f
Cylindrocladium heptaseptatum Sobers, Alfieri & Knauss	Brazil, Florida, USA	*Polystichum* sp., *Rumohra* sp.		Leaf spot, stem lesions	Marousky, Risse, Wildt & Dow, 1982; Marousky & Wildt, 1982	Ferreira, 1989; Sobers, Alfieri & Knauss, 1975
Cylindrocladium ilicicola (Hawley) Boedijn & Reitsma Synonym: *Candelospora ilicicola* Hawley *apud* Rea & Hawley Teleomorph: *Calonectria ilicicola* Boedijn & Reitsma	Brazil, Europe, India, Sicily, Florida, USA	Aesculus sp., *Arbutus* sp., *Betula* sp., *Buxus*, sp., *Cissus* sp., *Eucalyptus* spp., *Gaultheria* sp., *Ilex* sp., *Salix* sp.	*E. alba*, *E. globulus*, *E. grandis*, *E. robusta*, *E. saligna*, *E. tereticornis*	Damping-off, leaf and shoot blight, stem canker, dieback		Alfieri, El-Gholl & Schoulties, 1982; Boedijn & Reitsma, 1950; Brayford & Chapman, 1987; Figueiredo & Cruz, 1963; Peerally, 1974e; Rea & Hawley, 1912; Reddy, 1974; Rossman, 1983; Sharma & Mohanan, 1982
Cylindrocladium leucothoes El-Gholl, Leahy & Schubert	Florida, USA	*Leucothoe axillaris*		Leaf spot		El-Gholl, Leahy & Schubert, 1989
Cylindrocladium pteridis Wolf Synonym: *C. macrosporum* Sherb	Brazil, Florida, USA	*Arachis* sp., *Asparagus* sp., *Callistemon* sp., *Chamadorea* sp., *Cocos* sp., *Collinia* sp., *Dryopteris* sp., *Eucalyptus* spp., and others (see references)	*E. camaldulensis*, *E. grandis* *E. robusta* *E. rudis* *E. saligna* *E. tereticornis*	Leaf spot, root rot	Bedendo & Kruger, 1984; Chase, 1984; Marousky & De Wildt, 1982	Sherbakoff, 1928; Sobers, 1967, 1968; Sobers & Alfieri, 1972; Wolf, 1926

TABLE 1. Host range, geographic distribution, symptoms and literature pertaining to Cylindrocladium *spp.* (Contd)

Fungus	Geographic distribution	Hosts	*Eucalyptus* spp.	Symptoms	References on control	General references
Cylindrocladium quinqueseptatum Boedijn & Reitsma Teleomorph: *Calonectria quinqueseptata* Figueiredo & Namekata	Australia, Brazil, India, Indonesia, Malaysia, Mauritius	*Ageratum* sp., *Annona* sp., *Camellis* sp., *Eucalyptus* spp., *Eugenia* sp., *Psidium* sp., and others (see references)	*E. alba*, *E. camaldulensis*, *E. citriodora*, *E. deglupta*, *E. gigantea*, *E. grandis*, *E. pilularis*, *E. tereticornis*, *E. urophylla*	Damping-off, seedling and shoot blight, root rot, leaf blight, stem canker, leaf spot	Sehgal, 1983	Anahosur, Padaganur & Hegde, 1976; Anahosur, Padaganur & Hedge, 1977; Figueiredo & Namekata, 1967; Mohanan & Sharma, 1985a, 1985b, 1986; Peerally, 1974c; Pitkethley, 1976; Sanakaran, Florence & Sharma, 1988; Sharma & Mohanan, 1982, 1988; Sulochana, Wilson & Nair, 1982
Cylindrocladium scoparium Morgan Synonyms: *Diplocladium cylindrosporum* Ell. & Everh.; *Cylindracladium pithecolobii* Petch Teleomorph: *Calonectria scoparia* Ribeiro & Matsuoka	Worldwide	Acacia spp., *Eucalyptus* spp., *Pinus* spp. and others (see references)	Most *Eucalyptus* species are susceptible, see Bertus, 1976a, 1976b	Damping-off, root rot, stem cankers, needle blight, epicormic growth, leaf spot, seedling and shoot blight	Alfenas, Demuner & Da Silva, 1988; Aycock, 1973; Cox, 1953; Engelhard, 1971; Hodges, 1962; Keirle, 1981; Kessler, 1982; Martinez, Cruz & Figueiredo, 1961; Niebisch & Kelling, 1986; Prest, 1988; Roos, 1980; Thies & Patton, 1971	Affeltranger & Burns, 1983; Bazan de Segura, 1970; Boesewinkel, 1986; Bugbee, 1962; Chase, 1984; Cordell & Matuszewski, 1974; Cordell & Rowan, 1975; Cruz & Figueiredo, 1960, 1961; Ellis & Everhart, 1900; Freter & Wilcoxson, 1964; Gibson 1979; Gill, 1979; Grieve, 1931; Kelman & Gooding, 1965; Lentz, 1955; Lundquist, 1986; Mehta & Bose, 1947; Morrison & French, 1969; Ponnappa, Janardhan & Hiremath, 1977; Rattan & Cohan, 1984; Reis, 1966; Ribeiro, 1978; Ross, 1967; Sharma, 1986; Sharma & Mohanan, 1982; Sobers, 1973; Stevens, Palmer & Yang, 1985; Storey, 1964; Timonin & Self, 1955; Upadhyaya & Nirwan, 1979; Wormald, 1944
Cylindrocladium spathiphylli Schoulties, El-Gholl & Alfieri	Florida, USA	*Spathiphyllum* spp.		Root and foliar disease	Chase & Poole, 1987	Schoulties & El-Gholl, 1980; Schoulties, El-Gholl & Alfieri, 1982
Cylindrocladium spathulatum El-Gholl, Kimbrough, Barnard, Alfieri & Schoulties Teleomorph: *Calonectria spathulata* El-Gholl, Kimbrough, Barnard, Alfieri & Schoulties	Brazil	*Eucalyptus* spp.	E. cloeziana, E. grandis, E. viminalis	Leaf spot		El-Gholl, Kimbrough, Barnard, Alfieri & Schoulties, 1986

TABLE 1. Host range, geographic distribution, symptoms and literature pertaining to Cylindrocladium *spp.* (Contd)

Fungus	Geographic distribution	Hosts	*Eucalyptus* spp.	Symptoms	References on control	General references
Cylindrocladium theae (Petch) Subramanian Synonyms: *Cercosporella theae* Petch; *Candelospora theae* (Petch) Wakefield: Gadd; *Cylindrocladium theae* (Petch) Alfieri & Sobers Teleomorph: *Calonectria theae* Loos	Brazil, Ceylon, India, USA	*Acacia* spp., *Albizia* sp., *Camellia* sp., *Eucalyptus* sp.	*E. grandis*	Leaf spot, defoliation, root rot, stem and petiole lesions		Alfieri, Linderman, Morrison & Sobers, 1972; El-Gholl, Schoulties & Alfieri, 1983; Loos, 1950; Mims, Benson & Jones, 1981; Mohanan & Sharma, 1984, 1986; Peerally, 1974d; Petch, 1917; Sharma, Mohanan & Maria Florence, 1985; Subramanian, 1971

TABLE 2. Host range, geographic distribution, symptoms and literature pertaining to Cylindrocladium *spp.*

Fungus	Geographic distribution	Hosts	*Eucalyptus* spp.	Symptoms	References on control	General references
Cylindrocladiella camelliae (Venkatar, *et* Venkata Ram) Boesewinkel Synonym: *Cylindrocladium camelliae* Venkatar, *et* Venkata Ram	Australia, India, New Zealand	*Acacia* spp., *Camellia* sp., *Cinnamomum* sp., *Eucalyptus* spp., *Mangifera* sp., *Myristica* sp., *Theobroma* sp., *Wisteria* sp.	*E. grandis*, *E. tereticornis*	Leaf spot, root rot		Boesewinkel, 1982a, 1982b; Mohanan & Sharma, 1985a; Peerally, 1974h; Rahman, Sankaran, Leelavathy & Zachariah, 1981; Reddy, 1975; Shipton, 1977, 1979; Venkataramani, 1952; Venkataramani & Venkata Ram, 1961.
Cylindrocladiella infestans Boesewinkel	New Zealand, Papua New Guinea	*Pinus pinea*		Root rot		Boesewinkel, 1982a; Matsushima, 1971
Cylindrocladiella novae-zelandiae (Boesew.) Boesewinkel Synonym: *Cylindrocladium novae-zelandiae* Boesewinkel	New Zealand	*Rhododendron indicum*		Root rot		Boesewinkel, 1981, 1982a, 1982b
Cylindrocladiella parva (Anderson) Boesewinkel Synonym: *Cylindrocladium parvum* Anderson	India, Java, New Zealand, South Africa, Massachusetts and Florida, USA	*Camellia* spp., *Eucalyptus* spp., *Macadamia* sp., *Musanga* sp., *Persea* sp., *Pinus radiata*, *Psidium* sp., *Rosa* sp., *Spondias* sp.	E. grandis E. tereticornis	Damping off, seedling blight		Boedijn & Reitsma, 1950; Boesewinkel, 1981, 1982a; 1982b; Darvas, Scott & Kotze, 1978; Mandal & Dasgupta, 1983; Mohanan & Sharma, 1986; Roth & Griffin, 1981; Sobers & Alfieri, 1972; Sharma & Mohanan, 1982
Cylindrocladiella peruviana (Bat., Bez. *et* Herrera) Boesewinkel Synonym: *Cylindrocladium peruvianum* Bat., Bez. *et* Herrera	Brazil	*Eucalyptus* spp.	Not given	Leaf spot		Almeida & Bolkan, 1981a; Batista, Bezerra Maia & Herrera, 1965; Boesewinkel, 1982b

SPECIES OF DUBIOUS VALIDITY

Several *Cylindrocladium* and *Cylindrocladiella* species are incorrectly described or of dubious authenticity. These species are as follows:

Cylindrocladium avesiculatum Gill, Alfieri & Sobers var. *microsporae* Nair & Nair was described in 1983 from roots of cabbage in India (Nair and Nair, 1983). This species is not validly described, owing to the omission of a designated type specimen (International Code of Botanical Nomenclature, Art. 37.1).

Cylindrocladium couratarii Ram & Ram (as *C. couratariae*) was described from wood of *Couratari* in Brazil (Ram and Ram, 1972). Examination of a type culture (ATCC 24711) revealed that it is neither a *Cylindrocladium* nor a *Cylindrocladiella* species.

Cylindrocladium gracile (Bugn.) Boesewinkel and *C. reteaudii* (Bugn.) Boesewinkel were placed in *Cylindrocladium* by Boesewinkel in 1982. Although they are validly described species (Bugnicourt, 1939), they were primarily described as new on the basis of stipe septation (Boesewinkel, 1982b). This criterion alone, is little justification for their establishment as new species.

Cylindrocladium gregarium (Bres.) de Hoog was originally described as *Diplocladium gregarium* Bres. (Bresadola, 1903) and later placed in the genus *Cylindrocladium* (de Hoog, 1978). Although we have as yet not examined this fungus, the explicit illustrations by De Hoog (1978) show a fungus with a branching habit and conidia atypical of *Cylindrocladium* or *Cylindrocladiella*.

Cylindrocladium intermedium Matsushima was described from soil in Papua New Guinea (Matsushima, 1971). The illustration given by Matsushima does not show the vesicle morphology, but based upon conidial septation, branching habit and the presence of collaretts, the genus *Cylindrocladiella* might be more suitable.

Cylindrocladium lanceolatum Peerally was never validly described (Peerally, 1972). An examination of the culture (IMI 167579) revealed it to be a *Gliocladium* sp., whereas the published illustration (Peerally, 1972) shows it to be identical to *Cylindrocladiella camelliae* (Venkatar *et* Venkata Ram) Boesewinkel.

Cylindrocladium musae Semer, Mitchell, Mitchell, Martin & Alfenas was reported as a new species on bananas from Costa Rica, but no valid description was provided (Semer *et al.*, 1987).

Cylindrocladium penicilloides (Tubaki) Tubaki was initially described as a *Candelospora* Hawley species, and later placed in *Cylindrocladium* (Tubaki, 1958). No type material has yet been examined by us, and the culture (CBS 174.55) is sterile.

Cylindrocladium simplex Meyer and *C. simplex* var. *microchlamydosporum* Meyer was described from soil and litter in Zaire (Meyer, 1959). Wiley and Simmons (1971) found that these two species were not representative of *Cylindrocladium*, and placed them in *Gliocephalotrichum* Ellis & Hesseltine.

Cylindrocladium terrestre Roy & Dwivedi was described from soil in India in 1969 (Roy and Dwivedi, 1969). We have not, however, been able to locate a description, type material or a culture of this fungus.

Cylindrocladium spathiphylli Schoulties, El-Gholl & Alfieri f. sp. *heliconia* Aragaki, Yohata & Uchida was isolated from *Heliconia* spp. in Hawaii, and proposed as a new species by Aragaki, Yahata and Uchida (1988). No valid description has yet been published, nor any reference made to type material.

Several other species, lodged at the International Mycological Institute, Surrey, England, have never been described. These are *Ca. mangiferae* Chowhry & Varma (IMI 317057, 317058); *C. angustatum* Peerally (IMI 167578); *C. cacao* Booth (IMI 131072); *C. dixi* Booth (IMI 101,972b); *C. oumaiensis* Peerally (IMI 167983); *C. pini* Andrews (IMI 281445); *C. sclerotiorum* Peerally (IMI 167982); *C. scoparium* var. *mauritiensis* Peerally (IMI 167582) and *C. theobromae* Booth (IMI 108770).

DISEASE SYMPTOMS

1. Damping-off

Sharma *et al.* (1984) found *C. quinqueseptatum* Boedijn & Reitsma, *C. ilicicola* (Hawley) Boedijn & Reitsma, *C. floridanum* Sobers & Seymour and *Ca. parva* to cause post-emergence damping-off of *E. grandis* Hill: Maid. *E. tereticornis* Sm., *E. citriodora* Hook and *E. tessellaris* F. Muell. in Kerala, India. A water-soaked constricted area at soil level which caused the seedlings to collapse within one week of emergence was described. The disease spread more rapidly under water-logged conditions (Sharma *et al.*, 1984). We have found *C. scoparium* to cause damping-off in trays

FIGURE 1. C. scoparium *damping-off of* E. tereticornis *seedlings.*

of *E. grandis*, *E. camaldulensis* Dehnh. and *E. tereticornis* (*Figure 1*). Symptoms occurred in distinct loci and gradually spread radially. *C. scoparium* has also been found to cause damping-off of *Eucalyptus* in Brazil (Batista, 1951; Ferreira, 1989), and Japan (Terashita and Itô, 1956).

2. Seedling blight

Several species, including *C. quinqueseptatum*, *C. ilicicola*, *C. clavatum* Hodges & May, *Ca. parva* and *Ca. camelliae* have been associated with seedling blight of *E. grandis*, *E. tereticornis* and *E. tessellaris* in India (Sharma and Mohanan, 1982; Sharma *et al.*, 1984). In South Africa, *C. scoparium* and a number of other species have been found to cause seedling blight of *E. grandis* and several hybrids (*Figure 2*). Infection usually occurs just above soil level, from where it spreads upwards. Cuttings and seedlings turn dark brown to black, and profuse sporulation occurs on the lower part of the stem. Spores are splash-dispersed (Booth and Gibson, 1973; Mohanan and Sharma, 1986; Ferreira, 1989) under mist irrigation if such seedlings are not removed. *Rhizoctonia solani* Kühn, *Pythium* and *Phytophthora* spp., have also been found to occur in association with *Cylindrocladium* spp. on seedlings with blight symptoms.

FIGURE 2. C. scoparium *seedling blight of* E. grandis *seedlings.*

3. Leaf spot

Sharma *et al.* (1984) reported that *C. quinqueseptatum*, *C. ilicicola* and *C. clavatum* cause leaf spot on *Eucalyptus* spp. in India, while Hodges and May (1972) reported that the latter species causes leaf spot of *E. saligna* Sm. in Brazil. *C. scoparium* is known to cause a serious needle disease and top blight of *Picea* and *Pinus* spp. (Anderson *et al.*, 1962; Bugbee and Anderson, 1963a, 1963b). Various *Cylindrocladium* spp., cause leaf and needle diseases of *Eucalyptus* and *Pinus* spp., as well as other hosts (Boedijn and Reitsma, 1950; Alfieri *et al.*, 1970; Gill *et al.*, 1971; Peerally, 1974d, 1974f, 1974i, 1974j; Sobers *et al.*, 1975; Schoulties *et al.*, 1982; El-Gholl *et al.*, 1986). On *Eucalyptus* spp., leaf spots first appear on water-soaked lesions, which turn dark red to purple, and eventually light brown, usually surrounded by a red to purple border within a chlorotic zone (*Figure 3*). Spots vary from round to irregular, extending through the lamina, and occurring on old as well as young foliage, from where infection can also spread towards the petioles and stem (Barnard, 1984).

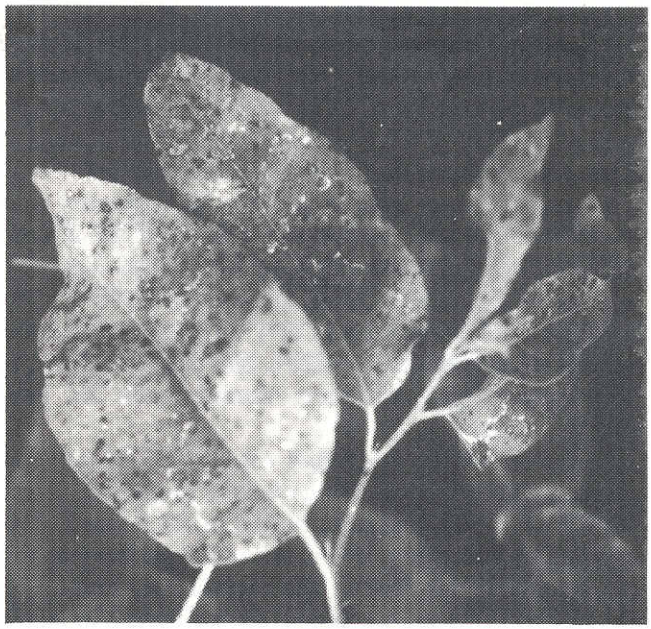

FIGURE 3. Leaf spot symptoms of C. scoparium *on* E. grandis.

4. Stem cankers

Cankers can occur on the lower half of stems on *Eucalyptus* seedlings that are in the hardening stage of cultivation. *C. scoparium* and several other species are frequently isolated from such cankers. Under favour-

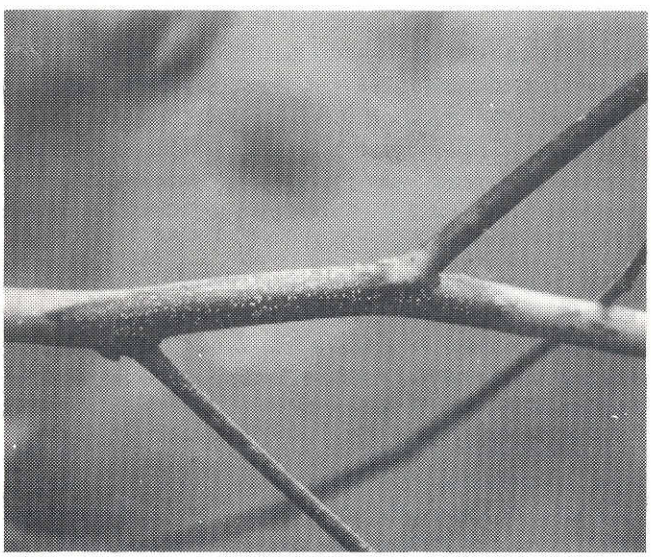

FIGURE 4. Symptoms of C. scoparium *canker on* E. globulus *trees in Brazil.*

able conditions these cankers eventually lead to seedling blight. The seedlings can, however, recover by forming epicormic shoots.

C. quinqueseptatum, *C. clavatum* and *C. ilicicola* are frequently isolated from cankers on *Eucalyptus* seedlings in India (Sharma *et al.*, 1984; Mohanan and Sharma, 1985a). Furthermore, *Eucalyptus* plantations situated in high rainfall areas of India frequently develop stem infections, which occur on copice shoots and branches of young trees. Symptoms such as these usually lead to shoot die-back. In addition to the species causing cankers in nurseries, *C. scoparium* and *C. theae* (Loos) Subramanian also induce cankers on plantation trees (Sharma *et al.*, 1985). Field canker symptoms attributed to *Cylindrocladium* have been observed in Brazil (*Figure 4*) (Ferreira, 1989), but have not yet been found in South African plantations.

5. Shoot blight

Shoot blight is usually the result of leaf infection or stem cankers. *C. quinqueseptatum* and *C. ilicicola* have been reported to cause shoot blight on *Eucalyptus* in Brazil (Ferreira, 1989), while the latter species and *C. clavatum* have been associated with these symptoms in India (Sharma *et al.*, 1984). In South Africa, *C. scoparium* frequently causes shoot blight symptoms on *Pinus* and *Eucalyptus* spp. in nurseries (*Figure 5*), but these symptoms have not been observed in plantations.

FIGURE 5. Cylindrocladium *spp. causing shoot and cutting blight on* E. grandis.

6. Root disease

In this study *C. scoparium* has frequently been isolated from roots of seedlings of *E. grandis* hybrids (*Figure 6*), *A. mearnsii* and *P. radiata*. Furthermore, in plantations and clonal orchards the fungus frequently occurs on roots of young *E. grandis* (*Figure 7*), *E. nitens* (*Deane et* Maid) Maid. and *E. smithii* R.T. Bak. trees. *Ca. parva* has been found on roots of *P. radiata* and *A. mearnsii* seedlings and trees.

In Brazil *C. clavatum* is regarded as an important root pathogen of up to 15-year-old *Eucalyptus* and *Pinus* trees (Hodges and May, 1972). Mohanan and Sharma (1985a) reported *C. scoparium, C. clavatum, C. curvatum* Boedijn and Reitsma and *Ca. camelliae* as

FIGURE 6. C. scoparium *causing root rot and wilt of a* E. grandis *cutting.*

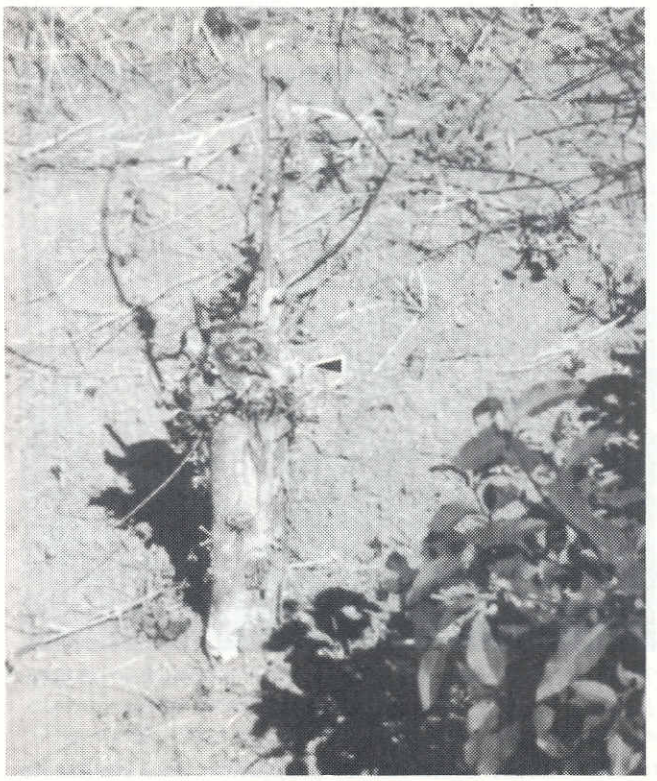

FIGURE 7. Die-back of a E. grandis *ramet due to* Cylindrocladium *root rot.*

important root pathogens of two-month-old *Eucalyptus* seedlings in India. In addition, *C. floridanum* was found to cause root rot of nine-month-old *E. tereticornis* trees (Mohanan and Sharma, 1985a; Sharma *et al.*, 1985).

Both *C. scoparium* and *C. floridanum* are important root pathogens of yellow poplar (*Liriodendron tulipifera* L.) in the USA (Filer, 1970), and *C. scoparium* has also been associated with the mortality of plantation trees up to 27 years old (Ross, 1967). Cordell and Skilling (1975) reported both *C. floridanum* and *C. scoparium* as causing root rot on a wide range of conifers and hardwoods. Infected roots usually become necrotic and discoloured, dying back towards the root crown and inducing needle necrosis (Cordell and Skilling, 1975).

DISEASE CYCLE OF *CYLINDROCLADIUM SCOPARIUM* IN *EUCALYPTUS* CUTTING NURSERIES

Ferreira (1989) established the disease cycle for *Cylindrocladium* in a Brazilian nursery. In order to determine whether the cycle was similar in South Africa, a clonal cutting nursery was examined.

Cuttings were collected at weekly intervals (over a period of six months) at the different stages in the nursery, and from within the clone bank. Soil samples were randomly collected in the cultivated, upper 150 mm of soil in the clone bank, and across the benches on which the trays were placed in the nursery. To detect the presence of *Cylindrocladium* in these soils, they were baited with *Medicago* seedlings (Thies and Patton, 1966, 1970a) and azalea leaves and stems (*Figure 8*) (Linderman, 1972, 1974).

FIGURE 8. Cylindrocladium *spp. colonising an azalea stem in infected nursery soil.*

The disease cycle for *C. scoparium* was similar to that proposed by Ferreira (1989) (*Figure 9*), except that the *Calonectria* state also occurred naturally in the nurseries, which is not the case in Brazil (Ribeiro, 1978). The disease is usually enhanced by excessive soil-moisture, heavy shade, high seedling density and high humidity (Mohanan and Sharma, 1986).

MICROSCLEROTIA

Chains of clusters of chlamydospores are generally referred to as microsclerotia. Cylindrocladium produces abundant microsclerotia in infected roots and leaves (Bugbee and Anderson, 1963b; Linderman, 1973). When infected tissues disintegrate, microsclerotia are released to the soil and can survive for extended periods in the absence of a host (Mohanan and Sharma, 1986). Sobers and Littrell (1974) reported that microsclerotia can survive in fallow soil for as long as nine years. They further found that *C. floridanum* can survive in a dormant state for 15 years or more. Almeida and Bolkan (1981b) observed that microsclerotia could survive for at least 150 days in the absence of plant residues. Alternative hosts were also found to play a role in the long-term survival of *Cylindrocladium* in nurseries (Sobers and Littrell, 1974; Mohanan and Sharma, 1986). Hunter and Barnett (1976) confirmed observations of Weaver (1974), who found the carbon:nitrogen ratios to be the most important factor determining the formation of microsclerotia. Maximum numbers were formed at ratios of 40:1 and 100:1. Pataky *et al.* (1984) confirmed these results when he found that large applications of nitrogen could control *Cylindrocladium* black rot of peanuts.

Thies and Patton (1970b) observed a vertical gradient in numbers if microsclerotia in nursery soil, increasing from the surface down to the plowline at 150 mm. They concluded that microsclerotia are more important than mycelium or conidia in the survival of the fungus from one crop to the next. Rowe *et al.* (1974) trapped root fragments (large enough to carry microsclerotia) 235 m downwind from the infected site, where they re-infected fumigated soils. This indicates that nurseries can become contaminated from adjacent infested areas when conditions are favourable. Severe drought (Taylor *et al.*, 1981; Pataky and Beute, 1983) and low soil temperatures (Phipps and Beute, 1979; Roth *et al.*, 1979), have been found to cause a decline in the numbers of viable microsclerotia.

CONTROL

1. Top blight of conifers

Bugbee and Anderson (1976b) obtained good control of *C. scoparium* on *Picea pungens* Englm. and *P. mariana* Mill. by means of a soil drench of Phytoactin L-318, as well as foliar applications of calcium copper chloride, ferric dimethyldithiocarbamate and 75 % N-trichloromethylthiophthalimide. Cox (1953) controlled *C. scoparium* on various conifer species with a foliar application of bordeaux mixture, or ferric dimethyldithiocarbamate.

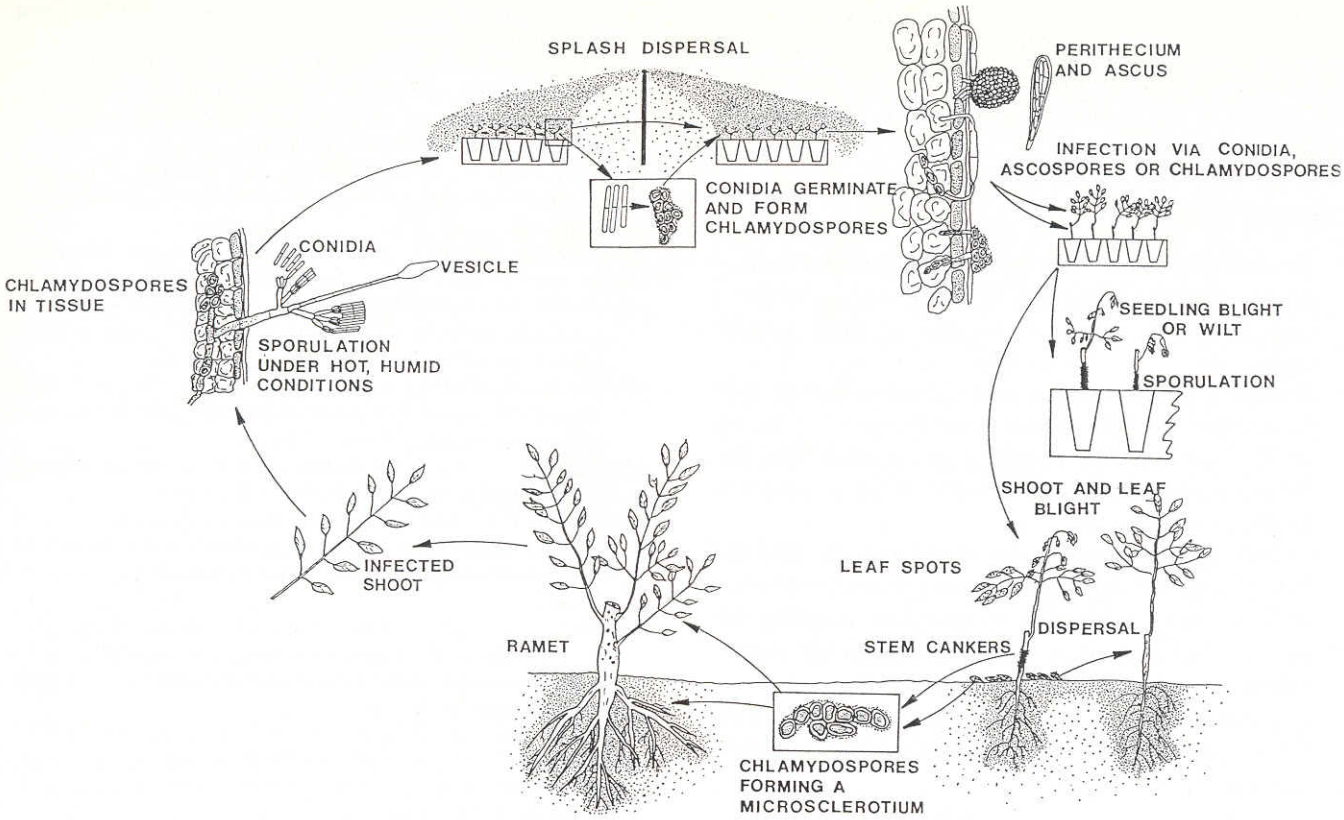

FIGURE 9. Disease cycle of C. scoparium *in* Eucalyptus *cutting nurseries (adapted from Ferreira, 1989).*

2. Leaf spotting, shoot blight and stem cankers

Bertus (1976b) found that foliar sprays of non-systemic fungicides gave poor control of *C. scoparium* on *Acacia flexuosa* (Willd.) Schau. seedlings. Foliar applications of benomyl, carbendazim or thiabendazole, however, gave significant disease control. Soil drenches of either carbendazim or thiophanate-methyl eradicated the disease on *Banksia marginata* Cav. (Bertus, 1976b). Reis and Chaves (1967) controlled *C. scoparium* on *Eucalyptus* spp. with a foliar application of fentinacetate, ferbam and zineb. The latter pathogen was also controlled on *E. grandis* and *E. robusta* Sm. by foliar applications of chlorothalonil and benomyl, when used in conjunction with methyl bromide fumigation of Styrofoam seedling trays (Barnard, 1984). Bedendo and Krugner (1987) found that a foliar application of benomyl to *E. cloeziana* F. Muell, leaves, inhibited the germination of *C. pteridis* Wolf for up to 11 days. *C. pteridis* and *C. heptaseptatum* Sobers, Alfieri & Knauss could be controlled on leatherleaf fern (*Polystichum foliar application (Marousky and Wildt, 1982; Marousky et al.*, 1982). This was also found to be the case for *C. scoparium* on ornamental plants (Niebisch and Kelling, 1986). Cox (1953) controlled *C. scoparium* on conifers by means of monthly applications of bordeaux, manzate, zineb, ferban or thiram.

3. Seedling and cutting wilt

A benomyl drench on azalea gave good control of *C. scoparium* and *C. floridanum* infections (Horst and Hoitink, 1968; Engelhard, 1971).

4. Damping-off and root rot

Soil sterilisation or fumigation have been found to be effective in reducing soil populations of *Cylindrocladium* (Pickel, 1940; Jauch, 1943). Thies and Patton (1971) found that Mylone and methyl bromide reduced the numbers of viable *C. scoparium* microsclerotia in soils. Cordell *et al.* (1971) reported that fumigation with 67 % methyl bromide and 33 % chloropicrin controlled *C. floridanum* on *L. tulipifera*. Cox (1953) used formaldehyde and chloropicrin to fumigate soils in conifer nurseries infected with *C. scoparium*.

5. Seedling and cutting blight

Rattan and Dhanda (1985) obtained good control of *C. scoparium* and *C. clavatum* on *E. tereticornis* in seeds treated with Bavistin (carbendazim), Argoll-3, thiram and Panoram (fenfuram). Roos (1980, 1981) found that good control of a *Cylindrocladium* sp. could be obtained on azaleas if the mother plants were treated with benomyl 9–12 d before cuttings were taken. Control was improved if cuttings were also dipped in a benomyl solution.

Alfenas *et al.* (1988) observed that constant use of benomyl to control *C. scoparium* in nursery cuttings led to the selection of benomyl-resistant strains. They suggested that fungicides with different modes of action should be used in rotation.

Barnard (1984) stated that fungicidal application appears to be necessary to prevent foliar infection under certain conditions. Bugbee and Anderson (1963b) reported that control measures should include soil fumi-

gation for root rot as well as foliar sprays to prevent needle blight. Bertus (1976b) felt that further research on the timing and frequency of fungicidal application was required. Very little has, however, subsequently been done in this regard.

CONCLUSIONS

1. *C. scoparium* is an important pathogen of *Eucalyptus, Acacia* and *Pinus* spp. in South Africa, where it causes a wide range of diseases at most growth stages.
2. Several *Cylindrocladium* and *Cylindrocladiella* spp. pathogenic to *Eucalyptus* are present in South Africa. Surveys are required to establish the distribution and relative importance of these species in local forest nurseries.
3. Collections obtained in this study indicate that the initial fungicide dip used in many cutting nurseries does not reduce the primary inoculum entering the nursery. An evaluation of various fungicide combinations is required to solve this problem.
4. Epidemiological studies are required to determine factors influencing conidial germination, infection and disease development.

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