

## Fungi from palms. I. The genus *Linocarpon*, a revision

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The genus *Linocarpon* is diagnosed with ten species accepted. Descriptions and illustrations of these taxa are given, two of which are new. A key to the accepted species is given and the genus is compared with *Gaeumannomyces*.

Keywords: *Linocarpon*, *Gaeumannomyces*, palm fungi.

The genus *Linocarpon* was originally described for *Linocarpon pandani* (H. Sydow & P. Sydow) H. Sydow & P. Sydow, a fungus colonising dead *Pandanus* leaves in the Philippines (Sydow & Sydow, 1917). Several species were later described and Petrak (1952) transferred to *Linocarpon* a number of species previously placed in *Ophiobolus* Riess and reduced *Gaeumannomyces* von Arx & Olivier to synonymy. Walker (1980) could not accept Petrak's concept of *Linocarpon* since it incorporated several characteristics not shown by the type species of *Linocarpon*. He therefore chose to keep the two genera separate and accepted five species of *Linocarpon*, which were considered distinct from *Gaeumannomyces*. In the former, ascomata are immersed with a central ostiole and develop under a clypeus with variable stromatic development, ascospores are aseptate, hyphopodiate mycelium is lacking and the species have a saprobic habit. Specimens of *Gaeumannomyces* have non-stromatic ascomata which are embedded in the host tissue with an erumpent neck of variable length and position, multiseptate ascospores, superficial hyphopodiate mycelium, and are parasitic on the Poaceae and Cyperaceae (Walker, 1980).

Walker (1980) limited *Linocarpon* to mostly palmicolous species. He described and illustrated the type species, *L. pandani*, and provided notes on other *Linocarpon* species, excluding thirteen [*L. cariceti* (Berk. & Br.) Petrak, *L. eucryptum* (Berk. & Br.) Petrak, *L. halimum* (Diehl & Mounce) Petrak, *L. livistonae* (Henn.) Schrantz, *L. manihotis* (H. Sydow in H. Sydow & Butler) Petrak, *L. maritimum* (Sacc.) Petrak, *L. medusae* (Ellis & Everhart) Petrak, *L. muroianum* Hino & Katumoto, *L. oryzinum* (Sacc.) Petrak, *L. stipae* Hansford, *L. umbelliferarum* Barr, *L. verminosum* (Montagne) Schrantz, *L.*

*williamsii* Hansford] from the genus. Hyde (1988) described a new species of *Linocarpon*, *L. appendiculatum* Hyde, from *Nypa fruticans* Wurm. and transferred three *Ophiobolus* species to *Linocarpon*.

The aim of this paper is to update the information on the genus *Linocarpon*. All species known to the author are examined and their diagnoses given. Several *Linocarpon* specimens were examined and two new species are described in this paper. A key to accepted species of *Linocarpon* is provided.

### Materials and methods

Specimens used in this study were borrowed from BPI, DAR, S, P, NY and IMI or were living material collected in the field. Single spore isolations were carried out onto potato-dextrose-agar (PDA) or cornmeal-dextrose-agar (CMD). Sections were cut on a freezing microtome and differential interference contrast microscopy was carried out on an Olympus BH2 photomicroscope. Appendages in this paper refer to such structures as mucilage or mucilaginous pads or drops found at the ends of the ascospores (Figs. 2, 10, 11, 30).

### Taxonomy

***Linocarpon*** H. Sydow & P. Sydow, Ann. Mycol. 15: 210. 1917.

Type species. – *L. pandani* (H. Sydow & P. Sydow) H. Sydow & P. Sydow.

Appearing on host fronds as black, shiny, raised dome-shaped spots, each with a central dot or papilla and containing one ascoma. – Clypeus of epidermal cells packed with fungal hyphae. – Ascomata developing amongst leaf cortical cells beneath the host epidermis, with overlying clypeus and variable amounts of stromatic tissue laterally, usually lenticular, occasionally globose, brown to black, with a central periphysate ostium. – Paraphyses seen in mature and immature ascomata, embedded in a gel, hyaline, septate, longer than asci, wider at the base, tapering towards the apex. – Asci 8-spored, cylindrical, pedunculate, unitunicate, apically rounded, with a small non amyloid apical ring, developing from the base and periphery of the ascoma. – Ascospores filiform, hyaline or pale-yellowish in mass, parallel or spiral in the ascus, ends rounded, inflated, appendaged or acute, containing numerous refringent septum-like bands.

Anamorph.– *Phialophora*-like spp. have been produced in culture by *L. appendiculatum* and *L. elaeidis* but not by any other species.

Mode of Life.— Saprobic, endophytic or parasitic.

Habitat.— On dead rachids, twigs or living leaves of various palms (Palmae), *Cajanus* (Fabaceae), *Miscanthus* (Poaceae), *Pandanus* (Arecidae) and *Phenakospermum* (Zingiberidae).

A genus close to *Linocarpon* was recently described by Hyde (1991). *Neolinocarpon* Hyde differs from *Linocarpon* in having a globose body as well as an apical apparatus in the ascus tip. The ascomata are also rounded and deeply immersed.

Müller & von Arx (1975) placed *Linocarpon* in the Diaporthaceae, (Sphaeriales), while Barr (1978) included the genus in the Gnomoniaceae (Diaporthales). In Eriksson & Hawksworth (1991) *Linocarpon* is included in the Valsaceae (=Diaporthaceae). More recently Barr (1990) removed *Linocarpon* from the Gnomoniaceae to the Hyponectriaceae (Xylariales). In her discussion Barr (1990) indicated that the anamorph suggests deposition in the Lasiosphaeriaceae, while the teleomorph features are those of the Hypolectriaceae. Monod (1983) also pointed out that *Linocarpon* has many features in common with *Ophiodothella* in the Phyllachoraceae. My own preference is to include *Linocarpon* in the Lasiosphaeriaceae, Sordariales *sensu* Barr (1990), or *sensu* Eriksson & Hawksworth (1991). *Ophioceras* Sacc., in the Lasiosphaeriaceae (Barr, 1990), has filiform ascospores, asci with an apical apparatus and distally tapering paraphyses (Conway & Barr, 1977). *Lasio-sphaeria raciborski* Penz. & Sacc. also has an ascus apical ring that is similar to *Linocarpon*, while the ascospores are filiform and multiseptate (Samuels – pers. com.). The tapering persistent paraphyses, the anamorph, the asci remaining attached to the subhymenium and its apical ring and the subglobose sub-structure found in asci of *Neolinocarpon* Hyde (Hyde, 1992), all suggest affinities with genera already placed in the Lasiosphaeriaceae.

A synopsis of the *Linocarpon* species treated here is presented in Tab. 1.

### Key to *Linocarpon* species

1. Taxa forming a necrotic region on palm leaves ..... 8. *L. palmetto*
- 1.\* Taxa on rachids or wood, no necrotic region ..... 2
2. Appendages (mucilage) at both ends of the ascospore ..... 3
- 2.\* Appendages (mucilage) not at both ends of the ascospore .. 4
3. Ascospores 90–139 µm long, on intertidal *Nypa* palm ..... 2. *L. bipolaris*

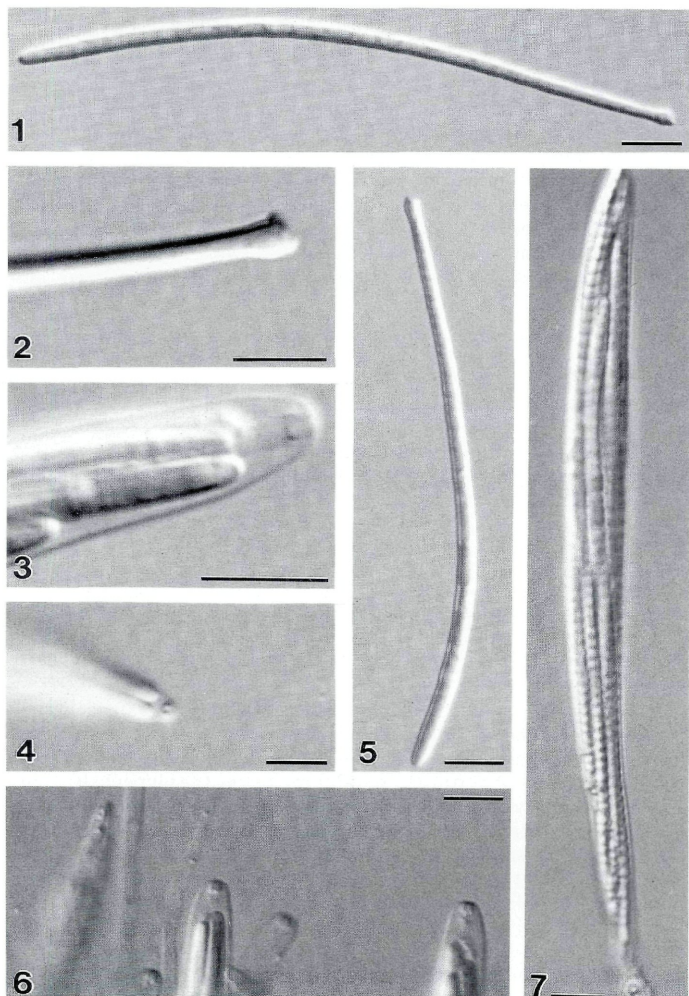
- 3.\* Ascospores 50–80  $\mu\text{m}$  long, on *Cajanus* and palms ..... 3. *L. cajani*
4. Ascospores lacking appendages/mucilage ..... 5
- 4.\* Ascospores with appendages/mucilage at one end of the ascospore ..... 6
5. Ascospores mostly broader, 62–80 x 2–4  $\mu\text{m}$ , ascomatal neck not raised, on *Pandanus* or *Miscanthus* ..... 9. *L. pandani*
- 5.\* Ascospores mostly thinner, 60–88 x 1.9–3.2  $\mu\text{m}$ , ascomatal neck raised, on palms ..... 10. *L. verminosum*
6. Ascospores with distinct bell-shaped appendage ..... 1. *L. appendiculatum*
- 6.\* Ascospores with acute end and mucilage only ..... 7
7. Ascospore width always less than 2.5  $\mu\text{m}$  .... 5. *L. livistonae*
- 7.\* Ascospore width mostly greater than 2.5  $\mu\text{m}$  ..... 8
8. Ascospores 72–97 x 3–4  $\mu\text{m}$ , on terrestrial palms ..... 4. *L. elaeidis*
- 8.\* Ascospores 91–123.5 x 2.6–4.3  $\mu\text{m}$ , on intertidal *Nypa* ..... 7. *L. nipa*
- 8.\*\* Ascospores 124–140 x 2.5–3.0  $\mu\text{m}$ , on intertidal *Nypa* ..... 6. *L. longisporum*

1. *Linocarpon appendiculatum* Hyde, Trans. Mycol. Soc. Japan 29 : 339. 1988. – Figs. 1–7, 47.

Appearing on host fronds as black, raised dome-shaped spots, up to 530  $\mu\text{m}$  diam, with a small central papilla, and containing one ascoma. – Clypeus of epidermal cells packed with fungal hyphae. – Ascomata developing below the clypeus, lenticular in section, with variable amounts of the stromatic tissue laterally, 330–510  $\mu\text{m}$  diam, 120–180  $\mu\text{m}$  high, dark-brown to black and with a central periphysate ostiolum. – Peridium thin, 3–6 layers of elongate cells, fusing with the clypeus above. – Paraphyses embedded in a gel, hyaline, filamentous, wide at the base, tapering towards the apex, longer than the asci. – Asci 110.5–169 x 7.8–9.8  $\mu\text{m}$ , 8-spored, long-cylindrical, mostly straight, pedunculate, tip rounded containing a ring-like apical apparatus, 2.0–2.3  $\mu\text{m}$  diam and 2.2–2.75  $\mu\text{m}$  high (Figs. 3, 4, 6, 7). – Ascospores 75–120 x 2.2–3.5  $\mu\text{m}$ , filiform, straight or very slightly curved, hyaline singly and in mass, containing numerous refringent septum-like bands, apex rounded and slightly wider (3.3–3.6  $\mu\text{m}$ ), base narrower (2.0–2.5  $\mu\text{m}$ ) and provided with an appendage (Figs. 1, 5) 2.5–3.3  $\mu\text{m}$  wide, appearing as a polar swelling with a flattened end (bell-shaped) containing mucilage (Fig. 2).

Tab. 1. – A synoptic table of *Linocarpon* species with some characteristics.

	<i>L. appendiculatum</i>	<i>L. bipolaris</i>	<i>L. cajani</i>	<i>L. elaeidis</i>	<i>L. livistonae</i>	<i>L. longisporum</i>	<i>L. nipae</i>	<i>L. palmetto</i>	<i>L. pandani</i>	<i>L. verminosum</i>
Host(s)	<i>Nypa</i>	<i>Nypa</i>	<i>Cajanus, Elaeis</i>	<i>Calamus, Elaeis, Mauritia, Raphia, Phenakospermum</i>	<i>Arenga, Livistonia, Pandanus, Phenakospermum, Ptychosperma</i>	<i>Nypa</i>	<i>Nypa</i>	<i>Sabal</i>	<i>Pandanus, Miscanthus</i>	<i>Sabal</i>
Ascospore size	75-120 x 2.2-3.5 µm	90-139 x 2-3 µm	50-80 x 1.5-2.5 µm	72-97 x 3-4 µm	70-104 x 1.6-2.3 µm	124-140 x 2.5-3.0 µm	91-123.5 x 2.6-4.3 µm	50-56 x 2.5-3.5 µm	62-80 x 2-4 µm	60-88 x 1.9-3.2 µm
Appendages	Bell-shaped, at one end	Pad-like, at each end	Pad-like, at each end	Base with mucilage	Base narrow with mucilage	Base tapering with mucilage	Base narrow with mucilage	Base with mucilage	Mucilage lacking	Lacking mucilage
Habitat	Saprobic/intertidal	Saprobic/intertidal	Saprobic/terrestrial	Saprobic/terrestrial	Saprobic/terrestrial	Saprobic/intertidal	Saprobic/intertidal	Parasitic/Leaf spots	Saprobic/terrestrial	Saprobic/terrestrial



Figs. 1–7. – Interference contrast micrographs of *Linocarpon appendiculatum*. – 1,2 and 5. Ascospores. Note the basal bell-shaped appendage. – 3,4. Ascus apex with apical ring-like body. – 6. Several ascus tips illustrating apical ring-like body and paraphyses. – 7. Ascus. – Bars, = 10  $\mu$ m.

Colonies on cornmeal-dextrose-agar (CMD) and potato-dextrose-agar (PDA) growing very slowly. – Aerial hyphae cinereous, cottony; surface of colony crustose; sterile on CMD, abundant conidial production on PDA. – Conidiophores arising from the aerial mycelium, macronematous, mononematous and monophialidic, pale grey to near hyaline, 11–35  $\mu\text{m}$  long, 2.0–3.5  $\mu\text{m}$  wide at the base, (0–) 2(–3)–septate. – Conidiogenous cells phialidic, subulate, smooth, translucent brown; wall visibly thickened; tip 1.8  $\mu\text{m}$  wide; periclinal thickening visible; the collarette ca. 1  $\mu\text{m}$  deep and clasping the base of each conidium. – Conidia clavate, straight, slightly curved, or slightly sinuous, (10.0–) 10.6–13.4(–14.4)  $\times$  1.0–1.5  $\mu\text{m}$ , unicellular, lacking a visible basal abscission scar, smooth, colourless.

Material examined. – BRUNEI: Tungit Api Api, on intertidal fronds of *Nypa fruticans*, 14 June 1987, K.D. Hyde (IMI 326619, Holotype). Anduki Beach, sand-buried fronds of *Nypa fruticans*, 20 Sept 1985, K.D. Hyde (BRIP 19709). – PAPUA NEW GUINEA: Western Province, Mouth of Fly River, on intertidal frond of *Nypa fruticans*, Nov 1990, K.D. Hyde (BRIP 17375).

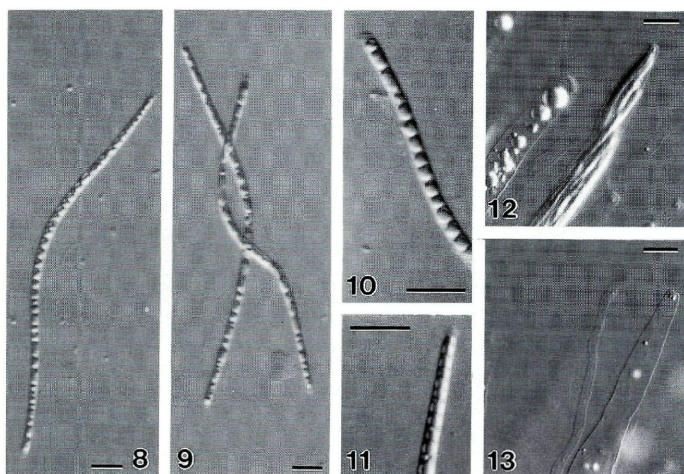
*Linocarpon appendiculatum* has a distinctive bell-shaped ascospore appendage (Fig. 2) that separates it from other taxa. This appendage is illustrated at the SEM level in Hyde (1988).

## 2. *Linocarpon bipolaris* Hyde, sp. nov. – Figs. 8–13.

*Linocarpon cajani* Deighton apud Petrak & Deighton similis sed ascosporarum longitudine 90–139  $\times$  2–3  $\mu\text{m}$  differt.

Etymology. – in reference to the mucilaginous pads at each end of the ascospore.

Appearing on host fronds as brown or black, raised dome-shaped spots, 650–1170  $\mu\text{m}$  diam, with a central short papilla and containing one ascoma. – Clypeus of epidermal cells packed with fungal hyphae. – Ascomata developing below the clypeus, lenticular in section, with variable amounts of stromatic tissue laterally, 520–1040  $\mu\text{m}$  diam, 195–325  $\mu\text{m}$  high, brown to black and with a central periphysate ostiolum. – Peridium thin, of elongate cells, fusing above with the clypeus. – Paraphyses embedded in a gel, long, tapering distally, hyaline, persistent, septate, 9  $\mu\text{m}$  at the base and 1  $\mu\text{m}$  distally and longer than asci (Fig. 12). – Asci 150–215  $\times$  7.5–12  $\mu\text{m}$ , 8-spored, long-cylindrical, long-pedunculate, tip rounded and containing a ring-like apical apparatus, with semi-fissitunicate dehiscence, 1.6–2.0  $\mu\text{m}$  diam, 2.4–2.8  $\mu\text{m}$  high, (Figs. 12, 13). – Ascospores 90–139  $\times$  2–3  $\mu\text{m}$  (mean = 115,  $n$  = 50), filiform, straight, slightly curved, or mostly sigmoid, arranged spirally in the ascus, hyaline, with refringent septum-like bands, ends slightly



Figs. 8–13. – Interference contrast micrographs of *Linocarpon bipolaris*. – 8–11. Ascospores with a mucilaginous pad at each end. – 12,13. Apex of asci with ring-like structure and paraphyses. – Bars = 10µm.

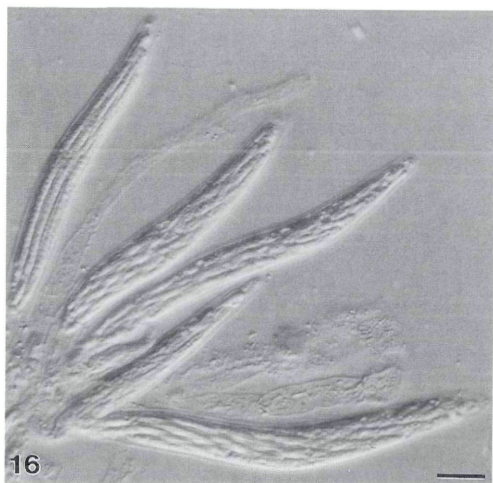
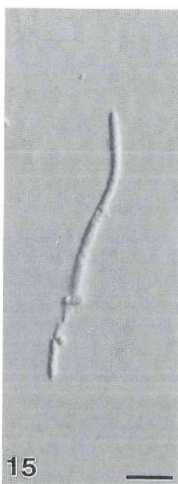
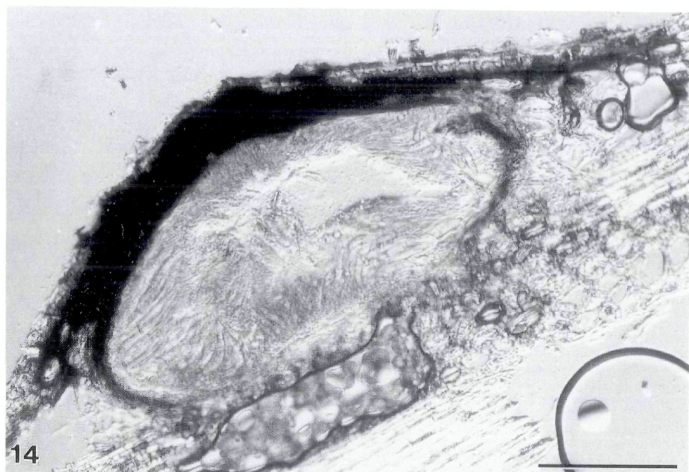
inflated and rounded, with small pad-like conspicuous appendages at each end (Figs. 8–11).

Holotype. – BRUNEI: Tungit Api Api, intertidal fronds of *Nypa fruticans*, Dec 1988, K.D. Hyde (BRIP 19713).

Other material examined. – BRUNEI: Anduki Beach, sand-buried fronds of *Nypa fruticans*, 20 Sept 1985, K.D. Hyde (BRIP 19708).

Hyde (1988) reported *Linocarpon pandani* from sand-buried fronds of *Nypa fruticans* in Brunei and discussed the differences between this collection and the holotype [*Linospora pandani* (S!)]. New material show that the fungus from *Nypa* is a new taxon. *L. bipolaris* is closest to *L. cajani* since appendages are found at both spore poles. It differs in having much longer ascospores (90–139 µm, vs. 50–80 µm), in its host *Nypa fruticans* and in its intertidal habitat. It is different from other species on *Nypa*, as appendages (mucilaginous pads) are distinctly seen at both ends of the ascospores. The semi-fissitunicate ascus dehiscence observed in *L. bipolaris* and in *L. longispora* is similar to that observed in *Oxydothis* species (Samuels & Rossman, 1987). Appendages of *L. bipolaris* are illustrated at the SEM level in Hyde (1988).





Figs. 14–16. – Interference contrast micrographs of *Linocarpon cajani*. – 14. Section through ascoma. Note the overlaying clypeus and lenticular ascoma. – 15. Ascospore which is slightly damaged, but mucilaginous pads can be seen at each end. – 16. Squash illustrating several asci. Note the ring-like apical structures. – Bars: 14 = 100  $\mu\text{m}$ ; 15, 16 = 10  $\mu\text{m}$ .

3. *Linocarpon cajani* Deighton apud Petrak & Deighton, Sydowia 6: 312. 1952. – Figs. 14–16.

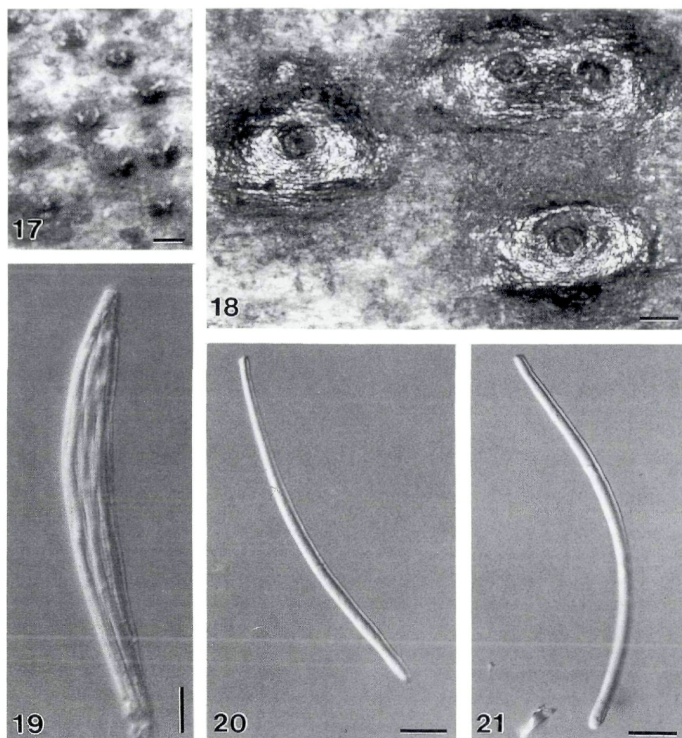
Appearing on host fronds or twigs as darkened raised dome-shaped spots, up to 700  $\mu\text{m}$  diam, with a central black short papilla, gregarious, and containing one ascoma. – Clypeus of epidermal cells packed with fungal hyphae. – Ascoma a developing below the clypeus, lenticular in section, with variable amounts of stromatic tissue laterally, 325–390  $\mu\text{m}$  diam, 130–260  $\mu\text{m}$  high, dark-brown and with a central periphysate ostiolum (Fig. 14). – Peridium thin, brown, of several layers of elongate cells, fusing above with the clypeus. – Paraphyses embedded in a gel, long, tapering, persistent, septate, 5  $\mu\text{m}$  at the base, 2  $\mu\text{m}$  at the apex and longer than asci. – Asci 82–100  $\times$  7–10  $\mu\text{m}$ , 8-spored, cylindrical, pedunculate, tip rounded and containing an apical ring-like apparatus (Fig. 16). – Ascospores 50–80  $\times$  1.5–2.5  $\mu\text{m}$ , filiform, arranged spirally in the ascus, hyaline, both ends rounded with a small mucilaginous pad at each end (Fig. 15).

Material examined. – SIERRA LEONE: Newton, on dead twigs of *Cajanus cajan* (L.) Huth, 16 Nov 1950, Deighton (IMI 46618; Holotype). – TANZANIA: Kakombe, on dead rachids of *Elaeis guineensis* Jacq., 19 Dec 1963, K. Pirozynski (IMI 105784c). – PARAGUAY (intercepted at Miami, Florida, USA): on palm fruit, 17 Feb 1982, T. Washington 502C (BPI).

Pirozynski (1972) described *L. cajani* from the type and from a collection on dead rachids of the oil palm (*Elaeis guineensis*), the specimen from *Cajanus* differing only in having shorter ascospores. He illustrated ascospores from both specimens without polar appendages. Both collections are good *Linocarpon* species. However, it was extremely difficult to dislodge ascospores from asci of these specimens. After several attempts with repeated aggressive squashing, a few damaged ascospores were obtained from the Tanzanian specimen and these had mucilaginous pads at each pole. The specimen from *Cajanus* may differ to that from *Elaeis*, however until fresh material becomes available I retain *L. cajani* for species developing on *Cajanus* or palms with mucilaginous appendages at each end of the ascospore. Few ascospores were obtained and ascospore measurements are those of Pirozynski (1972). I could also make no measurements of the apical rings of the asci, since it was not possible to separate them.

4. *Linocarpon elaeidis* Petrak, Sydowia 6: 312. 1952.– Figs. 17–21, 48.

Appearing on host fronds or twigs as black, shiny, raised dome-shaped spots, up to 600  $\mu\text{m}$  diam, with a central blackened, short



Figs. 17–21. – *Linocarpon elaeidis*. – 17,18. Surface view of ascomata. – 19–21. Interference contrast micrographs. – 19. Ascus. – 20,21. Ascospores. One end is rounded and slightly inflated, while the other (base) is acute with a pad of mucilage. – Bars: 17 = 500  $\mu\text{m}$ ; 18 = 100  $\mu\text{m}$ ; 19 – 21 = 10  $\mu\text{m}$ .

papilla, singly or occasionally in groups of two or three, and containing one ascoma (Figs. 17, 18). – Clypeus of epidermal cells packed with fungal hyphae. – Ascomata developing below the clypeus, lenticular in section, with variable amounts of stromatic tissue laterally, up to 520  $\mu\text{m}$  diam, 195  $\mu\text{m}$  high and with a central periphysate ostiolum. – Paraphyses embedded in a gel, wide, septate, and tapering. – Asci 116–148 x 9–13  $\mu\text{m}$ , cylindrical, pedunculate, rounded at the apex, with a ring-like apical apparatus, 2.4–2.8  $\mu\text{m}$  diam and 1.0–1.2  $\mu\text{m}$  high (Fig. 19). – Ascospores 72–97 x 3–4  $\mu\text{m}$ , filiform, rounded at the apex, with mucilage at the base (Figs. 20, 21).

Colonies on PDA growing very slowly. – Aerial hyphae cinereous, cottony, with abundant conidial production. – Conidiophores arising from the aerial mycelium, macronematous, nearly hyaline, 1.2 – 8.8  $\mu\text{m}$  long, 1.2 – 4.8  $\mu\text{m}$  wide, non-septate, cylindrical, weakly conical or ampulliform. – Conidiogenous cells phialidic, smooth, translucent brown; one or rarely two per conidiophore, wall visibly thickened, periclinal thickening visible, the collarette ca. 1  $\mu\text{m}$  deep and clasping the base of each conidium. – Conidia clavate to fusiform, some slightly curved, or slightly sinuous, 11.2 – 24.0  $\times$  1.2 – 1.6  $\mu\text{m}$ , 1–4 celled, some basally truncate, smooth, colourless, forming light-brown, slimy heads on mycelium.

Material examined. – SIERRA LEONE: Newton, on *Elaeis guineensis* Jacq. 16 Nov 1950, F.C. Deighton (IMI 46620a, holotype). Mosongo, on *Raphia vinifera* Palisot De Beauvois, 27 July 1953, F.C. Deighton (IMI 53377). – GUYANA: East Berbice–Corentyne Region, VI, Subregion VI–1, Torani Canal, 05° 48' N, 57° 31' W, on dead leaf of *Phenakospermum guianense* Endl., 18, 19 April 1987, G.J. Samuels, J. Pipoly, G. Gharbarran & G. Bacchus, 5492 (NY); Subregion VI–5, Canje River, 05° 36' N, 57° 35' W, on dead leaf on *Phenakospermum guianense*, 12–15 April 1987, G.J. Samuels, J. Pipoly, G. Gharbarran & G. Bacchus, 5428 (NY); on dead leaf of *Mauritia* sp., 12–15 April 1987, G. Samuels, J. Pipoly, G. Gharbarran, G. Bacchus, 5424 (NY). – AUSTRALIA: Queensland, Mossman Gorge National Park, on rachis of *Calamus* sp., 10 June 1991, K.D. Hyde (BRIP 19714).

Ascospores of *L. elaeidis* are rounded at the apex, with a mucilaginous pad at the base (Figs. 20, 21). The ascospores differ from those of *L. nipae* and *L. longisporum* which are longer (91–123.5  $\mu\text{m}$  and 124–140  $\mu\text{m}$  vs. 72–97  $\mu\text{m}$ ) and *L. livistonae*, which are narrower (1.6–2.3  $\mu\text{m}$  vs. 3–4  $\mu\text{m}$ ). The *Phialophora*-like anamorph was produced in an isolate from the Australian specimen.

5. *Linocarpon livistonae* (Henn.) Hyde, Trans. Mycol. Soc. Japan 29: 346. 1988.

= *Ophiobolus livistonae* Henn., Hedwigia 47: 257.1908.

= *Linospora pandani* Rehm, Leaflets of Philippine Botany 8: 2954. 1916.

Appearing on the host surface, as dark, raised, dome-shaped shiny spots, with or without some hyphal cover, up to 750  $\mu\text{m}$  long and 600  $\mu\text{m}$  wide and containing one ascoma. – Clypeus of epidermal cells packed with fungal hyphae. – Ascomata developing below the clypeus, lenticular in section, with variable amounts of stromatic tissue laterally, up to 700  $\mu\text{m}$  diam and 195  $\mu\text{m}$  high, brown to black and with a central periphysate ostiolum. – Paraphyses embedded in a gel, wide, septate, and tapering. – Asci 100–140  $\times$  6–12  $\mu\text{m}$ , whitish in mass, 8-spored, cylindrical, short-pedunculate, with rounded apex and ring-like apical apparatus, ring 2.4–3.2 diam

and 1.0–1.6  $\mu\text{m}$  high. – Ascospores 70–104 x 1.6–2.3  $\mu\text{m}$ , filiform, spiral in the ascus, with refringent bands along length of spore, apex rounded, the base narrow with mucilage.

Material examined. – PHILIPPINE ISLANDS: Mindanao, Davao, on rachids of *Livistona* sp., March 1904, E.B. Copeland 524, Holotype of *Ophiobolus livistonae* (S, Holotype); Los Baños, Mount Maquiling, on *Pandanus sabotan* Blanco, April 1914, C.F. Baker, Fungi Malayana 152, as *Linospora pandani* Rehm (NY). – FRENCH GUIANA: Saül, Saut Mais, on palm rachis, Nov 1986, A. Rossman, AR2967 (BPI). – GUYANA: Cuyuni – Mazaruni Region, VII, Mazaruni Subregion VII–2; 05° 28'N, 60° 04'W, on dead palm leaf midrib, Feb–March 1987, G.J. Samuels, J. Pipoly, G. Gharbarran, J. Chin, R. Edwards 4932 (NY); East Berbice – Corentyne Region VI, Subregion VI–5: Canje River, 05° 36'N, 57° 35'W, on dead petiole of *Phenakospermum guianense*, 12–15 April 1987, G.J. Samuels, J. Pipoly, G. Gharbarran, & G. Bacchus 5450 (NY). – INDONESIA: North Sulawesi, Eastern Dumoga–Bone National Park, vic. 'Hog's Back' Camp, 00° 35'N, 123° 51'E, on arecoid palm, 30–31 Oct 1985, G.J. Samuels 2462 (NY); Camp 'Edwards' on *Livistona* sp., 6–8 Oct 1985, G.J. Samuels 2059 (NY). – BRAZIL: Amazonas, near Pico Rondon, 01° 32'N, 62° 48'W, on palm midrib, 3 Feb 1984, G.J. Samuels 94 (NY); Parana, palm rachis, 18 March 1977, P. Hewett (IMI 248548). – TAIWAN: Kenting, on rachis of *Ptychosperma* sp., 8 Feb 1988, A. Sivanesan (IMI 323881); on *Arenga engleri* Sató, 8 Feb 1988, A. Sivanesan (IMI 323930). – AUSTRALIA: Queensland, Bamaga, Lockerbie, on palm rachids, March 1991, K.D. Hyde (BRIP 19716).

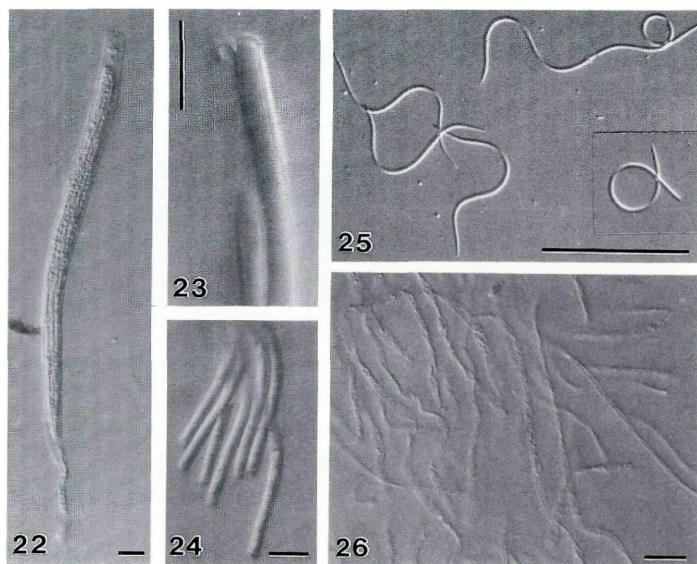
*Linospora pandani* Rehm is almost identical to *L. livistonae* and is considered synonymous. Minor differences include the slightly smaller, but overlapping ring and smaller fruiting bodies. *L. livistonae* is closest to *L. elaeidis*, but differs in having narrow ascospores (1.6–2.3  $\mu\text{m}$  vs. 3–4  $\mu\text{m}$ ).

#### 6. *Linocarpon longisporum* Hyde sp. nov. – Figs. 22–26.

*Linocarpon nipae* (Henn.) Hyde similis sed ascosporarum longitudine 124–140 x 2.5–3.0  $\mu\text{m}$  differt.

Etymology. – In reference to the long ascospores.

Appearing on host fronds as black, raised dome-shaped spots, 650–910  $\mu\text{m}$  diam, with a central short papilla and containing a single ascoma. – Clypeus of epidermal cells packed with fungal hyphae. – Ascomata developing below the clypeus, lenticular in section, with variable amounts of stromatic tissue laterally, 585–780  $\mu\text{m}$  diam, 130–210  $\mu\text{m}$  high, brown to black, with a central periphysate ostiolum. – Peridium thin, of elongate cells, fusing above with the clypeus. – Paraphyses embedded in a gel, long, tapering, hyaline, persistent, septate, 6  $\mu\text{m}$  at the base, 2  $\mu\text{m}$  at the apex and longer than asci (Fig. 26). – Asci 170–216 x 8–12  $\mu\text{m}$ , 8-spored, cylindrical, long-pedunculate, tip rounded and containing a ring-like apical apparatus, with semi-fissitunicate dehiscence, ring 2.4–



Figs. 22–26. – Interference contrast micrographs of *Linocarpon longisporum*. – 22,23. Cylindrical, pedunculate asci with an apical ring-like structure. – 24. Bases of several ascospores semi-released from an ascus, with mucilaginous pads. – 25. Ascospores. These can be C-shaped or sigmoid. – 26. Paraphyses surrounded by gel. – Bars = 10  $\mu\text{m}$ .

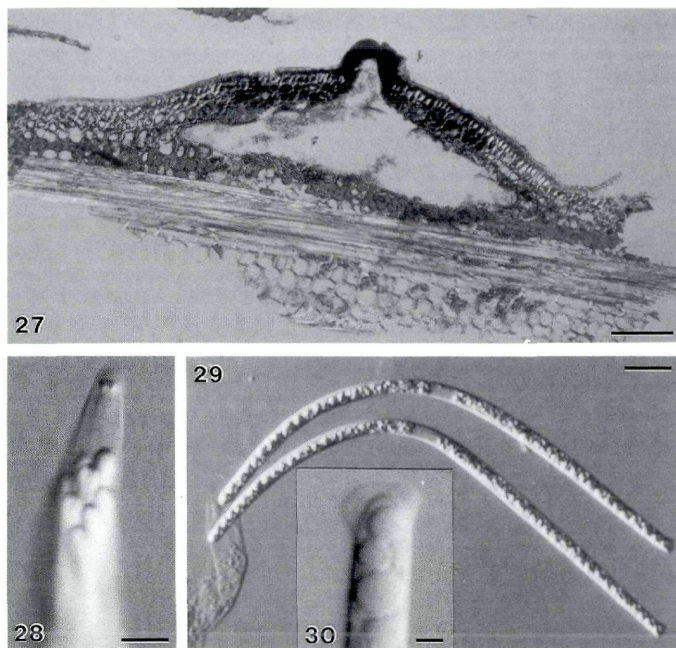
3.2  $\mu\text{m}$  diam and 1.0–1.6  $\mu\text{m}$  high (Figs. 22, 23). – Ascospores 124–140  $\times$  2.5–3.0  $\mu\text{m}$ , filiform, arranged spirally in the ascus, hyaline with refringent septum-like bands, one end rounded, one end tapering with mucilage, curved, C-shaped or sigmoid, very rarely 1-septate in the centre (Figs. 24, 25).

Holotype. – BRUNEI: Tungit Api Api, intertidal fronds of *Nypa fruticans*, Dec 1988, K.D. Hyde (BRIP 19715).

*L. longisporum* is closest to *L. nipae*, but differs in having longer ascospores (124–140  $\mu\text{m}$  vs. 91–123.5  $\mu\text{m}$ ), which are distinctly curved, C-shaped or sigmoid (Figs. 24, 25).

7. *Linocarpon nipae* (Henn.) Hyde, Trans. Mycol. Soc. Japan 29: 346. 1988.– Figs. 27–30.

= *Ophiobolus nipae* Henn., Hedwigia 47:257. 1908.

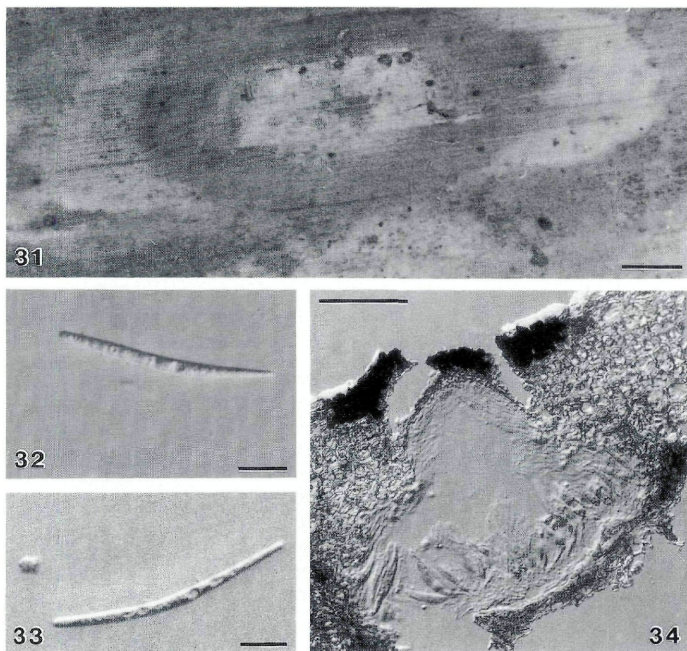


Figs. 27–30. – Interference light contrast micrographs of *Linocarpon nipae*. – 27. Section through ascoma. Note the raised papilla and variable stromatic tissue around the ascoma. – 28. Ascus with ring-like structure. – 29, 30. Ascospores rounded at one end and narrow at the other with mucilage. – Bars 27 = 100  $\mu\text{m}$ ; 28 – 29 = 10  $\mu\text{m}$ ; 30 = 1  $\mu\text{m}$ .

Appearing on host fronds as black, raised dome-shaped spots, up to 750  $\mu\text{m}$  diam, with a small central ostiolar dot or short papilla and containing one ascoma (Fig. 27). – Clypeus of epidermal cells packed with fungal hyphae. – Ascomata developing below the clypeus, lenticular in section, with variable amounts of stromatic tissue laterally, 465–620  $\mu\text{m}$  diam, 150–290  $\mu\text{m}$  high, brown to black, with a central periphysate ostiolum. – Peridium thin, of elongate cells, 3–6 cells thick, fusing with the clypeus above. – Paraphyses embedded in a gel, hyaline, filamentous, wide at the base, tapering towards the apex and longer than the asci. – Asci 147–221  $\times$  11.7–18.2  $\mu\text{m}$ , 8-spored, long-cylindrical, strongly curved, long-pedunculate, tip rounded and containing a ring-like apical apparatus, wedge-shaped, 1.6–2.2  $\mu\text{m}$  diam and 2.75–3.3  $\mu\text{m}$  high (Fig. 28). – Asco-

spores 91–123.5 x 2.6–4.3  $\mu\text{m}$ , arranged spirally in the ascus, hyaline, singly, yellowish in mass, containing numerous refringent septum-like bands, slightly wider centrally (3.2–4.3  $\mu\text{m}$ ), ends rounded, one end slightly inflated (3.8–4.3  $\mu\text{m}$ ), the other end narrow (2.6–2.75  $\mu\text{m}$ ) and provided with basal mucilage (Figs 29, 30).

Material examined. – PHILIPPINE ISLANDS: Luzon Province, Pangasinana, San Esteban, (no further details given), Sept 1905, Merrill n. 4257, holotype of *Ophiobolus nipae* Henn. (K, Holotype). – BRUNEI: Tungit Api Api, all from intertidal fronds of *Nypa fruticans*: 10 Oct 1985, K.D. Hyde (BRIP 19707); 20 June 1987 (BRIP 19705); 10 Oct 1987 (BRIP 19706). – THAILAND: Phang Nga Bay, 11 Jan 1988, K.D. Hyde (KDH 0888).



Figs. 31–34. – *Linocarpon palmetto*. – 31. Leaf spot on host surface with minute black spots of clypeus. – 32–33. Interference contrast micrographs. – 32,33. Ascospores. – 34. Section through ascoma. Note the clypeus. – Bars: 31 = 500  $\mu\text{m}$ ; 32 – 33 = 10  $\mu\text{m}$ ; 34 = 100  $\mu\text{m}$ .



8. *Linocarpon palmetto* (Ellis & Everhart) Barr, Mycol. Mem. 7: 72. 1978. – Figs. 31–34.

= *Linospora palmetto* Ellis & Everhart, Jour. Mycol. 3:45. 1887.

Forming a zonate, brown, necrotic leaf spot on host surface (Fig. 31). – Ascumata 325–429  $\mu\text{m}$  diam, immersed, globose to subglobose (Fig. 34), on host surface appearing as small, blackened circular dots, 80–130  $\mu\text{m}$  diam, comprised of the ascoma ostiole and a small amount of clypeal tissue. – Paraphyses embedded in a gel, hyaline, filamentous, wide at the base and tapering toward the apex. – Asci 70–100  $\times$  8–10  $\mu\text{m}$ , hyaline in mass, 8-spored, cylindrical, pedunculate, unitunicate, apex rounded with a ring-like apical apparatus, 2.5–3  $\mu\text{m}$  diam and 1–5.7  $\mu\text{m}$  high. – Ascospores straight in the ascus, 50–56  $\times$  2.5 – 3.5  $\mu\text{m}$ , filiform, one end wider and tapering towards the base, with refringent bands and with mucilage at the base (Figs 32,33).

Holotype. – USA: Louisiana, Point a la Hache, on *Sabal palmetto* Lodd, Dec 1886, Langlois 869 (NY).

*L. palmetto* is distinctive since it forms necrotic spots on *Sabal palmetto* (Fig. 31) and has immersed globose ascumata.

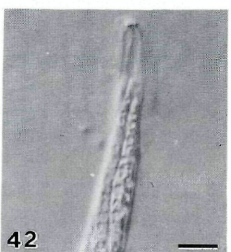
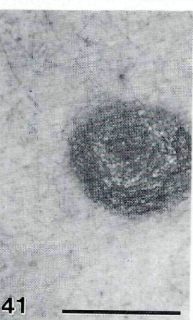
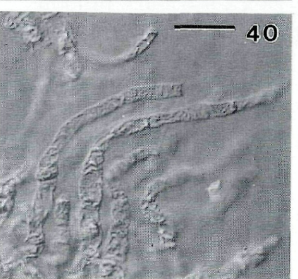
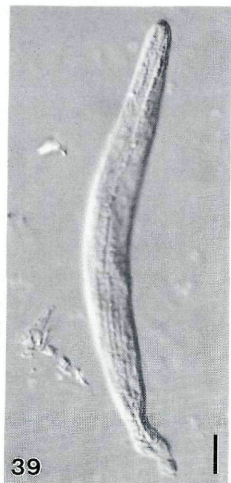
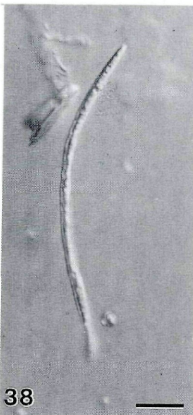
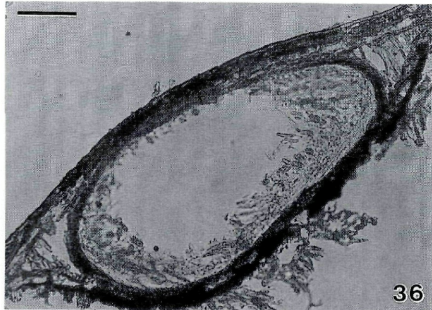
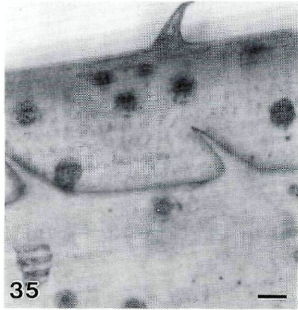
9. *Linocarpon pandani* (H. Sydow & P. Sydow) H. Sydow & P. Sydow, Ann. Mycol. 15: 210. 1917. – Figs. 35–42.

= *Linospora pandani* H. Sydow & P. Sydow, Ann. Mycol. 11: 60. 1913.

Appearing on host leaves as brown, dome-shaped spots, up to 1000  $\mu\text{m}$  diam (Fig. 35), with a small central ostiolar dot and containing a single ascoma. – Clypeus of epidermal cells packed with fungal hyphae. – Ascumata developing below the clypeus, lenticular in section, with variable amounts of stromatic tissue laterally (Figs. 36,37), up to 600–650  $\mu\text{m}$  diam and 200–300  $\mu\text{m}$  high when mature, several 150  $\times$  40–50  $\mu\text{m}$  and immature, dark brown to black and with a central ostiolum. – Peridium thin, of elongate cells and fusing above with the clypeus. – Paraphyses embedded in a gel, hyaline, 3–4  $\mu\text{m}$  wide at base, tapering towards the apex, longer than asci and

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Figs. 35–42. – *Linocarpon pandani*. – 35. Surface view of ascumata on a *Pandanus* leaf. – 36–40 and 42. Interference contrast micrographs. – 36,37. Section through ascoma under a clypeus with variable stromatic development. – 38. Ascospore. – 39. Ascus. – 40. Tapering paraphyses. – 41. Ascoma on *Pandanus*. – 42. Apex of ascus with ring-like structure. – Bars 35, 41 = 500  $\mu\text{m}$ ; 36, 37 = 100  $\mu\text{m}$ ; 38–40, 42 = 10  $\mu\text{m}$ .



sparingly septate (Fig. 40). – Asci 100–140 x 8–10  $\mu\text{m}$ , 8-spored, in a basal layer, long-cylindrical, pedunculate, apex rounded, with small apical ring, 2.0  $\mu\text{m}$  diam x 1.6  $\mu\text{m}$  high (Fig. 42). – Ascospores 62–80 x 2–4  $\mu\text{m}$ , filiform, pale yellowish in mass, hyaline to faintly tinted singly, centrally slightly wide, ends rounded, parallel or slightly spiralled, containing numerous refringent septum-like bands, without gelatinous appendages or mucilage (Fig. 38).

Material examined. – PHILIPPINE ISLANDS: Mindanao, Davao, on *Pandanus laevis* Lour., March 1904, E.B. Copeland 592, Holotype of *Linospora pandani* (S, holotype). – TAIWAN: Taipei, Yang Ming Shan, *Miscanthus* sp., 8 Jan 1988, A. Sivanesan (IMI 323942).

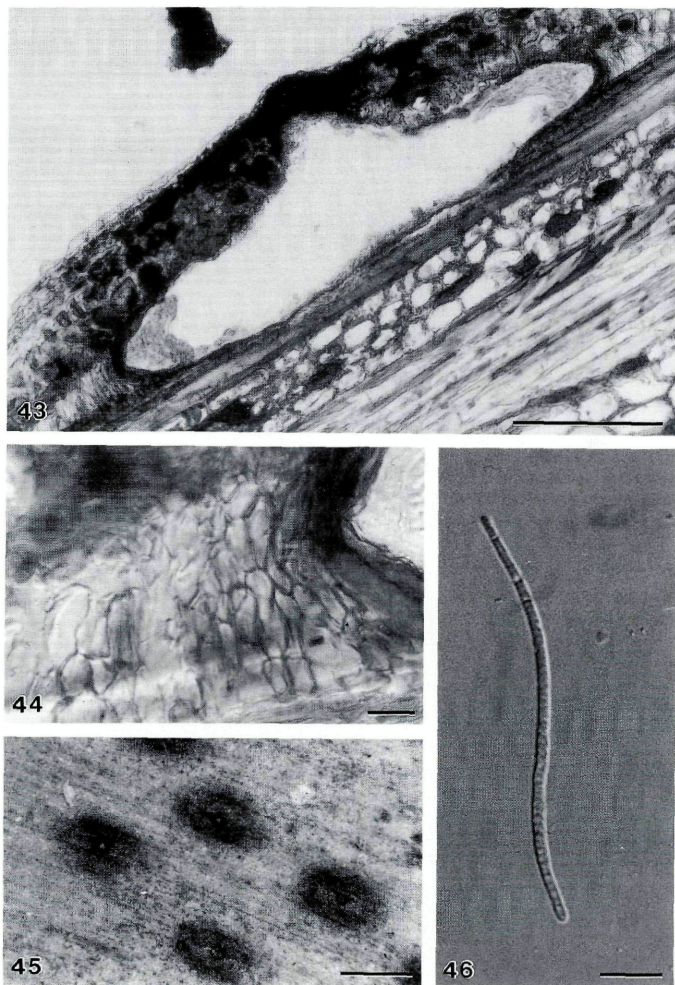
10. *Linocarpon verminosum* (Montagne) Hyde, Trans. Mycol. Soc. Japan 29: 349. 1988.– Figs. 43–46.

- = *Sphaeria verminosa* Montagne Crypt. Guyan. 127: 155. 1855.
- = *Rhaphidospora verminosa* (Montagne) Montagne, Syll. Gen. Sp. Crypt. 252. 1856.
- = *Ophiobolus verminosus* (Montagne) Sacc., Syll. Fung. 2: 351. 1883.
- = *Ophiobolus versisporus* Ellis & Martin, J. Mycol. 1: 99. 1885.
- = *Linocarpon versisporum* (Ellis & Martin) Petrak, Sydowia 6: 388. 1952.

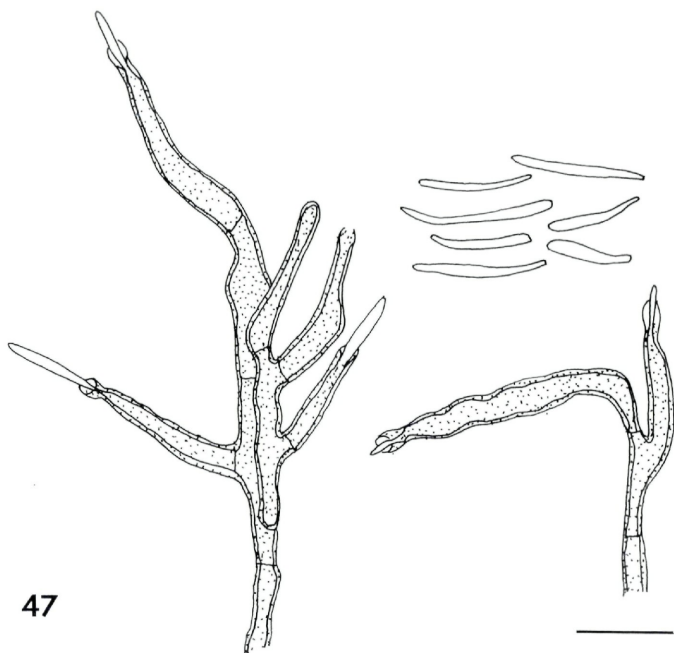
Appearing on host fronds as raised, black, shiny dome-shaped spots, up to 600  $\mu\text{m}$  diam, with a central, short papilla and containing a single ascoma (Figs 43–45). – Clypeus of epidermal cells packed with fungal hyphae. – Ascomata developing below the clypeus, lenticular in section, with variable amounts of stromatic tissue laterally. – Paraphyses embedded in a gel, wide, septate and tapering. – Asci 70–102 x 9–12  $\mu\text{m}$ , 8-spored, cylindrical, pedunculate, with rounded apex and ring-like apical apparatus, 2.5–3.0  $\mu\text{m}$  diam. and 1.7–2.0  $\mu\text{m}$  high. – Ascospores 60–88 x 1.9–3.2  $\mu\text{m}$ , filiform, curved, spiral in ascus, hyaline in mass, rounded and slightly inflated at the poles, lacking any mucilage (Fig. 46).

Material examined. – FRENCH GUIANA: Cayenne, in petioles of *Palmae*, Leprieur, n 1137, Holotype of *Sphaeria verminosa* (P, Holotype). – FLORIDA: on petioles of *Sabal palmetto*, 1885, Martin, (NY).

*L. verminosum* is closest to *L. pandani*. However, ascospores of the former are longer and narrower (60–88 x 1.9–3.2  $\mu\text{m}$  vs. 62–80 x 2–4  $\mu\text{m}$ ) and it occurs on palm fronds as opposed to leaves of *Pandanus* or *Miscanthus*.



Figs. 43–46. – *Linocarpon verminosum*. – 43,44,46. Interference contrast micrographs. – 43,44. Section through ascoma. Note the clypeus and variable stromatic development. A wedge-shaped area of parallel cells is located at the rim. – 45. Surface view of fruiting bodies. – 46. Ascospore. – Bars: 43 = 100  $\mu\text{m}$ ; 45 = 500  $\mu\text{m}$ ; 44, 46 = 10  $\mu\text{m}$ .



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Fig. 47. – *Phialophora* state of *Linocarpon appendiculatum*. – Bar = 10  $\mu$ m.

### Discussion

Ten species are now accepted in *Linocarpon*. The salient features that characterise *Linocarpon* are:

- 1) Lenticular ascomata immersed beneath a clypeus. The clypeus is usually large, black and shiny, but may be small and appear as a disc around the neck. The ascomata are surrounded by a variable amount of stromatic development.
- 2) Saprobes (endophytes or parasites) on palm rachids or leaves, or on *Cajanus*, *Miscanthus*, *Pandanus*, or *Phenakospermum*, most having palm like leaves or stems.
- 3) Cylindrical asci with rounded apices and a ring-like apical apparatus. Spores may be spiral or parallel in the ascus.
- 4) Filiform ascospores with refringent bands. Their apices may or may not contain mucilage.

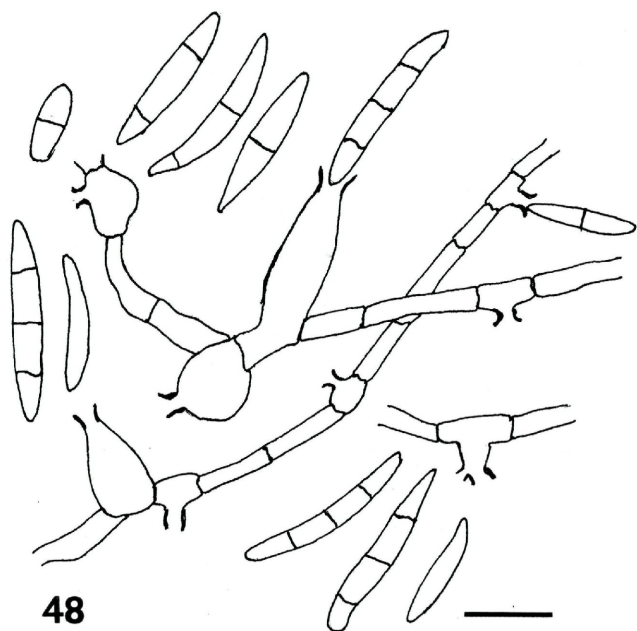


Fig. 48. — *Phialophora* state of *Linocarpon elaeidis*. — Bar = 10  $\mu$ m.

- 5) Tapering paraphyses tending to be persistent. These are more readily seen in fresh specimens.
- 6) An unusual *Phialophora*-like anamorph with a clasping of the collarete around the base of the long and narrow conidia has been found in *L. appendiculatum* and *L. elaeidis*.

In most *Linocarpon* species the ascoma is lenticular and is immersed beneath a dull black or shiny dome-shaped clypeus, a striking feature in herbarium material. Only in *L. palmetto* the ascomata are globose. Lenticular ascomata may result from the limited space that occurs between the hard inner fibres and host epidermis. They may not be developmental characteristics of the fungus and are found in host tissue of species of several other palm fungal genera (i.e. *Fronidicola*, *Carinispora*; Hyde, 1991). *Linocarpon* was considered closely related to *Gaeumannomyces* by Petrak (1952), a genus of parasitic species on Poaceae and Cyperaceae, and both have

*Phialophora*-like anamorphs (Hyde, 1988; Walker, 1980). The presence of a dome-shaped clypeus, the stromatic development around the ascomata, the lack of hyphopodiate mycelium and saprobic habitat mostly on the palm host clearly distinguishes *Linocarpon* from *Gaeumannomyces*.

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I am grateful to Dr J. Walker and Dr. G. Samuels for comments and discussions on the genus *Linocarpon* and for commenting on the manuscript. The curators of herbaria BPI, DAR, S, P, NY and IMI are also thanked for loan of material. The anamorph of *L. appendiculatum* was drawn by Dr. G. Samuels.

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