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Cylindrocladium leucothoes and *C. hederae*, synonyms of *C. reteaudii*

P.W. Crous*† and M.J. Wingfield‡

†Department of Plant Pathology, University of Stellenbosch, Stellenbosch, 7600 Republic of South Africa

‡Department of Microbiology and Biochemistry, University of the Orange Free State, P.O. Box 339, Bloemfontein, 9300 Republic of South Africa

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Cylindrocladium reteaudii (Bugn.) Boesew. is recognized as the correct name for *C. hederae* Arnaud *ex* Peerally and *C. leucothoes* El-Gholl, Leahy & Schubert, which are regarded as synonyms. *Calonectria hederae* Booth & Murray is reduced to a synonym of *Cal. reteaudii* (Bugn.) Booth. Each species is described and illustrated.

Cylindrocladium reteaudii (Bugn.) Boesew. word erken as die korrekte naam vir twee sinonieme, *C. hederae* Arnaud *ex* Peerally en *C. leucothoes* El-Gholl, Leahy & Schubert. *Calonectria hederae* Booth & Murray word tot sinoniem met *Cal. reteaudii* (Bugn.) Booth verklaar. Beskrywings en illustrasies van die spesies word voorsien.

Keywords: *Calonectria*, *Cylindrocladium*, hyphomycetes, synonyms

*To whom correspondence should be addressed.

Species of *Cylindrocladium* Morgan have a worldwide distribution, and are important plant pathogens with wide host ranges (Crous *et al.* 1991; Peerally 1991). Morphologically, species are characterized by having penicillate conidiophores with hyphae or stipes raised above the conidiogenous locus, and terminating in thin-walled vesicles of characteristic shape. Cylindrical, hyaline conidia are one- to multiseptate. Conidia are borne on monophialides arranged in terminal branch clusters in groups of two to six per branch. Species in the genus are generally distinguished on differences in conidium, vesicle and phialide morphology.

In a recent review of *Cylindrocladium* (Peerally 1991), three *Cylindrocladium* spp., *C. reteaudii* (Bugn.) Boesewinkel, *C. hederae* Arnaud *ex* Peerally and *C. leucothoes* El-Gholl, Leahy & Schubert, which we regard to be morphologically similar, were treated as separate species. The aim of this study was to re-examine type specimens of these species, and to consider their validity as separate taxa.

Bugnicourt (1939) described *Cylindrocarpon reteaudii* Bugn. from *Smithia bequaertii* De Wild. in Indo China (Figure 1A–C). The original collection of this fungus also produced a teleomorph in culture, and this was described as *Neonectria reteaudii* Bugn. (Figure 1D). In his review of *Cylindrocarpon* Wollenw., Booth (1966) illustrated the conidiophores of *C. reteaudii* as having a branching pattern typical of *Cylindrocladium* (Figure 1A). Boesewinkel (1982) re-examined the collection, and found that most of the material of Bugnicourt's original collection had been discarded, and that only a slide was available from IMI. In his examination of this material, Boesewinkel found that stipes and vesicles were present, thus confirming that the anamorph was a typical *Cylindrocladium* sp. He found this species to have a 5-septate stipe and a clavate to subglobose vesicle (Table 1), and thus transferred it to *Cylindrocladium* as a new species *C. reteaudii* (Bugn.) Boesew.

Peerally (1991) recognized *C. reteaudii* as a valid species. In his circumscription of this species, he combined the observations of Booth (1966) and Boesewinkel (1982). The species was reported to have 5 – 6 septate conidia, and clavate to subglobose vesicles (Peerally 1991) (Table 1). The original observations of Bugnicourt (1939) were, however, not considered.

In this study we examined the only remaining material of *C. reteaudii* (IMI 55922), which is represented by a dried culture on corn meal agar, obtained by Booth (1966) from Herb. Paris. A few 1 – (3) – 4 septate conidia were observed (Figure 1B). Phialides varied from being allantoid to cylindrical. When Booth (1966) originally prepared slides from the same specimen, he observed 5 – 6 septate conidia only [as cited by Peerally (1991)]. In the original description, Bugnicourt (1939) reported conidia of the so-called *Cylindrocarpon* sp. to be 1 – (3) – 6 septate. Bugnicourt also compared the fungus on different media, eventually concluding that conidia were primarily 3-septate (43%), and that only some were 5-septate (3%) or 6-septate (1%) (Table 1).

In 1928, *Cylindrocladium macrosporum* Sherb. was described as a 1-septate species with characteristically large conidia (Sherbakoff 1928). In subsequent studies on the pathogenicity and morphology of this fungus (Sobers 1967, 1968; Sobers & Alfieri 1972), *C. macrosporum* was reduced to synonymy with the earlier described *C. pteridis* Wolf (Wolf 1926). However, several years before this synonymy was made, Arnaud (1952) collected a *Cylindrocladium* sp. characterized by large conidia, and proposed the name *Cylindrocladium macrosporum* Sherb. var. *hederae* Arn. for this collection. In his CMI description, Peerally (1974)

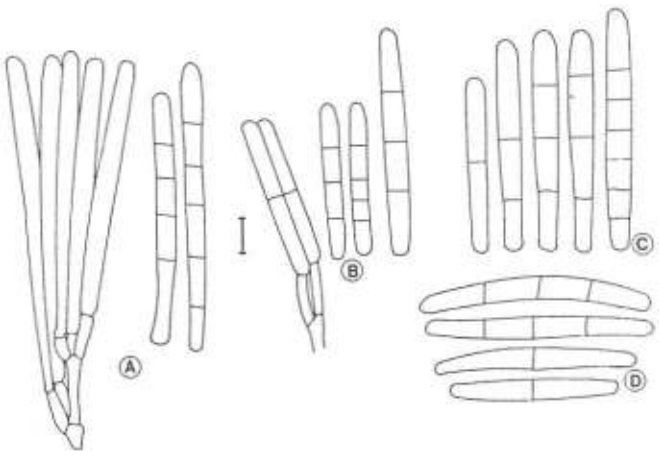

Figure 1 Conidia and ascospores from the type specimen of *Calonectria reteaudii*. **A.** Conidia and conidiophore (redrawn from Booth 1966); **B.** Conidia and phialides (IMI 55922) (scale bar: 10 μm); **C.** *Conidia* (redrawn from Bugnicourt 1939) (×500); **D.** ascospores (redrawn from Bugnicourt 1939) (×500).

Table 1 Comparison of conidial and vesicle morphology of isolates in *Cylindrocladium reteaudii*

Species	Conidia		Vesicles		Accession number	Reference
	Length × width (µm)	Septation	Width (µm)	Shape		
Cylindrocarpon reteaudii Bugn.	36–68 × 4.5–7.5	1–(3)–6	not observed	—	Herb. Paris (type)	Bugnicourt 1939
	80–110 × 6–7	5–6	not observed	—	IMI 55922 (*ex* type)	Booth 1966
Cylindrocladium reteaudii						
(Bugn.) Boesew.	not stated	—	5–7	Clavate to subglobose	IMI 55922	Boesewinkel 1982
	80–110 × 6–7	5–6	5–7	Clavate to subglobose	Not stated	Peerally 1991
	22–60 × 4–7	1–(3)–6	5–7	Clavate to oval	IMI 55922	Present study
Cylindrocladium hederae						
(Arn.) *ex* Peerally	44.2–102 × 3.6–9.2	1–(3)–5	6.4–14.4	Clavate to oval	Not stated	Peerally 1974
	44–102 × 6–9	1–(3)–5	6–14	Clavate to oval	IMI 39232 (type)	Peerally 1991
	53–68.5 × 6.5–8	1–(3)–4	—	Clavate to oval	IMI 39232	Present study
	42–83 × 5.5–7.5	1–(3)–5	—	Clavate to oval	IMI 75300	Present study
Cylindrocladium leucothoes						
El-Gholl, Leahy & Schubert	62–102 × 4–5.9	1–(3)–6	5.9–11.6	Clavate to oval	FLAS F55387 (type)	El-Gholl *et al.* 1989
	65–(72)–86.5 × 4.8–(5.5)–6.5	1–(3)–6	4.0–6.5	Clavate to oval	ATCC 68424 (*ex* type)	Present study*

* Observations made on carnation leaf agar after 7 days at 25°C.

raised this variety to species status as *C. hederae* (Arn.) Peerally. Arnaud (1952) had, however, not provided a Latin diagnosis for his proposed variety of *C. macrosporum*, and Peerally's (1974) combination was thus not valid. Peerally (1991) corrected this error and provided a Latin diagnosis for the species, describing it as *C. hederae* Arnaud *ex* Peerally (Figure 2A–C).

Peerally (1991) examined the original type specimen of *C. macrosporum* var. *hederae* (IMI 39232 *ex* Herb. Paris) and described the species as having 1 – (3) – 5 septate conidia with clavate to oval vesicles (Table 1, Figure 2B). We have also examined this material, and found conidia to be 1 – (3) – 6 septate with clavate to oval vesicles (Table 1). The herbarium specimen of this species was annotated by Arnaud with a statement that conidia of up to 120 µm were also present on the original specimen. The similarity between these conidial lengths and those commonly observed for *C. pteridis* (= *C. macrosporum*) might explain why it was originally considered as a variety of *C. macrosporum*.

Cylindrocladium leucothoes El-Gholl, Leahy & Schubert (1989) (as *C. leucothoeae*) was originally described from leaf spots on *Leucothoe axillaris* (Lam.) D. Don. in Florida, U.S.A. (El-Gholl *et al.* 1989). This species was characterized by having 1 – (3) – 6 septate conidia, with clavate to oval vesicles (Table 1). In this study we examined a culture (ATCC 64824) derived from the type collection. Single-conidial isolates were placed on carnation leaf agar (CLA) (Fisher *et al.* 1982) and incubated for 7 days under near-ultraviolet light at 25°C. Conidia produced under these conditions were 1 – (3) septate, becoming up to 6-septate in older cultures (Table 1, Figure 3A–D). Vesicles were similar to those of *C. reteaudii* and *C. hederae*, being clavate to oval (Figure 3C). Phialides were allantoid to cylindrical, becoming more doliiform when examined on potato-dextrose or malt extract agar.

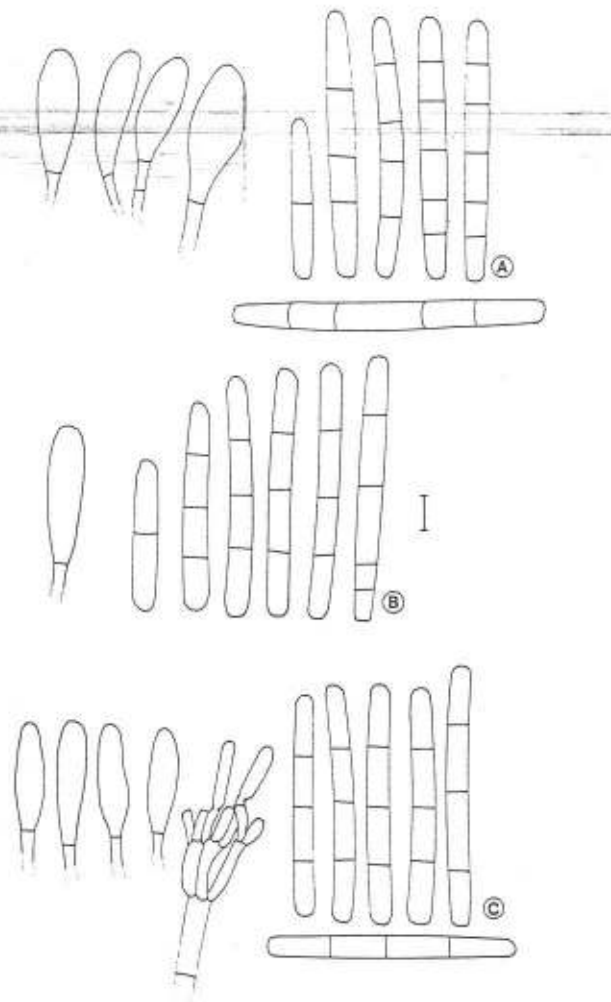

Figure 2 Vesicles and conidia of *Cylindrocladium reteaudii*. **A.** Vesicles and conidia of *Calonectria hederae* (type) (IMI 75300); **B.** Vesicles and conidia of *Cylindrocladium hederae* (type) (IMI 39232); **C.** Vesicles, conidiophore and conidia of *C. hederae* (IMI 241261) (scale bar, 10 µm).

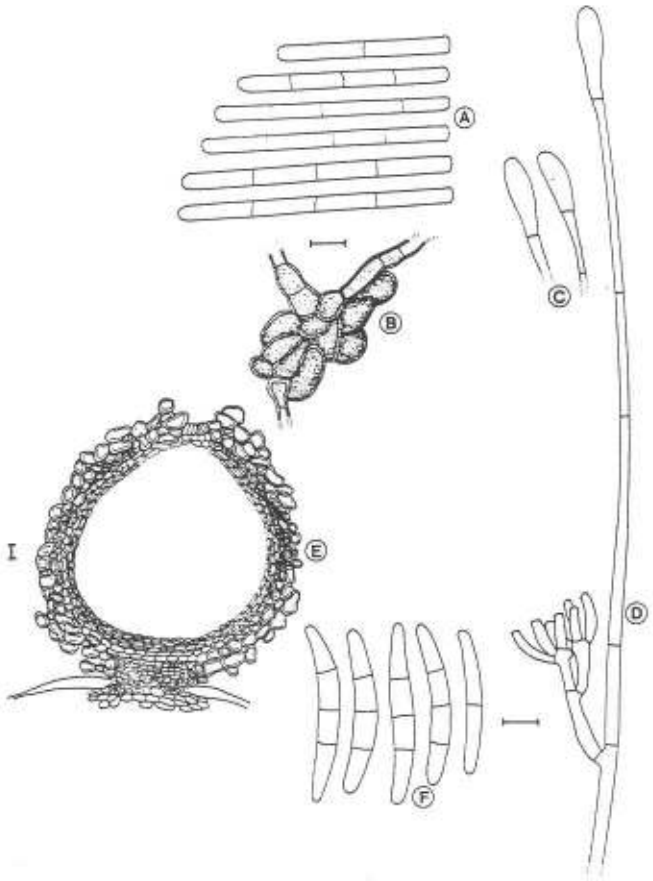

Figure 3 *Calonectria reteaudii* and its anamorph *Cylindrocladium reteaudii*. **A.** Conidia; **B.** Chlamydospores; **C.** Vesicles; **D.** Conidiophore of *Cylindrocladium reteaudii* (type of *C. leucothoes*, ATCC 64824 on CLA) (scale bar, 10 μm); **E.** Transverse section through a perithecium of *Cal. reteaudii* (IMI 75300) (scale bar, 20 μm); **F.** Ascospores of *Cal. reteaudii* (type of *Cal. hederae*, IMI 75300) (scale bar, 10 μm).

Detailed comparisons in this study of *C. reteaudii*, *C. hederae* and *C. leucothoes* have shown the three species to be indistinguishable, based on commonly accepted morphological criteria. These include phialide and vesicle shape, conidial morphology as well as septation and dimensions of all these structures (Table 1). These observations lead us to conclude that the three species would best be treated as synonyms accommodated under the older, validly published epithet as follows:

Cylindrocladium reteaudii *(Bugn.) Boesewinkel*, Trans. Br. mycol. Soc. 78: 554 (1982). *Cylindrocarpon reteaudii* Bugn., Encycl. Mycol. 11: 189 (1939) (described as *reteaudi*).

Cylindrocladium macrosporum var. *hederae* Arn., Bull. Soc. mycol. Fr. 68: 205 (1952) (*nom. nud.*). *Cylindrocladium hederae* (Arn.) Peerally, (1974) CMI Descriptions of Pathogenic fungi and Bacteria No. 426 (*nom. nud.*). *Cylindrocladium hederae* Arn. *ex* Peerally, Mycotaxon 40: 335 (1991).

Cylindrocladium leucothoes El-Gholl, Leahy & Schubert, Can. J. Bot. 67: 2530 (1989) (as *leucothoeae*).

Bugnicourt (1939) described the teleomorph of *C. reteaudii* as *Neonectria reteaudii*. Booth (1966) transferred this collection to *Calonectria* de Not. as *Cal. reteaudii* (Bugn.) Booth, and showed it to have 1 – 3 septate ascospores (Table 2, Figure 1D). These are slightly larger than those originally described by Bugnicourt (1939) (Table 2). This collection is no longer present in Herb. Paris or IMI, and we were thus unable to examine it.

Arnaud (1952) described *Cal. hederae* Arn. as a fungus responsible for causing the death of leaves of *Hedera helix* L. in France. As was the case with its anamorph *C. macrosporum* var. *hederae*, no Latin diagnosis supported the description, rendering the name invalid. Booth & Murray (1960) validly re-described the teleomorph as *Cal. hederae* Booth & Murray, having re-collected it from ivy leaves in Surrey, England (IMI 75300) (Table 2, Figure 3E–F). Perithecia were described as being red with a warty outer layer, having clavate, 8-spored asci, with long stalks. Ascospores were 3-septate. We have re-examined this specimen, and found ascospores to be 1 – 3 septate (Table 2, Figure 3F), and conclude that the teleomorph species *Cal. reteaudii* and *Cal. hederae* are indistinguishable from each other. This is not surprising, considering the similarity of their anamorphs, *C. reteaudii* and *C. hederae*. We therefore provide the following synonymy for the teleomorph:

Calonectria reteaudii *(Bugn.) Booth*, Mycol. Pap. 104: 41 (1966). *Neonectria reteaudii* Bugn., Encycl. Mycol. 11: 189 (1939) (as *reteaudi*).

Calonectria hederae Arnaud, Bull. Soc. Mycol. France 68: 214 (1952) (*nom. nud.*). *Calonectria hederae* Booth & Murray, Trans. Br. mycol. Soc. 43: 70 (1960).

Table 2 Comparison of ascus and ascospore morphology of isolates in *Calonectria reteaudii*

	Asci		Ascospores			
Species	Length × width (μm)	Shape	Length × width (μm)	Septation	Accession number	Reference
Neonectria reteaudii Bugn.	88–(130)–154 × 7–(11)–15	Long claviform	28–76 × 3.6–5.8	1–3	(type) herb. Paris	Bugnicourt 1939
Calonectria reteaudii (Bugn.) Booth	88–154 × 7–15	Elongated claviform	56–60 × 4.5–5.8	1–3	(ex type) herb. Paris	Booth 1966
Calonectria hederae Booth & Murray	160–180 × 24–40	Clavate	45–65 × 6–8	3	IMI 75300 (type)	Booth & Murray 1960
	130–180 × 17–35	Clavate	33.6–68.8 × 4.8–7.2	3	IMI 75300	Peerally 1974
	—	—	37.5–50 × 5.6–6.5	1–3	IMI 75300	Present study

Specimens examined

Calonectria hederae, Hedera helix leaf, Great Britain, 1958, IMI 75300 (holotype); *C. hederae, Hedera helix* leaf, Great Britain, 1978, IMI 241261; *C. hederae, Hedera helix* leaves, France, 1948, G. Arnaud, IMI 39232 (lectotype); *Cylindrocarpon reteaudii*, on *Smithia bequaertii*, Indo China, F. Bugnicourt, IMI 55922 (dried culture derived from type, Herb Paris).

Culture examined

C. leucothoeae, from *Leucothoeae axillaris* leaves, Florida, U.S.A., Feb. 1988, El-Gholl, ATCC 64824 (type culture).

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The distribution of C_3 and C_4 plants in a successional sequence in the Okavango Delta

Karen Ellery,* W.N. Ellery* and B.Th. Verhagen†

*Department of Botany, University of the Witwatersrand, P.O. Wits, 2050 Republic of South Africa

†Schonland Research Centre, University of the Witwatersrand, P.O. Wits, 2050 Republic of South Africa

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Carbon isotope techniques were used to determine the photosynthetic pathway of a number of wetland plant species. The relative cover abundances of C_3 and C_4 plants were compared along a successional sequence of the Maunachira River system of the Okavango Delta. Plants with a C_3 photosynthetic pathway were dominant in early successional stages and C_4 plants were dominant in late successional stages. It is proposed that nutrient availability, particularly nitrogen limitation, could be a determinant of the change from C_3 to C_4 plant dominance during succession.

Die fotosintetiese verloop in 'n aantal moerasplante is deur middel van koolstof-isotooptegnieke vasgestel. Die relatiewe dekkingsdigthede van C_3 en C_4 plante in opeenvolgende seksies van die Maunachira riviersisteem van die Okavango Delta is met mekaar vergelyk. In die aanvanklike seksies was plante met 'n C_3 fotosintetiese verloop dominant, terwyl C_4 plante in die daaropvolgende seksies dominant was. Daar word voorgestel dat die beskikbaarheid van voedingstowwe, veral stikstof, 'n rol speel in die verandering van C_3 dominansie na C_4 dominansie.

Keywords: carbon isotope, C_3, C_4, nutrients, Okavango Delta, succession.

The C_4 photosynthetic pathway has been shown to have an adaptive advantage under conditions of high temperature, high irradiance and in an arid environment (Osmond *et al.* 1982; Pearcy & Ehleringer 1984). The field studies in which the distribution of C_3 and C_4 plant species was investigated, have been either along environmental gradients (Tieszen *et al.* 1979; Boutton *et al.* 1980) or on a phyto-geographical basis (Vogel *et al.* 1978; Ellis *et al.* 1980; Cowling 1983; Hattersley 1983; Vogel *et al.* 1986). No work relating photosynthetic metabolic pathways to a successional sequence of plant communities has been conducted.

The area of the present study was the permanently inundated Maunachira River system situated in the north-eastern part of the Okavango Delta, north-western Botswana. The vegetation consists of a heterogeneous mix of wetland plant communities comprising submerged and floating-leaved species dominant in deep open water bodies and short, emergent plant species dominant in shallow peat bogs. A successional sequence for the wetland plant communities of the study area, based on phytosociological associations and peat stratigraphy, is described by Ellery *et al.* (1991).