Reassessment of the anamorph genera *Botryodiplodia*, *Dothiorella* and *Fusicoccum*

Pedro W. Crous[1] & Mary E. Palm[2]

[1] Department of Plant Pathology, University of Stellenbosch, P. Bag X1, Matieland 7602, South Africa
[2] USDA-APHIS-PPQ, Systematic Botany and Mycology Laboratory, Beltsville, MD 20705, USA

Crous, P. W. & M. E. Palm (1999). Reassessment of the anamorph genera *Botryodiplodia*, *Dothiorella* and *Fusicoccum*. – Sydowia 51(2): 167–175.

The generic concepts of *Botryodiplodia*, *Dothiorella* and *Fusicoccum* have been unclear. The nomenclatural history of these genera is presented as well as a description of their types. The type species of *Botryodiplodia* is a valsoid fungus and the type of *Dothiorella* has conidiomata varying from pycnidial to multilocular, eustromatic, and hyaline, branched conidiophores, that produce brown, ellipsoidal, 1-euseptate conidia. *Dothiorella* is considered a synonym of the earlier described genus *Diplodia*. *Fusicoccum* is characterised by pycnidial to multilocular, eustromatic conidiomata, hyaline, aseptate, fusiform conidia that are produced enteroblastically on branched conidiophores with cylindrical conidiogenous cells that proliferate at the same level, resulting in periclinal thickening, or percurrently, resulting in annellations.

Keywords: *Botryosphaeria*, *Diplodia*, *Lasiodiplodia*, systematics.

The genus *Botryosphaeria* Ces. & De Not. has been linked to various anamorph genera, including *Botryodiplodia* (Sacc.) Sacc., *Diplodia* Fr., *Dothiorella* Sacc., *Fusicoccum* Corda, *Lasiodiplodia* Ellis & Everh., *Macrophoma* (Sacc.) Berl. & Vogl., *Macrophomopsis* Petrak, and *Sphaeropsis* Sacc. and (Sivanesan, 1984; Sutton, 1980). Sutton (1980) considered *Macrophoma* to be a synonym of *Sphaeropsis*, while Pennycook & Samuels (1985) considered *Macrophomopsis* to be a synonym of *Fusicoccum*. Many of these genera are not clearly delimited because the morphological features that separate them are not well-defined, or the genera include a heterogeneous assembly of taxa. Morphological and molecular data are needed to clearly define *Botryosphaeria* and these anamorph genera (Jacobs & Rehner, 1998). Studies of type specimens are required to stabilize the generic names. For that reason, we have re-examined the type species of *Botryodiplodia*, *Dothiorella* and *Fusicoccum*, with the aim of stabilizing their generic concepts. The other reported anamorphs of *Botryosphaeria* will not be treated in this paper, but most are in need of similar type studies.

Materials and methods

Hand-cut sections of the type specimens were mounted in water as well as lactophenol, and examined using Nomarski interference contrast microscopy. Where sufficient material was available, 30 measurements were obtained of each structure, the 95% confidence intervals determined, and the extremes given in parentheses.

Results

Botryodiplodia

The name *Botryodiplodia* was first used as a subdivision of the genus *Diplodia* by Saccardo (1880), who gave *Diplodia juglandis* Fr. as an example. This same treatment was presented by Saccardo in 1883, where he listed "*Diplodia juglandis* Fr. (Summa Veg. Sc. p. 417), based on *Sphaeria juglandis* Fr. (Syst. Mycol. II, p. 493)" in the group *Sphaeriae Compositae*.

In 1884, Saccardo published *Botryodiplodia* Sacc. as a genus for the first time, but cited Mich. II p. 7 (Saccardo, 1880) as the place of publication. However, the first species Saccardo (1884) listed was *Botryodiplodia juglandicola* (Schw.) Sacc. *Diplodia juglandis* Fr. was treated under *Diplodia*, rather than with *Botryodiplodia* as he had done in 1880. Saccardo (1884) thus changed the concept of his subgenus and erected this new genus based on a different species. Therefore, the correct generic citation is *Botryodiplodia* Sacc. (1884). *Botryodiplodia juglandicola* (Schw.) Sacc. (basionym *Sphaeria juglandicola* Schw.) is the first species listed and has been considered the type of *Botryodiplodia* (see Sutton, 1977). We follow that designation.

Cooke (1884/85) studied the first 89 species in Saccardo's (1883) *Sphaeriae Compositae*. Based on his examination of the Berkeley specimen 8846 of *S. juglandicola*. Cooke treated this species as *Valsa juglandicola* Schw. In doing so he established a new combination which Saccardo correctly cited as *Valsa juglandicola* (Schw.) Cooke (Saccardo, 1886).

We have been unable to locate the type material of *S. juglandicola* (BPI, PH) but have examined authentic Schweinitz specimens of *S. juglandicola* (U.S.A. Pennsylvania: Bethlehem, Collins Collection No. 113 (PH, BPI US800048); Salem-Bethlehem, "1328-181-Syn. Fung." (PH); *Hicoria* sp., Shear types and rarities [annotated by Shear as *Eutypella*], Schweinitz Mtd. Coll. no 1328 (BPI US800046); on *Carya* sp. ex herb. Schweinitz #1328, in Michener Collection [annotated by Shear as *Eutypella*] (BPI US800047). We observed only a valsoid fungus and nothing suggestive of *Botryodiplodia sensu lato*. The name *Botryodiplodia* Sacc. refers to a valsoid ascomycete and

therefore cannot be used as a name for a coelomycete, as it has been applied in the past, and is therefore declared as a *nomen dubium*.

Dothiorella

A great deal of confusion has surrounded the type specimen and generic concept of *Dothiorella* Sacc. Saccardo erected *Dothiorella* in 1880, based on the type species which he cited as "*Dothiorella pyrenophora* (Berk.) Sacc." Saccardo apparently based this genus on "*Dothiora* Berk." *Dothiora* Berk. was never validly published, but the ascomycete genus *Dothiora* Fr. was, and Saccardo actually was referring to *Dothiora* Fr. *sensu* Berk. Berkeley (1860) had treated *Dothiora* Fr., but described the anamorph, as he did not believe in separate names for anamorphs and teleomorphs. Saccardo, however, wanted to name the anamorph separately, and on this basis erected the anamorph genus *Dothiorella*. Therefore, *Dothiora pyrenophora* Fr. *sensu* Berk. was the basionym of *Dothiorella* Saccardo (1880). The situation is fully explained in Sutton (1977). As Sutton (1980) pointed out, the type species of *Dothiorella* should be cited as *Dothiorella pyrenophora* Sacc., because his descriptive account is regarded as a *descriptio generico-specifica*.

Saccardo (1884) further confused matters by transferring "*Dothiora pyrenophora* Berk." (*nom. inval.*) to *Botryodiplodia* as *B. pyrenophora* (Berk.) Sacc. Furthermore, Saccardo later also referred to *Dothiorella pyrenophora* (Karst.) Sacc. (syn. *Dothiora pyrenophora* Karst.). Karsten (1884) had used the names *Dothiora pyrenophora* Fr. and *Dothiorella pyrenophora* Sacc. for Finnish material. Saccardo (1884) thus introduced a second *Dothiorella pyrenophora* Sacc., this one based on Karsten's Finnish material, rather than Berkeley's English material. The name *Dothiorella pyrenophora* Sacc. (1884) must thus be seen as a homonym of *Dothiorella pyrenophora* Sacc. (1880).

Dothiorella pyrenophora Sacc., the type species of *Dothiorella*, is typified by Berkeley's English material of *Dothiora pyrenophora* Fr. (Berk. Exs. No. 282, K 54913). Cooke (1871) re-examined Berkeley's material (K 54913) on which Saccardo based his concept of *Dothiorella*. He reported observing brown, uniseptate conidia, indistinguishable from those of a *Diplodia* species. In re-examining this specimen, we found that although the conidiomata seemed more variable than pycnidia of *Diplodia* (unilocular to multilocular, eustromatic), the conidiogenous cells and conidia were quite distinct from *Botryosphaeria* anamorphs that are commonly listed as species of *Dothiorella* in the literature. In fact, the branched, septate conidiophores, holoblastic conidiogenesis, and smooth to finely verruculose but not striate, brown, 1-euseptate conidia support the syno-

nymy of *Dothiorella* Sacc. (1880) with *Diplodia* Fr. (1834). Based on Cooke's observations (1871) and our examination of the type, *Dothiorella* should be considered an additional synonym of *Diplodia*, and all anamorphs of *Botryosphaeria* that were placed in *Dothiorella* will have to be re-examined.

In this study we were unable to affiliate the type specimen of *Dothiorella pyrenophora* with a known species of *Diplodia*. This specimen is therefore redescribed, and a new combination proposed in *Diplodia*.

Diplodia pyrenophora (Sacc.) Crous & M. E. Palm comb. nov. – Fig. 1.

≡ *Dothiorella pyrenophora* Sacc., Michelia 2: 5 (1880).

Mycelium immersed, consisting of septate, branched, brown, finely verruculose hyphae, 3.5–4.5 µm diam. – Conidiomata pycnidial, unilocular, or multilocular, aggregated in eustromatic tissue, dark brown to black, immersed, thick-walled; outer layer consisting of dark brown, thick-walled textura angularis; inner layer of thin-walled, hyaline cells. – Ostiole single, circular to irregular. – Conidiophores hyaline, smooth, cylindrical, rarely branched, 20–35 × 4–5 µm. – Conidiogenous cells integrated, hyaline, smooth, cylindrical, forming a single apical conidium, 8–20 × 4–5 µm. – Conidia hyaline, thick-walled, aseptate, becoming dark brown, finely verruculose, guttulate, 1-euseptate with age (a few conidia were observed to develop one additional septum once on the host surface), ellipsoidal, apex obtuse, base truncate, (12–)25–30(–35) × (7–)11–14(–16) µm.

Holotype. – *Dothidea pyrenophora* Fr., on apple twigs, UK, Berkeley British Fungi 1836-1843, No. 282, K(M) 54913; *Dothidea pyrenophora* Fr., on apple twigs, UK, Berkeley British Fungi 1836-1843, No. 282, ex herb. Broome, K(M) 54912 (!).

The name *Dothiorella* has been used for coelomycetes with fusiform, hyaline, non-septate conidia produced in stromatic conidiomata. However, based on study of the type specimen, *Dothiorella* is considered a synonym of *Diplodia* Fr. Types of many species described in *Dothiorella*, including several *Dothiorella* anamorphs of *Botryosphaeria*, need to be re-examined in order to determine their correct generic placement. Many probably would be accommodated better in *Diplodia*, *Fusicoccum* or *Sphaeropsis*.

Fusicoccum

The prevailing concept of *Fusicoccum*, exemplified by Sutton (1980), includes coelomycetes with fusiform, hyaline, non-septate conidia produced holoblastically in stromatic conidiomata.

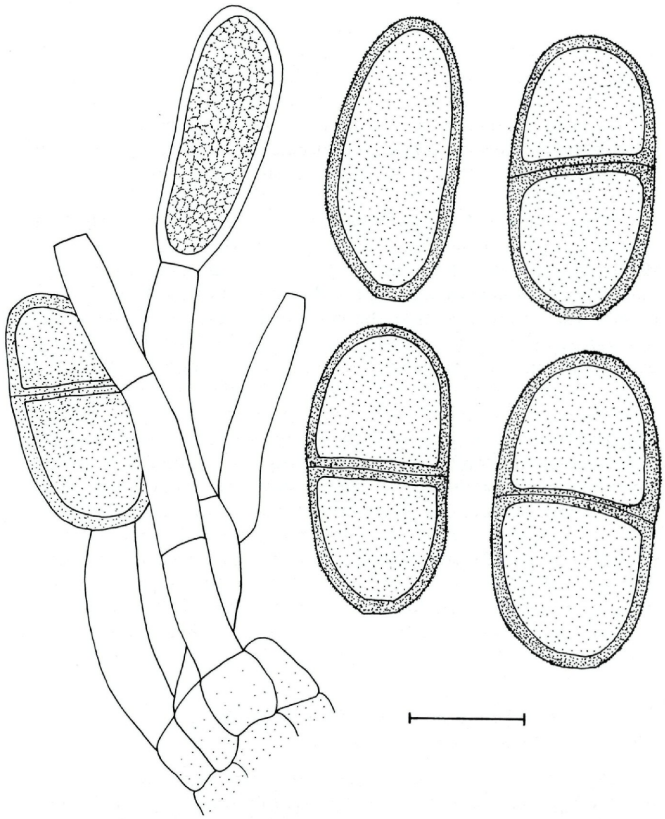

Fig. 1. – Conidia and conidiogenous cells of *Dothiorella pyrenophora* (type, K). – Bar = 10 µm.

Sutton (1980) explained why the name *Fusicoccum* Corda, based on *Fusicoccum aesculi* Corda, has led to so much confusion in the past. As Sutton indicated, Petrak (1922) placed the fungus called *F. aesculi* Corda by Saccardo (1880, 1884, 1886) in *Dothiorella* as the anamorph of *Botryosphaeria berengeriana* De Not. Sutton regarded the correct citation for this fungus to be *D. aesculi* Petrak, because Saccardo's identification was regarded as a misapplication. Sutton

could not locate Corda's type material of *Fusicoccum aesculi*, but indicated that the illustrations of Corda (1829) and Saccardo (1886) were quite similar, and therefore provided a description of the material identified by Saccardo as *F. aesculi* (IMI 201771 ex PAD) as representative of that species. Furthermore, Sutton (1980) regarded *Fusicoccum* as the genus that would likely best accommodate to be most likely to accommodate the anamorphs of ascomycetes such as *B. ribis* and *B. dothidea*, an opinion later also shared by Maas & Uecker (1984).

Pennycook & Samuels (1985), in a paper dealing with the species of *Botryosphaeria* associated with kiwifruit, also reported that the type material of *F. aesculi* was not in Corda's herbarium in Prague. They accepted the concept of *Fusicoccum* as defined by Sutton (1980) and commented that the specimen upon which Sutton based his concept (Saccardo in PAD), appears to be immature, with most conidiogenous loci appearing to produce only one holoblastic conidium. Pennycook & Samuels (1985) expanded the generic circumscription of *Fusicoccum* based on their observations that older conidiogenous cells of *F. aesculi* were enteroblastic and proliferated percurrently. We confirm that observation. Additionally, we observed that some conidiogenous cells proliferate at the same level, resulting in periclinal thickening of the apex of the conidiogenous cell. The concept of *Fusicoccum* should include pycnidial conidiomata, and conidiogenous cells with enteroblastic conidiogenesis (Pennycook & Samuels, 1985) with proliferation at the same level, resulting in periclinal thickening, or percurrently resulting in annellations.

We herein designate the PAD specimen as neotype of *F. aesculi* and provide an emended description of *Fusicoccum*.

Fusicoccum Corda, in Sturm, Deutschlands Flora 2: 111 (1829).

Type species: *Fusicoccum aesculi* Corda.

Mycelium immersed, consisting of branched, septate, smooth, hyaline hyphae. – Conidiomata variable from solitary pycnidia to multilocular eustromatic structures; walls composed of dark brown *textura angularis*, becoming hyaline towards inner layer. – Ostioles indistinct to well defined, round or irregular. – Conidiophores hyaline, cylindrical, branched at the base, smooth, 0-1-septate. – Conidiogenous cells enteroblastic, first formed conidium holoblastic, integrated, hyaline, smooth, cylindrical, producing one or more conidia apically, often proliferating percurrently to produce conidia at successively higher levels on annellate conidiogenous cells. – Conidia hyaline, becoming olivaceous with age, smooth, thin-walled, aseptate, but sometimes becoming septate prior to germination, fusiform to ellipsoidal or clavate, straight, finely guttulate,

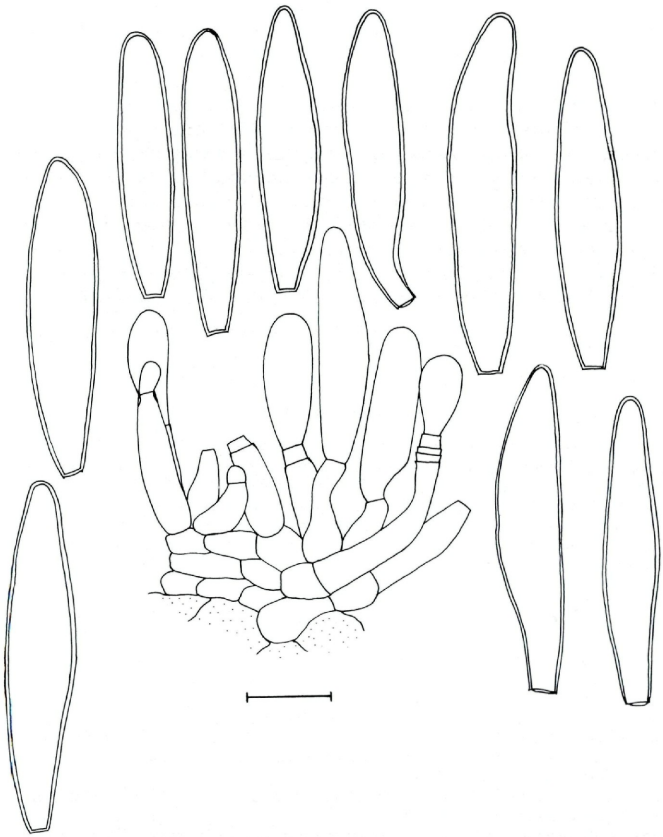

Fig. 2. – Conidia and conidiogenous cells of *Fusicoccum aesculi* (type, PAD). – Bar = 10 µm.

apex subobtuse to obtuse, base conspicuously truncate; minute marginal basal frill present.

Fusicoccum aesculi Corda, in Sturm, Deutschlands Flora 2: 111 (1829). – Fig. 2.

Mycelium immersed, consisting of branched, septate, smooth, hyaline hyphae, 3–4 µm diam. – Conidiomata variable from soli-

tary pycnidia to multilocular eustromatic structures; walls composed of dark brown *textura angularis*, becoming hyaline towards inner layer. – Ostioles indistinct to well-defined, round or irregular. – Conidiophores hyaline, cylindrical, branched at the base, smooth, 0–1-septate, 14–24 × 2–3 µm. – Conidiogenous cells initially holoblastic, becoming enteroblastic, integrated, hyaline, smooth, cylindrical, producing one or more conidia apically, often proliferating percurrently to produce conidia at successively higher levels on annellate conidiogenous cells. – Conidia hyaline, becoming olivaceous with age, smooth, thin-walled, aseptate, but sometimes becoming septate prior to germination, fusiform to narrowly ellipsoidal, straight, finely guttulate, apex subobtuse, base truncate, 18–25(–30) × 4–4.5(–5) µm; minute marginal basal frill present.

Neotype designated here: on branches of *Aesculus*, P.A. Saccardo, Italy, PAD.

Acknowledgments

The senior author is grateful to Dr. Amy Y. Rossman, Director, US National Fungus Collections, Beltsville, Maryland U.S.A., for providing laboratory space and facilities during this study, and the curators of PAD and K for providing the specimens examined. The Fulbright Foundation is acknowledged for financial support to the first author while on sabbatical leave at BPI, and Dr. Gary J. Samuels (USDA, Beltsville, Maryland U.S.A.) is also thanked for commenting on the manuscript.

References

Berkeley, M. J. (1860). Outlines of British Fungology. – Lovell Reeve, London, UK.
Cooke, M. C. (1871). Handbook of British Fungi. – Macmillan & Co., London, UK.
—— (1884/1885). Sphaeriaceae imperfectae cognitae. – Grevillea 13: 37–40.
Corda, A. C. I. (1829). Sturm's Deutschlands Flora 3: 105–136.
Jacobs, K. A. & S. A. Rehner (1998). Comparison of cultural and morphological characters and ITS sequences in anamorphs of *Botryosphaeria* and related taxa. – Mycologia 90: 601–610.
Karsten, P. A. (1884). Symbolae ad Mycologiam Fennicam. XIII. – Medd. Soc. Fauna Flora Fenn. 11: 1–20.
Maas, J. L. & F. A. Uecker (1984). *Botryosphaeria dothidea* cane canker of thornless blackberry. – Pl. Dis. 68: 720–726.
Pennycook, S. R. & G. J. Samuels (1985). *Botryosphaeria* and *Fusicoccum* species associated with ripe fruit rot of *Actinidia deliciosa*, kiwifruit in New Zealand. – Mycotaxon 24: 445–458.
Petrak, F. (1922). Beiträge zur Kenntnis der Pilzflora der südlichen Alpenländer und Norditaliens. – Annls Mycol. 20: 126–159.
Saccardo, P. A. (1880). Conspectus generum fungorum italiae inferiorum nempe ad Sphaeropsideas, Melanconieas et Hyphomyceteas pertinentium, systemate sporologico dispositu. – Michelia 2: 1–38.
—— (1883). – Syll. Fung. 2: 1–815.
—— (1884). – Syll. Fung. 3: 1–860.
—— (1886). – Syll. Fung. IVA: 1–484.

Sivanesan, A. (1984). The bitunicate ascomycetes and their anamorphs. – J. Cramer, Germany.
Sutton, B. C. (1977). Coelomycetes VI. Nomenclature of generic names proposed for Coelomycetes. – Mycol. Pap. 141: 1–253.
—— (1980). The Coelomycetes. Fungi imperfecti with pycnidia, acervuli and stromata. – CMI, Kew, Surrey, England.

(Manuscript accepted 6th June 1999)