Microfungi on the *Pandanaceae*: *Zygosporium*, a review of the genus and two new species

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Zygosporium pacificum sp. nov. and *Z. pandanicola* sp. nov. are introduced based on specimens identified on *Pandanus* leaves collected in the Pacific island nations of Niue and Vanuatu, and the Philippines, respectively. Both species are compared with presently accepted species and a key to the genus is provided. Specimens of *Z. echinosporum*, *Z. gibbum*, *Z. minus* and *Z. oscheoides* were also collected from members of *Pandanaceae*.

Key words: anamorphic fungi, *Freycinetia*, hyphomycetes, key, *Pandanus*, taxonomy.

Introduction

Zygosporium was introduced with *Z. oscheoides* Mont. as the type species. The genus is characterised by hyphomycetes possessing darkly pigmented, incurved vesicular cells that give rise to 2-4 ampulliform conidiogenous cells. The vesicles may be stalked or sessile, borne from the side of a setiform conidiophore, or arise directly from the mycelium. The conidia are aseptate, typically ellipsoid or globose, smooth or variously ornamented and produced on ampulliform conidiogenous cells that are typically slightly upturned (Mason, 1941; Hughes, 1951). Various authors have reported that only one conidium is produced per conidiogenous cell (Mason, 1941; Hughes, 1951; Meredith, 1962). Meredith (1962) studied the conidial discharge mechanism of *Z. oscheoides* and concluded that violent discharge occurs, but in dry conditions only. Due to differential wall thickness, rapidly decreasing vapour pressure causes the vesicular conidiophore to first bend inwards, a gas phase releases built-up pressure and the vesicle springs outward, discharging mature conidia.

When Mason (1941) reviewed the genus *Zygosporium* the vesicular portion of the conidiophore that gives rise to the conidiogenous cells was

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referred to as the 'falx', and the setiform conidiophore that give rise to the vesicular cells as the 'falciphore'. Various authors since have adopted these terms (e.g. Hughes, 1951; Barron, 1968; Pirozynski, 1972; Thakur and Udipi, 1976; Subramanian and Bhat, 1987). In most previous assessments, the genus is described as not having true setae, the setiform structures being described as conidiophores or setiform conidiophores. However, *Z. deightonii* M.B. Ellis (Ellis, 1976) and *Z. echinosporum* Bunting & E.W. Mason (Hughes, 1951) both produce setiform structures that do not produce vesicles and are referred to here as true setae. Where species produce vesicles from the side of the setiform structures (e.g. *Z. geminatum* S. Hughes, *Z. majus* Piroz., *Z. minus* S. Hughes and *Z. oscheoides* Mont.), these structures are referred to as setiform conidiophores. To differentiate between the setiform and the vesicular part of the structure they are referred to as setiform conidiophores and vesicular conidiophores in the following descriptions. This more or less follows the terminology utilised by Ellis (1971, 1976).

Several taxa treated in *Zygosporium* require discussion. *Zygosporium blighiae* Gonz. Frag. & Cif. and *Z. paraense* Vincens were both treated as synonyms of *Z. oscheoides* by Mason (1941) and Hughes (1951), and this treatment is continued in the current manuscript. Mason (1941) treated *Z. mycophilum* (Vuill.) Sacc. as a synonym of *Z. parasiticum* (Grove) Bunting & E.W. Mason as the vesicular conidiophores of both species are borne directly on the superficial mycelium and the differences in conidial dimensions were not considered significant enough to warrant specific recognition. Hughes (1951) also discussed the synonymy of *Z. mycophilum*, but concluded that due to dimensional differences of various morphological characters, especially those of the conidia, it was better to consider the two species as separate. Hughes (1958) reviewed many type specimens of hyphomycetes housed in European herbaria including *Clasterosporium gibbum* Sacc. M. Rousseau & Bommer, which he transferred to *Zygosporium*. In addition he placed *Z. parasiticum* into synonymy with *Z. gibbum* (Sacc., Rousseau & Bommer) S.J. Hughes, as he considered the types of both species to be conspecific. The type specimen of *Z. gibbum* has nomenclatural priority over *Z. parasiticum*. *Urobasidium rostratum* Giesenh. was transferred to *Zygosporium* by Bunting and Mason (in Mason, 1941). This species, known only from the description and figure of its type collection, is similar in morphology to *Z. gibbum*. The major differences being slightly broader conidia (6-8 µm diam.) and the vesicular conidiophores are reported to produce only two conidiogenous cells. As *Z. gibbum* produces 2-3 conidiogenous cells per vesicular conidiophore, the difference in conidial size is small, and no new material has been collected

since its introduction, *Z. rostratum* (Giesenh.) Bunting & E.W. Mason is regarded here as inadequately known to treat.

This work originates from an ongoing study of the saprobic microfungi that inhabit members of the monocotyledon family *Pandanaceae* (McKenzie, 1995; McKenzie and Hyde, 1996; Hyde, 1997; Whitton *et al*., 1999, 2000). No species of *Zygosporium* has been described from members of the *Pandanaceae* (McKenzie and Hyde, 1996). However, *Z. oscheoides* has been reported from *Pandanus odoratissimus* (Hughes, 1951) and *P. tectorius* (Matsushima, 1975). In this paper, *Zygosporium pacificum* found on unidentified species of *Pandanus* in Niue and Vanuatu and *Z. pandanicola* found on *Pandanus simplex* in the Philippines are described as new and compared with currently accepted species. Brief descriptions are given for four other species of *Zygosporium* found on decaying leaves of *Freycinetia* or *Pandanus*. A key to *Zygosporium* species is provided, together with a synopsis of the genus (Table 1).

Key to species of *Zygosporium*

Measurements in some cases refer to composite dimensions from additional published specimens. Some measurements have been rounded up or down to nearest 0.5 µm as appropriate.

1. Vesicular conidiophores always or sometimes borne directly on superficial mycelium 2
1. Vesicular conidiophores always produced from the side of the setiform conidiophores 7

2. With setae 3
2. Without setae 4

3. Vesicular conidiophores with 3 conidiogenous cells and a short, sterile apical cell, stalk cells up to 45 µm long; interspersed with sterile setae, apex hyaline and swollen (6-8 µm wide); conidia ellipsoid, hyaline to pale brown, smooth or verruculose, 9-15 × 6-9 µm .... *Z. deightonii*
3. Vesicular conidiophores with 3-4 conidiogenous cells, no sterile apical cell, either borne on setiform conidiophores or arising directly from mycelium; setae sterile or with 1-2 vesicular conidiophores, apex hyaline and swollen (5-7 µm wide); conidia spherical, hyaline, verrucose, 6-11 µm diam. ..... *Z. echinosporum*

4. Vesicular conidiophores in stacked chains of 1-6, each with 2 conidiogenous cells, and a cylindrical sterile cell at the apex (12-36 µm long); conidia ovoid, hyaline, smooth, 5-10 × 3-5 µm ..... *Z. masonii*
4. Vesicular conidiophores not in stacked chains 5

5. Vesicular conidiophores with 2-3 conidiogenous cells and a sterile apical cell (7-11 µm long); conidia ovoid, hyaline, minutely verruculose, 6-11 × 4-7 µm ..... *Z. mycophilum*
5. Conidia spherical 6

6. Vesicular conidiophores with 2-3 conidiogenous cells and a sterile apical cell (5-8 µm long); conidia hyaline, smooth to minutely verruculose, 4-8 µm diam. ..... *Z. gibbum*
6. Vesicular conidiophores with 3-4 conidiogenous cells; conidia hyaline, smooth, 8.5-10 µm diam. ..... *Z. tonellianum*

7. Conidia spherical 8
7. Conidia not spherical 12

8. Conidia echinulate, spines up to 3.5 µm long, subhyaline to pale brown, 12.5-16.5 µm diam.; setiform conidiophores 81-98 µm long, apical cell hyaline to pale-brown, tapering, sparsely roughened ..... *Z. tuberculatum*
8. Conidia not echinulate 9

9. Conidia tuberculate, raised areas flattened and irregular in shape, brown, 11-14.5 µm diam.; setiform conidiophores 60-100 µm long, apical cell subhyaline, smooth, narrowly clavate (2-2.5 µm wide) ..... *Z. pandanicola*
9. Conidia not tuberculate 10

10. Conidia verrucose or coarsely roughened 11
10. Conidia smooth, hyaline, 7-10 µm diam.; setiform conidiophores 20-70 µm long, apical cell hyaline, smooth, swollen (3-4 µm wide) ..... *Z. chartarum*

11. Conidia coarsely roughened, pale brown, 13-18 µm diam.; setiform conidiophores 75-100 µm long, apical cell subhyaline, smooth, tapering or narrowly clavate (1.5-2 µm wide) ..... *Z. majus*
11. Conidia verrucose, hyaline to pale-brown, 5.5-10 µm diam.; setiform conidiophores 35-50 µm long, apical cell subhyaline, smooth, narrowly clavate (1.5 µm wide) ..... *Z. minus*

12. Conidia tuberculate, raised areas flattened 13
12. Conidia smooth or minutely verruculose 14

13. Conidia ellipsoid, pale brown to brown, 20-30 × 8-11 µm; setiform conidiophores 65-110 µm long, apical cell subhyaline, sparsely echinulate, narrowly clavate (2-3.5 µm wide) ..... *Z. geminatum*
13. Conidia ellipsoid, pale brown, 11-16 × 6.5-7.5 µm; setiform conidiophores 53-61 µm long, apical cell subhyaline, smooth, narrowly clavate (2-2.5 µm wide) ..... *Z. pacificum*

14. Conidia ellipsoid, hyaline to pale-brown, smooth to minutely verruculose, 7-12.5 × 4-9 µm; setiform conidiophores 30-60 µm long, apical cell subhyaline, smooth, acute or narrowly clavate ..... *Z. oscheoides*
14. Conidia ovoid, hyaline, smooth, 6.5-13.5 × 5-6 µm; setiform conidiophores up to 45 µm long, apical cell hyaline, smooth and narrowly clavate or obtuse, erect lateral branch 46-75 µm long also produced ..... *Z. verticillatum*

Taxonomy

Zygosporium Mont., Annales des Sciences Naturelles, Botanique, Séries 2, 17: 120 (1842).

= *Pimina* Grove, Journal of Botany, London 26: 206 (1888).
= *Urobasidium* Giesenh., Flora, Jena 76: 139 (1893).

= *Urophiala* Vuill., Bulletin des Séances de la Société des Sciences de Nancy 11: 169 (1910).

Type species: *Zygosporium oscheoides* Mont., Annales des Sciences Naturelles, Botanique, Séries 2, 17: 120 (1842).

Zygosporium echinosporum Bunting & E.W. Mason, Mycological Papers 5: 135 (1941).

Setae and setiform conidiophores 2-4-septate, spherical head 4-7 µm wide, overall length 51-140 µm, 2-3 µm wide towards the base. *Conidiophore* stalk cell/s 12-40 × 2-3 µm, vesicular cell 9-14 × 5-6 µm. *Conidiogenous cells* 3-4 per vesicular cell, 6-10 × 3.5-5.5 µm. *Conidia* 6-10.5 µm diam.

Habitat: Known to inhabit decaying leaves of *Areca catechu*, *Artocarpus* sp., *Cocos nucifera*, *Cola lateritia*, *Cordia* sp., *Desplatzia lutea*, *Ficus* sp., *Glycine max*, *Hyphaene thebaica*, *Laurus nobilis*, *Livistona chinensis*, *Millettia* sp., *Pancovia bijuga*, *Pandanus simplex*, *Phormium tenax*, *Swietenia macrophylla*, *Theobroma* sp. and unidentified palm petioles, also isolated from cheese and air.

Known distribution: Brazil (Gusmão *et al*., 2001), Ghana (Hughes, 1951, 1952), Hawaii (Wang and Baker, 1967), Hong Kong (Yanna *et al*., 2001), India (UKNCC, 2002), Malaysia (UKNCC, 2002), Nigeria (Ellis, 1971), Peru (Matsushima, 1993), Philippines (current specimen), Sierra Leone (Ellis, 1971), Taiwan (Matsushima, 1980), Trinidad (Ellis, 1971), UK (Sutton and Pirozynski, 1963; Kirk, 1983).

Material examined: PHILIPPINES, Luzon Island, Quezon Region, Laguna, Baranggay Bakas Luisiana, on decaying leaves of *Pandanus simplex*, 22 October 1996, S.R. Whitton [HKU(M) 12908, 12916].

Notes: *Zygosporium echinosporum* is characterised by vesicular conidiophores being borne from the side of setiform conidiophores or directly from the superficial mycelium. The conidia are spherical, hyaline or pale, verruculose and 6-9 µm diam. (Hughes, 1951; Ellis, 1971; Kirk, 1983). The current specimen agrees with the description for *Z. echinosporum* given by Hughes (1951) with little observable variation; the slightly larger conidial diam. is thought to represent natural variation.

Zygosporium gibbum (Sacc., M. Rousseau & E. Bommer) S. Hughes, Canadian Journal of Botany 36: 825 (1958).

≡ *Clasterosporium gibbum* Sacc., M. Rousseau & E. Bommer, in Saccardo, Atti della Reale Istituto Scienze, Lettere ed Arti, VI, 2: 455 (1884).

= *Pimina parasitica* Grove, Journal of Botany, London 26: 206 (1888).

≡ *Urophiala parasitica* (Grove) A.L. Sm., Transactions of the British Mycological Society 6: 296 (1920).

≡ *Zygosporium parasiticum* (Grove) Bunting & E.W. Mason, Mycological Papers 5: 137 (1941).

Conidiophores 1-3 stalk cells, 6-17 × 3.5-4.5 µm, vesicular cell 11-14 × 6.5-8 µm, apical cylindrical appendage 4.5-8 × 3-4 µm. *Conidiogenous cells* 3 per vesicle, 6-8 × 3.5-4.5 µm. *Conidia* 5-6.5 µm diam.

Habitat: On decaying plant parts of *Acacia confusa*, *A. koa*, *A. koa* var. *hawaiiensis*, *Artocarpus* sp., *Avicennia officinalis*, *Bischofia javanica*, *Borassus* sp., *Camelia japonica*, *Ceriops decandra*, *Cola* sp., *Culcasia* sp., *Dacrydium cupressinum*, *Dioscorea* sp., *Elaeis* sp., *Eucalyptus saligna*, *E. tereticornis*, *Euonymus* sp., *Ficus* sp., *Hydnocarpus* sp., *Hyphane* sp., *Ilex aquifolium*, *Juncus roemerianus*, *Landolphia* sp., *Laurus nobilis*, *Litsea* sp., *Magnolia obovata*, *Mangifera indica*, *Matayba domingensis*, *Metrosideros collina*, *M. collina* subsp. *polymorpha*, *Metroxylon sagu*, *Musa* sp., *Nephelium* sp., *Ochthocosmus* sp., *Pandanus* sp., *Passiflora* sp., *Phormium tenax*, *Phyllostachys* sp., *Podocarpus* sp., *P. macrophyllus*, *Polypodium* sp., *Pteridium aquilinum*, *Quercus* sp., *Quercus phillyraeoides*, *Rhododendron ponticum*, *Rhopalostylis sapida*, *Sequoia sempervirens*, *Smilax* sp., and unidentified palm petiole.

Known distribution: Costa Rica (Ellis, 1971), Cuba (Holubová-Jechová and Mercado Sierra, 1986), Hawaii (Baker *et al*., 1979; Raabe *et al*., 1981), Hong Kong (Ellis, 1971), Ghana (Ellis, 1971), India (Vittal and Dorai, 1994; Sarma and Vittal, 2001; UKNCC, 2002), Japan (Matsushima, 1975; Hatano, 2002), New Zealand (Hughes, 1978), Pakistan (Ellis, 1971), Papua New Guinea (Shaw, 1984), Sabah (Ellis, 1971), Sierra Leone (Ellis, 1971), Solomon Islands (Ellis, 1971), Taiwan (Matsushima, 1980), UK (Kirk, 1981, 1983), USA (Sutton, 1978; Miller, 1991), Vietnam (current specimen).

Material examined: VIETNAM, Nah Trang, on decaying leaves of *Pandanus* sp., 28 May 1997, J.G. Wright [HKU(M) 12910].

Notes: *Zygosporium gibbum* is characterised by stalked vesicular conidiophores that are produced directly from the superficial mycelium. No setiform conidiophores or setae are produced. The conidia are spherical, hyaline, smooth to finely verruculose, and 4.5-6 µm diam. (Ellis, 1971). The only observable difference from the description given by Ellis (1971) for *Z. gibbum* is the slightly wider conidia, which is interpreted as natural variation.

Zygosporium minus S. Hughes, Mycological Papers 44: 6 (1951).

Setiform conidiophores 3-5-septate, 30-140 µm long, 2-4 µm wide towards the base, 1-1.5 µm wide at the apical septa. *Vesicular conidiophores* 1 stalk cell, 3-7 × 2.5-5.5 µm, vesicular cell 9-16 × 4.5-9 µm. *Conidiogenous cells* 2 per vesicle, 4-10 × 4-5.5 µm. *Conidia* 5.5-10 µm diam.

Habitat: Known to inhabit decaying leaves of *Artocarpus nobilis*, *Cocos* sp., *Cola lateritia*, *Corynocarpus laevigatus*, *Crinum* sp., *Dracaena* sp., *Elaeis* sp., *Ficus* sp., *Hibiscus* sp., *Livistona chinensis*, *Musa* sp., *Pandanus* sp., *P. copelandii*, *P. simplex*, *P. tectorius*, *Panicum* sp., *Phormium tenax*, *Polyalthia* sp., *Rhopalostylis sapida*, *Solanum aculeatum*, *Tabebuia serratifolia*, *T. shaferi*, *Tournefortia hirsutissima* and various unidentified leaves.

Known distribution: Cuba (Ellis, 1971), Fiji (current specimen), Ghana (Hughes, 1951), Hong Kong (Yanna *et al*., 2001; current specimen), India (Ellis, 1971), New Zealand (Hughes, 1978; McKenzie, 1991), Peru (Matsushima, 1993), Philippines (current specimens), Sierra Leone (Ellis, 1971), Tanzania (Ellis, 1971), Venezuela (Ellis, 1971), Zambia (Ellis, 1971).

Material examined: FIJI, Viti Levu Island, Naduruvatu, on decaying leaves of *Pandanus* sp., 15 February 1996, E.H.C. McKenzie (PDD 65787). HONG KONG, Lantau Island, north end of Discovery Bay, on decaying leaves of *Pandanus tectorius*, 6 August 1995, S.R. Whitton [HKU(M) 12915]. PHILIPPINES, Luzon Island, Quezon Region, Baranggay Maragondon Real, on decaying leaves of *P. copelandii*, 21 October 1996, S.R. Whitton

[HKU(M) 12911]; Luzon Island, Quezon Region, Laguna, Baranggay Bakas Luisiana, on decaying leaves of *P. simplex*, 22 October 1996, S.R. Whitton [HKU(M) 12912].

Notes: *Zygosporium minus* is characterised by setiform conidiophores, which are often slightly swollen and pale at the apex, and produce vesicular conidiophores typically just above the basal septum. The vesicular conidiophores give rise to two conidiogenous cells that in turn produce spherical, hyaline to pale brown, verruculose, 6-9 µm diam. conidia (Ellis, 1971). Morphologically, *Z. majus* is similar to *Z. minus*, but has larger conidia (13-18 µm diam.) and is reported to be a plant pathogen (Pirozynski, 1972; Ellis, 1976). The current specimens agree with the descriptions of *Z. minus*, the small variation in conidial size is thought to represent natural variation.

Zygosporium oscheoides Mont., Annales des Sciences Naturelles, Séries 2, 77: 121 (1842).

= *Cladotrichum passiflorae* Pim, Gardener's Chronicle 24: 724 (1885).

= *Zygosporium paraense* Vincens, Bulletin de la Société de Pathologie Végétale France 2: 19 (1915).

= *Zygosporium blighiae* Gonz. Frag. & Cif., Boletin de la Sociedad Española de Historia de la Natural 27: 332 (1927).

Setiform conidiophores 3-4-septate, 41-65 µm long, 2-3.5 µm wide towards the base, 1-1.5 µm wide at the apical septa. *Vesicular conidiophores* 1 stalk cell, 4.5-6 × 3-5 µm, vesicular cell 10-13 × 6-7.5 µm. *Conidiogenous cells* 2 per vesicle, 5-6 × 4.5-6 µm. *Conidia* 8-13.5 × 6-8 µm.

Habitat: Known to inhabit decaying leaves of *Agathis alba*, *Ananas comosus*, *Annona muricata*, *Anthurium* sp., *Areca catechu*, *A. lutescens*, *Arenga engleri*, *Artocarpus altilis*, *A. communis*, *A. incisa*, *A. integrifolia*, *A. nobilis*, *Bauhinia tomentosa*, *Borassus aethiopum*, *Caladium bicolor*, *Calotropis procera*, *Carica papaya*, *Carludovica insignis*, *Carpodinus hirsuta*, *Cecropia* sp., *Chamaedora* sp., *Citrus sinensis*, *Cocos nucifera*, *Cola lateritia*, *Crinum* sp., *Culcasia scandens*, *Cupania glabra*, *Desmodium* sp., *Desplatzia lutea*, *Dichapetalum flexuosum*, *Drypetes* sp., *Duranta repens*, *Elaeis guineensis*, *Encephalortos barteri*, *Erythrina senegalensis*, *Eucalyptus* sp., *Fagara xanthoxyloides*, *Ficus* sp., *F. elastica*, *Freycinetia* sp., *F. wilderi*, *Heliconia brasiliensis*, *Hevea brasiliensis*, *Hugonia* sp., *Livistona* sp., *L. chinensis*, *Mallotus oppositifolius*, *Malpighia punicifolia*, *Miscanthus sinensis*, *Musa acuminata*, *M. paradisiaca*, *M. sapientum*, *Nephthytis picturata*, *Nolina rucurvata*, *Ochthocosmus africanus*, *Pancovia bijuga*, *Pandanus* sp., *P. odoratissimus*, *P. tectorius*, *P. tectorius* var. *liukiuensis*, *P. wilderi*, *Passiflora suberosa*, *Petiveria alliacea*, *Phoenix reclinata*, *Phormium* sp., *P. tenax*, *Phyla strigillosa*, *Phyllanthus discoideus*, *Pisonia rotundata*, *Pithecellobium dulce*, *Podocarpus* sp., *Polianthes tuberosa*, *Polypodium* sp., *Pothos aureus*, *Rhopalostylis sapida*, *Ribes nigrum*, *Roystonea regia*, *Saccharum officinarum*, *Setaria chevalieri*, *Theobroma cacao*, *Thunbergia* sp., *Vanilla planifolia*, *Yucca gloriosa* and unidentified leaves, also isolated from air.

Known distribution: Brazil (Ellis, 1971; Abarca and Mercado Sierra, 1998), Congo (Ellis, 1971), Cook Islands (current specimen), Cuba (Hughes, 1951; Holubová-Jechová and Mercado Sierra, 1986), Ghana (Hughes, 1951), Guernsey (Ellis, 1971), Hawaii (Raabe *et al*., 1981), Hong Kong (Photita *et al*., 2001; Yanna *et al*., 2001; current specimen), India (Ellis,

1971), Jamaica (Ellis, 1971), Japan (Matsushima, 1975), Malaysia (Peregrine and Ahmad, 1982), Mauritius (Hughes, 1951), Mexico (Mercado Sierra and Heredia, 1994), New Zealand (Hughes, 1978), Nigeria (UKNCC, 2002), Panama (Goos and Pirozynski, 1975), Papua New Guinea (Matsushima, 1971; Shaw, 1984), Peru (Matsushima, 1993), Philippines (Teodoro, 1937), Samoa (Ellis, 1971; current specimen), Seychelles (Hughes, 1951), Sierra Leone (Hughes, 1951), Sri Lanka (Ellis, 1971), St Helena (Hughes, 1951), Tanzania (Matsushima, 1980), Togo (Hughes, 1951), Uganda (Hughes, 1951), UK (Dennis, 1986), USA (Hughes, 1951; Morgan-Jones, 1974; Sutton, 1978), Vanuatu (Ellis, 1971), Venezuela (Ellis, 1971), Vietnam (current specimen).

Material examined: COOK ISLANDS, Rarotonga, on decaying leaves of *Freycinetia wilderi*, August 1987, R.A. Fullerton (PDD 49589). HONG KONG, New Territories, Sai Kung Peninsula, on decaying leaves of *Pandanus tectorius*, 1 April 1994, E.H.C. McKenzie and K.D. Hyde (PDD 63331). SAMOA, on decaying leaves of *Freycinetia* sp., June 1987, P.C. Gardner (PDD 45629). VIETNAM, Nah Trang, on decaying leaves of *Pandanus* sp., 28 May 1997, J.G. Wright [HKU(M) 12913].

Notes: *Zygosporium oscheoides*, which is the commonest species of *Zygosporium* (Ellis, 1971), is characterised by setiform conidiophores that are slightly swollen and pale at the apex. These give rise to a single vesicular conidiophore just above the basal septum. The vesicular conidiophore in turn gives rise to two pale conidiogenous cells that produce ellipsoid, hyaline to pale brown, smooth to minutely verruculose, 7-12 × 4-7 µm conidia (Hughes, 1951; Ellis, 1971). The current specimens show very little variation from the description given by Hughes (1951) for *Z. oscheoides*; the slight difference in conidial size is interpreted as natural variation.

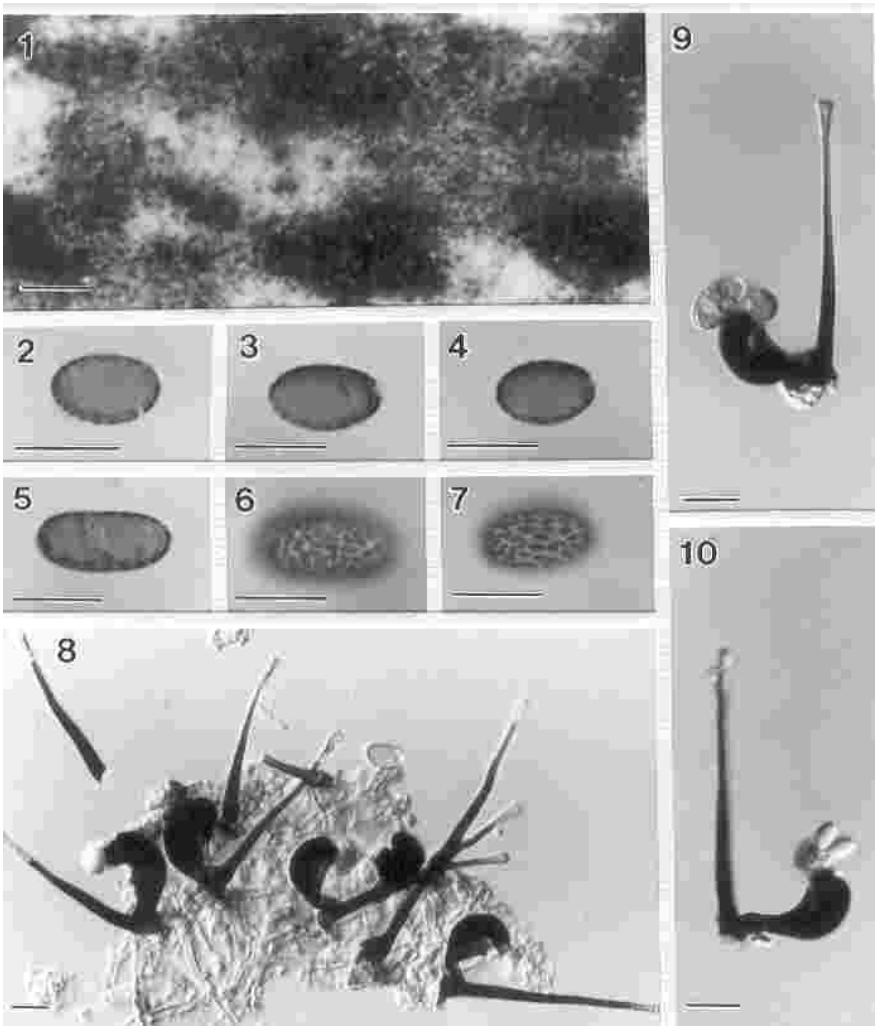
Zygosporium pacificum Whitton, McKenzie & K.D. Hyde, **sp. nov.**

(Figs. 1-10)

Etymology: *pacificum*, refers to the known distribution, Niue and Vanuatu, South Pacific.

Coloniae effusae. *Mycelium* partim superficiale, partim immersum, partim in substrato superficiale cylindricae, brunneae, laevia, septatis, ramosa, 2-3 µm diam. *Setiforma conidiophora* 53-61 µm longa, 3.5-5 µm lata ad basim, 1-2 µm lata ad apicem septata, erecta, plerumque recta, curvus vel flexuosa, laevia vel irregularis verrucosa, 3-septata, brunnae vel atrobrunnea, cellula apicem pallidae brunnea vel hyalinea, crassitunicata, cellula apicalis parce inflata (2-2.5 µm) et obtuse. *Vesicula conidiophora* lateralem ad suprabasalis, complectens de tres cellula; cellula ad stipitis, cylindrica, brunneae vel atrobrunnea, crassitunicata, laevia; cellula vesicula atrobrunnea vel atra, crassitunicata, laevia, inflata, introrsus curvati, 19-28 × 8-12.5 µm. *Cellulae conidiogenae* enatus vel cellula vesiculae, monoblasticae, discretae, inflatae, ampulliformae vel globosa, introrsus curvatae, laeviae vel parce verrucosa, pallidiae brunneae, apice obtusae, 6-8 µm diam. *Conidia* 11-16 × 6.5-7.5 µm, solitaria, sicca, ellipsoidea, crassitunicata, aseptata, pallidea brunnea, rotundata ad extremum, crassus verrucosa.

Colonies effuse to compact, forming a thin, irregular shaped patch on the substrate surface, black. *Mycelium* superficial and immersed, superficial hyphae cylindrical, brown fading to pale brown away from the base of the setae, smooth, septate, branched, 2-3 µm diam. *Stroma* none. *Hyphopodia*



Figs. 1-10. *Zygosporium pacificum* (from holotype). **1.** Colony on substratum. **2-7.** Conidia. Note the tuberculate ornamentation. **8-10.** Setiform conidiophores with attached vesicular conidiophores. Note the superficial mycelium in Fig. 8. Bars: 1 = 500 µm; 2-10 = 10 µm.

absent. *Setiform conidiophores* 53-61 µm long, 3.5-5 µm wide towards the base, 1-2 µm wide at the apical septa, erect, typically straight, sometimes curved or flexuous, tapered from the base towards the apex, smooth or with irregular granules, typically 3-septate, brown or dark brown, apical cell paler, thickened walls and septa, especially towards the base, apical cell thin walled, slightly enlarged (2-2.5 µm) and obtuse, first cell giving rise to a single vesicular conidiophore, basal cell concolourous with the lower parts of the setae, and branching in two directions, becoming part of the mycelium and connecting the conidiophores with each other. *Vesicular conidiophores*

typically arising at the base of the first cell of the setiform conidiophore, consisting of three cell types; stalk cell cylindrical, brown to darkish brown, thick walled, smooth, dark brown to black, thick walled, smooth; vesicular cell swollen, upwardly curved, 19-28 × 8-12.5 µm; 2 conidiogenous cells; inner curvature of the vesicular cell paler than the rest of the cell. *Conidiogenous cells* monoblastic, discrete, determinate, swollen, ampulliform to almost globose, upwardly curved, smooth or minutely verrucose, pale brown to almost hyaline, apex obtuse, 6-8 µm diam. *Conidia* 11-16 × 6.5-7.5 µm, solitary, dry, elliptical, thick walled, aseptate, pale brown, both ends rounded, coarsely verrucose with raised and flattened ornamentation.

Habitat: Known to inhabit decaying leaves of *Pandanus* sp.

Known distribution: Niue, Vanuatu.

Material examined: VANUATU, Espiritu Santo Island, South Santo, on decaying leaves of *Pandanus* sp., 31 October 1996, E.H.C. McKenzie [HKU(M) 12914, **holotype designated here**]. NIUE, on decaying leaves of *Pandanus* sp., 10 October 2000, E.H.C. McKenzie (PDD 72254).

Notes: The conidiophore morphology of *Z. pacificum* is similar to that of *Z. majus*, *Z. minus* and *Z. pandanicola*, but it differs in regard to conidial morphology (Ellis, 1971, 1976). The conidia of *Z. oscheoides* are similar to *Z. pacificum*, but are smaller (7-12 × 4-7 µm) and with different ornamentation morphology. In addition, the vesicular conidiophores of *Z. oscheoides* are borne directly on the superficial hyphae as well as on the setiform conidiophores (Ellis, 1971), a situation that has not been observed in *Z. pacificum*. The conidia of both *Z. minus* and *Z. majus* are spherical (Ellis, 1971, 1976; Pirozynski, 1972).

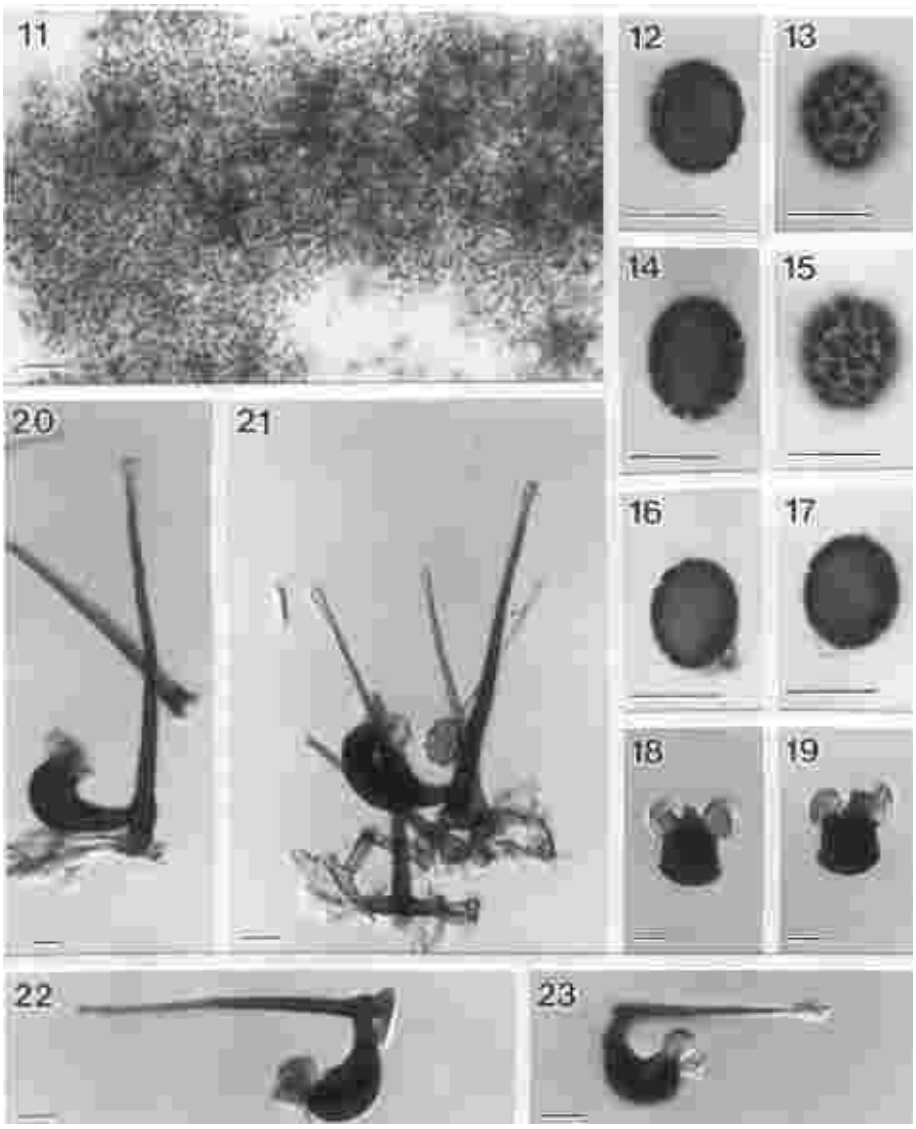
Zygosporium pandanicola Whitton, McKenzie & K.D. Hyde, **sp. nov.**

(Figs. 11-23)

Etymology: *pandanicola*, refers to the type substrate, *Pandanus*.

Coloniae effusae. *Mycelium* plerumque superficiale, partim in substrato superficiale, cylindricae, pallidae brunneae, laevia, septatis, ramosa, 2.5-4 µm diam. *Setiforma conidiophora* 60-100 µm longa, 4-5.5 µm lata ad basim, 1-1.5 µm lata ad apicem septata, erecta, recta, curvus vel flexuosa, laevia, 3-4-septata, brunnae, crassitunicata, cellula apicalis parce inflata (2-2.5 µm) et obtuse. *Vesicula conidiophora* lateralem ad suprabasalis, complectens de tres cellula; cellula ad stipitis, cylindrica, brunneae, crassitunicata, laevia, 5-8 × 4.5-5 µm; cellula vesicula brunneae vel atrobrunnea, crassitunicata, laevia, inflata, introrsus curvati, 15.5-16 × 8.5-9 µm. *Cellulae conidiogenae* enatus vel cellula vesiculae, monoblasticae, discretae, inflatae, ampulliformae, introrsus curvatae, laeviae, pallidiae brunneae, apice obtusae, 6-11 × 6.5-9 µm. *Conidia* 11-14.5 µm diam., solitaria, sicca, spherica vel late ellipsoidea, aseptata, brunnea, crassitunicata, grosse verrucosa.

Colonies effuse to compact, forming a thin, irregular-shaped patch on the substrate surface, black. *Mycelium* mostly superficial, cylindrical, pale brown, smooth, septate, branched, 2.5-4 µm diam., slightly thickened walls. *Stroma*



Figs. 11-23. *Zygosporium pandanicola* (from holotype). **11.** Colony on substratum. **12-17.** Conidia. **18, 19.** Vesicular conidiophores showing the two conidiogenous cells. **20-23.** Setiform conidiophores with attached vesicular conidiophores. Note the superficial hyphae in Fig. 21. Bars: 11 = 500 µm; 12-23 = 10 µm.

none. *Hyphopodia* absent. *Setiform conidiophores* 60-100 µm long, 4-5.5 µm wide towards the base, 1-1.5 µm wide at the apical septa, erect, straight, curved or flexuous, tapered from the base, narrowing towards the apex, smooth, 3-4-septate, brown except for the pale apical cell, thickened walls and septa, apical

Table 1. Synopsis of *Zygosporium*.

Species	Conidia		Setiform conidiophores (or setae)		Vesicular conidiophores		
	Morphology	**Size (µm)**	**Morphology**	**Size (µm)**	**Morphology**	**Size (µm)**	**Conidiogenous cells per VC**
Z. chartarum	Spherical, smooth, hyaline	7-10	Dark brown below, hyaline, swollen (3-4 µm) and smooth at the apex	20-70 × 3-3.5	Dark brown, arising from SC, 1 per SC	4-5 × 8-12	2
Z. deightonii	Ellipsoid, smooth or verruculose, hyaline to pale-brown	9-15 × 6-9	Dark brown below, hyaline, swollen (6-8 µm) and smooth at the apex	60-130 × 2-3	Dark brown, arising from the mycelium, short, pale-brown, sterile cell at apex	up to 45 × 7-9 wide	3
Z. echinosporum	Spherical (rarely ellipsoid), verruculose, hyaline to yellowish	6-11	Dark brown below, hyaline, swollen (5-7 µm) and smooth at the apex	50-300 × 2-4	Dark brown, arising from SC or mycelium, 1-5 per SC	9-15 × 6.5-10	3-4
Z. geminatum	Ellipsoid, tuberculate, raised areas flattened, pale brown to brown	20-30 × 8-11	Dark brown below, hyaline, clavate and sparsely echinulate at the apex	65-110 × 3.5-5	Dark brown, arising from SC, 1 per SC	12-15 × 6-8	2
Z. gibbum	Spherical, smooth to minutely verruculose, hyaline	4-8	Absent, 1 cylindrical stalk cell	NA	Dark brown, arising directly from mycelium, pale-brown sterile cell at apex	10-15 × 7-9	2-3
Z. majus	Spherical, coarsely roughened, pale-brown, basal scar	13-18	Dark brown below, hyaline, clavate and smooth at the apex	75-100 × 3.5-5	Dark brown, arising from SC, 1 per SC	13-20 × 7-12	2
Z. masonii	Ovoid, smooth, hyaline	5-10 × 3-5	Absent, 1-6 cylindrical stalk cells	Stalk cells 7-50 × 2-2.5	Dark brown, arising directly from mycelium, often in a chain of 2-6 VC, pale sterile cell at apex (12-36 × 1-2.5 µm)	6-12 × 4-6	2
Z. minus	Spherical, minutely verruculose, hyaline to pale-brown	5.5-10	Dark brown below, hyaline, clavate and smooth at the apex	35-50 × 2-3	Dark brown, arising from SC, 1 per SC	8-12 × 3.5-8	2

Measurements in some cases refer to composite dimensions from additional published specimens. Some measurements have been rounded up or down to nearest 0.5 µm as appropriate. SC = setiform conidiophore, VC = vesicular conidiophores.

Table 1. (continued).

Species	Conidia		Setiform conidiophores (or setae)		Vesicular conidiophores		
	Morphology	**Size (µm)**	**Morphology**	**Size (µm)**	**Morphology**	**Size (µm)**	**Conidiogenous cells per VC**
Z. mycophilum	Ovoid, minutely verruculose, hyaline, minute basal scar	6-11 × 4-7	Absent, 1-6 cylindrical stalk cells	Stalk cells 6-54 × 2-3	Dark brown, arising directly from mycelium, rarely in a chain of 2 VC, pale sterile cell at apex (7-11 × 2-3 µm)	11-15 × 6-8	3
Z. oscheoides	Ellipsoid, smooth to minutely verruculose, hyaline to pale-brown	7-12.5 × 4-9	Dark brown below, hyaline, clavate and smooth at the apex	30-60 × 3-4	Dark brown, arising from SC, 1 per SC	9-18 × 7-9	2
Z. pacificum	Ellipsoid, tuberculate, pale brown	11-16 × 6.5-7.5	Dark brown below, hyaline, clavate and smooth at the apex	53-61 × 3.5-5	Dark brown, arising from SC, 1 per SC	19-28 × 8-12.5	2
Z. pandanicola	Spherical, tuberculate to capitate, raised areas flattened, brown	11-14.5	Dark brown below, hyaline, clavate and smooth at the apex	67-86 × 4-5.5	Dark brown, arising from SC, 1 per SC	15.5-16 × 8.5-9	2
Z. tonellianum	Spherical, smooth, hyaline	8.5-10	Absent, 1-3 cylindrical stalk cells	Stalk cells 15-50 × 2.4-3.5	Dark brown, arising directly from mycelium	9.5-12 × 7-8.5	3-4
Z. tuberculatum	Spherical, spiny, subhyaline to pale brown, spines up to 3.5 long	12.5-16.5	Dark brown below, subhyaline and roughened at apex	81-98 × 4.5-7.5	Dark brown, arising from SC, 1 per SC	15-19.5 × 9-11	2(-3)
Z. verticillatum	Ovoid, smooth, hyaline	6.5-13.5 × 5-6	Dark brown below, apex hyaline, obtuse; with brown, apically acute lateral branch (46.5-75 × 1.5 µm)	6.5-25 × 1.5	Dark brown, arising from SC, 2-3 per SC	8-15 × 3-6.5	2

cell slightly enlarged (2-2.5 µm) and obtuse, upper section of the setiform conidiophore sterile, first cell giving rise to a single vesicular conidiophore, basal cell concolourous with the lower parts of the setae, branching in two directions becoming part of the mycelium and connecting the conidiophores with each other. *Vesicular conidiophores* arising on the side of the first cell of the setiform conidiophore, comprised of three cell types; stalk cell cylindrical, brown, thick walled, smooth, 5-8 × 4.5-5 µm; vesicular cell dark brown to black, thick walled, smooth, swollen, upwardly curved, inner curvature paler than the rest of the cell, 15.5-16 × 8.5-9 µm; 2 conidiogenous cells. *Conidiogenous cells* arise directly from the vesicular cell, monoblastic, discrete, determinate, swollen, ampulliform, upwardly curved, smooth, pale brown, apex obtuse, 6-11 × 6.5-9 µm. *Conidia* 11-14.5 µm diam., solitary, dry; initially globose, hyaline, smooth; spherical to broadly ellipsoid, aseptate, brown, thick-walled, covered by brown, raised, flattened, tuberculate ornamentation at maturity.

Habitat: Known to inhabit decaying leaves of *Pandanus simplex*.

Known distribution: Philippines.

Material examined: PHILIPPINES, Luzon Island, Quezon Region, Laguna, Baranggay Bakas Luisiana, on decaying leaves of *Pandanus simplex*, 22 October 1996, S.R. Whitton [HKU(M) 12919, **holotype designated here**]. PHILIPPINES, Luzon Island, Quezon Region, Laguna, Baranggay Bakas Luisiana, on decaying leaves of *Pandanus simplex*, 22 October 1996, S.R. Whitton [HKU(M) 12918]; Luzon Island, Quezon Region, Laguna, Baranggay Bakas Luisiana, on decaying leaves of *P. simplex*, 23 October 1996, S.R. Whitton [HKU(M) 12909, 12917, 12920].

Notes: Conidiophore morphology and conidial shape in *Z. pandanicola* is similar to *Z. majus*, *Z. minus*, *Z. oscheoides* and *Z. pacificum*. In *Z. pacificum* the conidia are elliptical and pale brown whilst in *Z. oscheoides* the conidia are smooth or minutely verruculose, pale in pigmentation, elliptical, and the vesicular conidiophores are produced both on the setiform conidiophores and directly from the superficial mycelium (Ellis, 1971). The conidia of *Z. minus* are smaller (6-9 µm diam.), hyaline to pale and verruculose, and those of *Z. majus* are generally larger (13-18 µm diam.), verrucose and pale brown (Ellis, 1971, 1976; Pirozynski, 1972).

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References

Abarca, G.H. and Mercado Sierra, A. (1998). Tropical hyphomycetes of Mexico 3. Some species from the Calakmal Biosphere Reserve, Campeche. Mycotaxon 68: 137-143.

Baker, G.E., Dunn, P.H. and Sakai, W.S. (1979). Fungus communities associated with leaf surfaces of endemic vascular plants in Hawaii. Mycologia 71: 272-292.

Barron, G.L. (1968). *The Genera of Hyphomycetes from Soil*. The Williams & Wilkins Company, Baltimore, USA.

Dennis, R.W.G. (1986). *Fungi of the Hebrides*, Royal Botanic Garden, Kew.

Ellis, M.B. (1971). *Dematiaceous Hyphomycetes*. Commonwealth Mycological Institute, Kew, Surrey, England.

Ellis, M.B. (1976). *More Dematiaceous Hyphomycetes*. Commonwealth Mycological Institute, Kew, Surrey, England.

Goos, R.D. and Pirozynski, K.A. (1975). Fungi of Barro Colorado Island: new and interesting hyphomycetes. Canadian Journal of Botany 53: 2927-2932.

Gusmão, L.F.P., Grandi, R.A.P. and Milanez, A.I. (2001). Hyphomycetes from leaf litter of *Miconia cabussu* in a Brazilian Atlantic rain forest. Mycotaxon 79: 201-213.

Hatano, K. (2002). *Institute for Fermentation, Osaka (IFO)*. http://www.ifo.or.jp, date accessed (2 September 2002).

Holubová-Jechová, V. and Mercado Sierra, A. (1986). Studies on hyphomycetes from Cuba IV. Dematiaceous hyphomycetes from the Province Pinar del Rio. Česká Mykologie 40: 142-164.

Hughes, S.J. (1951). Studies on micro-fungi X. *Zygosporium*. Mycological Papers 44: 1-18.

Hughes, S.J. (1952). Fungi from the Gold Coast I. Mycological Papers 48: 1-91.

Hughes, S.J. (1958). Revisiones Hyphomycetum aliquot cum appendice de nominibus rejiciendis. Canadian Journal of Botany 36: 727-836.

Hughes, S.J. (1978). New Zealand Fungi 25. Miscellaneous species. New Zealand Journal of Botany 16: 311-370.

Hyde, K.D. (1997). Ascomycetes described on *Freycinetia*. Sydowia 49: 1-20.

Kirk, P.M. (1981). New or interesting microfungi III. A preliminary account of microfungi colonising *Laurus nobilis* leaf litter. Transactions of the British Mycological Society 77: 457-473.

Kirk, P.M. (1983). New or interesting microfungi X. Hyphomycetes on *Laurus nobilis* leaf litter. Mycotaxon 18: 259-298.

Mason, E.W. (1941). Annotated account of fungi received at the Imperial Mycological Institute. Mycological Papers 5: 103-144.

Matsushima, T. (1971). *Microfungi of the Solomon Islands and Papua New Guinea*. Published by the author, Kobe, Japan.

Matsushima, T. (1975). *Icones Microfungorum a Matsushima Lectorum*. Published by the author, Kobe, Japan.

Matsushima, T. (1980). *Saprophytic Microfungi from Taiwan, Matsushima Mycological Memoirs 1*. Published by the author, Kobe, Japan.

Matsushima, T. (1993). *Matsushima Mycological Memoirs 7*. Published by the author, Kobe, Japan.

McKenzie, E.H.C. (1991). Fungi of the Chatham Islands. Mycotaxon 41: 195-217.

McKenzie, E.H.C. (1995). Dematiaceous hyphomycetes on *Pandanaceae*. 5. *Sporidesmium* sensu lato. Mycotaxon 56: 9-29.

McKenzie, E.H.C. and Hyde, K.D. (1996). Index of fungi described from the *Pandanaceae*. Mycotaxon 57: 125-144.

Mercado Sierra, A. and Heredia, G. (1994). Hyphomycetes associated with plant litter from the State of Veracruz, Mexico. Revista Mexicana de Micologia 10: 33-48.
Meredith, D.S. (1962). Spore discharge in *Cordana musae* (Zimm.) Höhnel and *Zygosporium oscheoides* Mont. Annals of Botany 26: 233-241.
Miller, J.W. (1991). Bureau of Plant Pathology. Tri-ology Technical Report of Division, Plant Industry, Florida 30: 3-5.
Morgan-Jones, G. (1974). Fungi of Alabama. I. Dematiaceous hyphomycetes. Journal of the Alabama Academy of Science 45: 144-155.
Peregrine, W.T.H. and Ahmad, K.B. (1982). Brunei: A first annotated list of plant diseases and associated organisms. Phytopathology Papers 27: 1-87.
Photita, W., Lumyong, S., Lumyong, P., Ho, W.H., McKenzie, E.H.C. and Hyde, K.D. (2001). Fungi on *Musa acuminata* in Hong Kong. Fungal Diversity 6: 99-106.
Pirozynski, K.A. (1972). Microfungi of Tanzania. I. Miscellaneous fungi on oil palm. II. New hyphomycetes. Mycological Papers 129: 1-65.
Raabe, R.D., Conners, I.L. and Martinez, A.P. (1981). Checklist of plant diseases in Hawaii, Hawaii Institute of Tropical Agriculture and Human Resources, College of Tropical Agriculture and Human Resources, University of Hawaii. Information Text Series 22: 1-313.
Sarma, V.V. and Vittal, B.P.R. (2001). Biodiversity of manglicolous fungi on selected plants in Godavari and Krishna deltas, east coast of India. Fungal Diversity 6: 115-130.
Shaw, D.E. (1984). Microorganisms in Papua New Guinea. Department of Primary Industries, Research Bulletin 33: 1-344.
Subramanian, C.V. and Bhat, D.J. (1987). Hyphomycetes from South India I. Some new taxa. Kavaka 15: 41-74.
Sutton, B.C. (1978). New and interesting hyphomycetes from Tampa, Florida. Mycologia 70: 784-801.
Sutton, B.C. and Pirozynski (1963). Notes on British microfungi. I. Transactions of the British Mycological Society 46: 505-522.
Teodoro, N.G. (1937). An enumeration of Philippine fungi. Technical Bulletin, Department of Agriculture and Commerce, Philippine Islands, Manila 4: 1-585.
Thakur, S.B. and Udipi, P.A. (1976). *Zygosporium verticillatum* sp. nov. from marine habitat. Kavaka 4: 59-60.
UKNCC (2002). United Kingdom National Culture Collection. http:\\www.ukncc.co.uk, date accessed (2 September 2002).
Vittal, B.P.R. and Dorai, M. (1994). Studies on litter fungi VIII. Quantitative studies of the mycoflora colonizing *Eucalyptus tereticornis* Sm. litter. Kavaka 22: 35-41.
Wang, C.J.K. and Baker, G.E. (1967). *Zygosporium masonii* and *Z. echinosporum* from Hawaii. Canadian Journal of Botany 45: 1945-1952.
Whitton, S.R., McKenzie, E.H.C. and Hyde, K.D. (1999). Microfungi on the *Pandanaceae*: *Troposporopsis* gen. nov. Fungal Diversity 3: 173-177.
Whitton, S.R., McKenzie, E.H.C. and Hyde, K.D. (2000). Microfungi on the *Pandanaceae*: *Acrodictys*, with two new species. Fungal Diversity 4: 159-169.
Yanna, Ho, W.H., Hyde, K.D. and Goh, T.K. (2001). Occurrence of fungi on tissues of *Livistona chinensis*. Fungal Diversity 6: 167-180.

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