

Taxonomic Notes on Marine Algae from Malaysia. III. Seven Species of Rhodophyceae

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Taxonomic Notes on Marine Algae from Malaysia

III. Seven Species of Rhodophyceae

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Six species of marine red algae are reported from Malaysia for the first time and their characteristic features are described: one species of the Halymeniaceae (Cryptonemiales), *Cryptonemia crenulata* (J. Agardh) J. Agardh; two species of the Solieriaceae (Gigartinales), *Solieria anastomosa* P. Gabrielson *et* Kraft and *Kappaphycus cottonii* (Weber-van Bosse) Doty *ex* P. Silva; three species of the Gracilariaceae (Gracilariales), *Gracilaria multifurcata* Børgesen, *Gracilaria tenuistipitata* Chang *et* Xia and *Gracilariopsis bailinae* Zhang *et* Xia. Furthermore, spermatangial plants of *Gracilaria firma* Chang *et* Xia that confirm its presence in Malaysian waters are reported.

Introduction

Ongoing investigations of the benthic marine algal flora of Malaysia have shown the presence of many unrecorded or noteworthy species in this region (Masuda *et al.* 1997a, 1997b, 1997c, 1999, 2000). These are very important in assessing the relationship between the marine algal flora of the Pacific and that of the Indian Ocean. The present paper details findings of six red algal species that are reported from Malaysia for the first time.

The occurrence of *Solieria anastomosa* P. Gabrielson *et* Kraft (Solieriaceae, Gigartinales) in Malaysian waters is the first report outside of the type locality, Lord Howe Island, Australia. *Gracilaria tenuistipitata* Chang *et* Xia and *Gracilariopsis bailinae* Zhang *et* Xia (Gracilariaceae, Gracilariales) are reported from the Indian Ocean for the first time. The presence of *Gracilaria firma* Chang *et* Xia (Gracilariaceae, Gracilariales) in Malaysia is confirmed on the basis of spermatangial plants. Species discrimination in the *Gracilaria/Gracilariopsis* complex is known to be complicated by the high degree of gross morphological variation within individual species (Yamamoto 1978), so that it is important to describe morphological features of geographically distant populations in detail within each species.

Materials and Methods

Specimens examined were collected at various localities in Malaysia. The specimens were fixed in 10% Formalin in seawater, and later some were dried as voucher herbarium specimens and deposited in the

Herbarium of the Graduate School of Science, Hokkaido University (SAP 070777–070801) or in the Seaweed Herbarium, Institute of Biological Sciences, University of Malaya. These specimens are cited in the following sequence: state, locality (latitude and longitude and date in parentheses) (specific localities are not given for small islands) and island, town or city. The latitude and longitude of each locality was determined using Panasonic GPS (Global Positioning System) Receiver [Model KX-G5500] (Matsushita-Denki-Sangyo, Oosaka, Japan).

Sections of specimens were made by hand using a razor blade and a pith stick. The sections were then stained with 0.5% (w/v) cotton blue in a lactic acid/phenol/glycerol/water (1:1:1:1) solution and mounted in 50% glycerol/seawater or Karo on microscope slides.

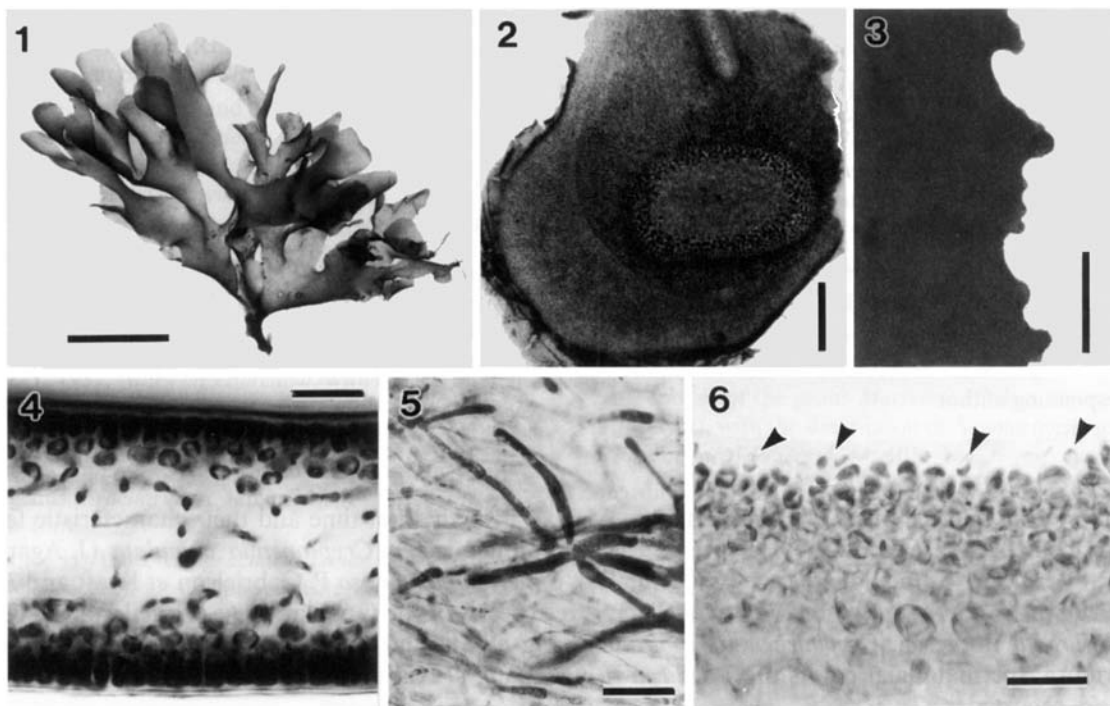
Observations and Discussion

Cryptonemia crenulata (J. Agardh) J. Agardh 1851: 225 (Figs 1–6)

Distribution: Tropical regions in the Pacific (Cordero 1977), Indian Ocean (Silva *et al.* 1996) and Atlantic (Wynne 1998).

Specimens examined: Sabah: Pulau Dinawan (5°51'05" N, 115°59'28" E; 5.vi.1998; SAP 070777), Kota Kinabalu.

Plants grow on bedrock in the upper subtidal zone of a reef flat. Thalli are attached to the substratum by a discoid holdfast from which several firm, upright blades up to 4 cm high arise. Each blade (Fig. 1) has a short terete stem 1 mm in diameter that shows clear growth rings (Fig. 2). The upright blades are re-



Figs 1–6. *Cryptonemia crenulata*.

Fig. 1. Herbarium vegetative specimen (SAP 070777) (scale bar = 1 cm). Fig. 2. Transverse section (TS) of a stipe (scale bar = 200 μ m). Fig. 3. Crenulate margin of a blade (scale bar = 300 μ m). Fig. 4. TS of a blade (scale bar = 20 μ m). Fig. 5. Highly refractive, stellate, medullary cells with long arms in TS (scale bar = 20 μ m). Fig. 6. Superficial spermatangia (arrowheads) in TS (scale bar = 20 μ m).

peatedly dichotomously branched with rounded axils (Fig. 1), the segments being 4–6 mm wide. The blade margins are mostly crenulate (Fig. 3) (sometimes entire) and undulate.

The blade consists of a cellular cortex and a filamentous medulla (Fig. 4) and is up to 200 μ m thick (65–100 μ m thick in young blades). The outer cortex consists of 1 or 2 rounded to ellipsoidal cells, and the inner cortex consists of 2 or 3 larger, irregularly polygonal or stellate cells. Lateral secondary pit-connections are occasionally present between adjacent cortical cells. The medulla consists of loosely running filaments, mostly periclinally directed (Fig. 4). Large stellate cells with long arms and highly refractive contents are occasionally present among normal medullary filaments (Fig. 5).

Spermatangia are formed beneath the apical segments as soral aggregations, one or two being produced from each superficial cortical cell (Fig. 6). Female reproductive structures and tetrasporangia were not found in our specimens.

This alga is characterised by the presence of a short, solid stipe, firmly membranous blades, and highly refractive large stellate cells in the medulla. This combination of features agrees well with that of *Cryptonemia* (Kraft 1977, Scott *et al.* 1982, Kawaguchi 1993), although female reproductive features were not observed in this study. Our Malaysian alga is most similar to *Cryptonemia crenulata* among some 45 known species of the genus. This species was origi-

nally described by Agardh (1841) from Bahia, Brazil, as *Phyllophora crenulata* J. Agardh and later transferred to *Cryptonemia* (Agardh 1851).

Two herbarium specimens of *Cryptonemia crenulata* which were collected from Praia do Cupe, Ipojuca, Pernambuco State, Brazil (24.ix.1999, leg. M. T. Fujii) were examined. These Brazilian specimens are larger in size (6–7 cm high) and have broader segments (1.2–1.5 cm broad in the widest portion) than our Malaysian plants. However, the dichotomous branching pattern of blades with round axils and crenulate margins and the internal construction of blades are common to specimens from Brazil and Malaysia. Furthermore, Brazilian and Malaysian male gametophytes produce the spermatangial sorus in apical segments in a similar way. Thus, *Cryptonemia crenulata* best accommodates our Malaysian material.

Solieria anastomosa P. Gabrielson *et* Kraft 1984: 222, f. 1C–E, 2C–E, 3–5 (Figs 7–15)

Distribution: Tropical regions in the Pacific (Gabrielson and Kraft 1984).

Specimens examined: Sabah: Pulau Tikus (6°04'06" N, 117°57'48" E; 14.v.1998; SAP 070778, 070779), Sandakan; Pulau Bai (5°47'00" N, 118°07'05" E; 19.v.1998; SAP 070780–070783), Sandakan.

Plants are attached to bedrock or dead coral in the upper subtidal zone in reef flats by a discoid holdfast.

They have a terete stipe that is cartilaginous and up to 2 mm in diameter. The stipe produces several upright axes (Figs 7, 8) up to 10 cm high. The axes are compressed below, usually becoming terete upwards, and are 3–5 mm wide, ending in acute apices. Short lateral branches with a constricted base and an acute apex are irregularly produced along the axis (Figs 7, 8). Anastomoses between adjacent axes are present (Fig. 9).

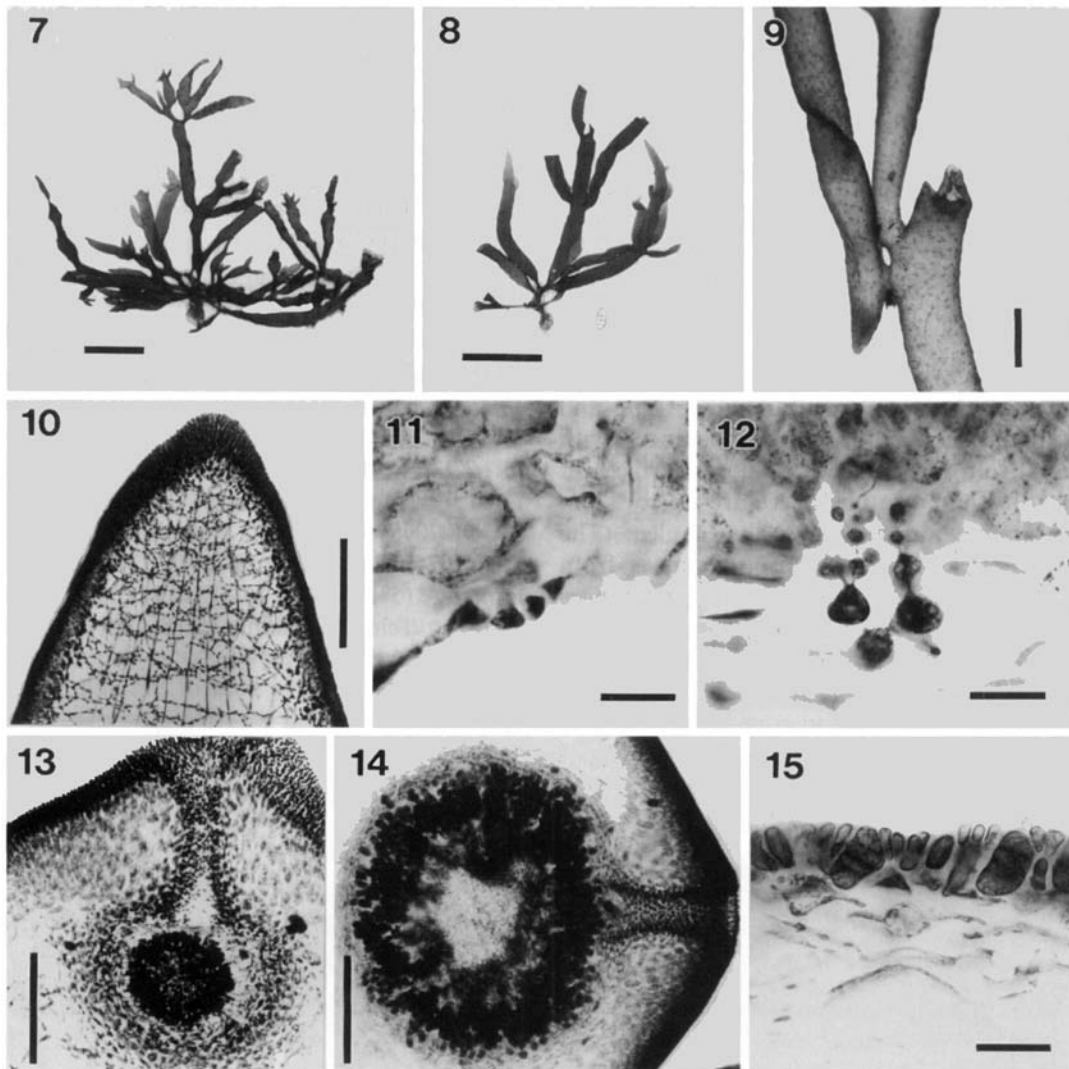
Thalli are multi-axial, and the vegetative construction is typical of *Solieria*: branched, multicellular interconnecting filaments link adjacent medullary cells (Fig. 10).

Carpogonial branches are three-celled and are borne on inner cortical cells that are 5–6 layers beneath the surface (Fig. 11). Auxiliary cells are produced on a supporting cell in a lateral filament which

is derived from the medullary cell. The supporting cell also bears another darkly staining cortical file. This cortical file and the cortical file including the auxiliary cell altogether form an auxiliary-cell complex prior to fertilization (Fig. 12). Advanced stages of gonimoblast development are typical of *Solieria* (Figs 13, 14), although early post-fertilization events were not traced. Male reproductive structures were not found in our collections.

Tetrasporangia are scattered over the thallus surface. They are cut off from the second or third cortical cells from the surface. Mature tetrasporangia, with zonately arranged spores, are ellipsoidal, 35–40 μm long by 20–25 μm wide (Fig. 15).

Compared with the eight described species of *Solieria* (Gabrielson and Kraft 1984, Yoshida 1989), our Malaysian alga is most similar to *S. anastomosa* that



Figs 7–15. *Solieria anastomosa*.

Fig. 7. Herbarium female specimen (SAP 070780) (scale bar = 2 cm). Fig. 8. Herbarium tetrasporangial specimen (SAP 070781) (scale bar = 2 cm). Fig. 9. Anastomosed upper portion of a plant (scale bar = 2 mm). Fig. 10. Longitudinal section (LS) of the apex of an axis (scale bar = 300 μm). Fig. 11. Three-celled carpogonial branch in TS (scale bar = 20 μm). Fig. 12. Auxiliary cell complex in TS (scale bar = 20 μm). Figs 13, 14. Stages of cystocarp development in TS (scale bar = 300 μm). Fig. 15. Zonately divided tetrasporangia in TS (scale bar = 20 μm).

is known only from Lord Howe Island in Australia. *Solieria anastomosa* has been characterised by its essentially prostrate habit and the stout anastomoses formed between adjacent branches (Gabrielson and Kraft 1984). Our Malaysian alga as a whole does not show a prostrate habit, but only basal portions are prostrate. However, other features are in good agreement with *S. anastomosa*. Above all, the presence of anastomoses supports the placement of our alga in *S. anastomosa*. This is the first record of the species outside the type locality.

Kappaphycus cottonii (Weber-van Bosse) Doty *ex* P. Silva *in* P. Silva *et al.* 1996: 333 (Figs 16–18)

Distribution: Tropical and subtropical regions in the Pacific (Doty 1988) and Indian Ocean (Weber-van Bosse 1913, Silva *et al.* 1996).

Specimens examined: Sabah: Pulau Sapangar (6°04'09" N, 116°04'14" E; 3.vi.1998; SAP 070784), Kota Kinabalu; Tanjung Kaitan (6°07'00" N, 116°05'49" E; 3.vi.1998; SAP 070785–070787), Kota Kinabalu.

Plants grow on bedrock or dead coral in the lower intertidal to upper subtidal zones in reef flats. They are prostrate and expand to a circular cluster 12–20 cm in diameter. Thalli are purple in colour and succulent, slippery but firm in consistency. Axes are terete near the base (4–5 mm in diameter) and become compressed to complanate upwards (10–12 mm wide and 5–7 mm thick), dividing irregularly. Anastomoses between adjacent axes are frequently present. Axes are longitudinally striate and produce numerous papilliform protuberances with blunt apices from the dorsal and lateral surfaces of axes (Fig. 16). These protuberances are up to 5 mm long by 1.5 mm wide and have blunt apices. The axes also bear less numerous protuberances from the ventral surface. Some of these protuberances grow to 2–8 mm long by 1.5–3.5 mm wide (sometimes branched once) and form a discoid holdfast

at the apex by which the thallus attaches to the substratum.

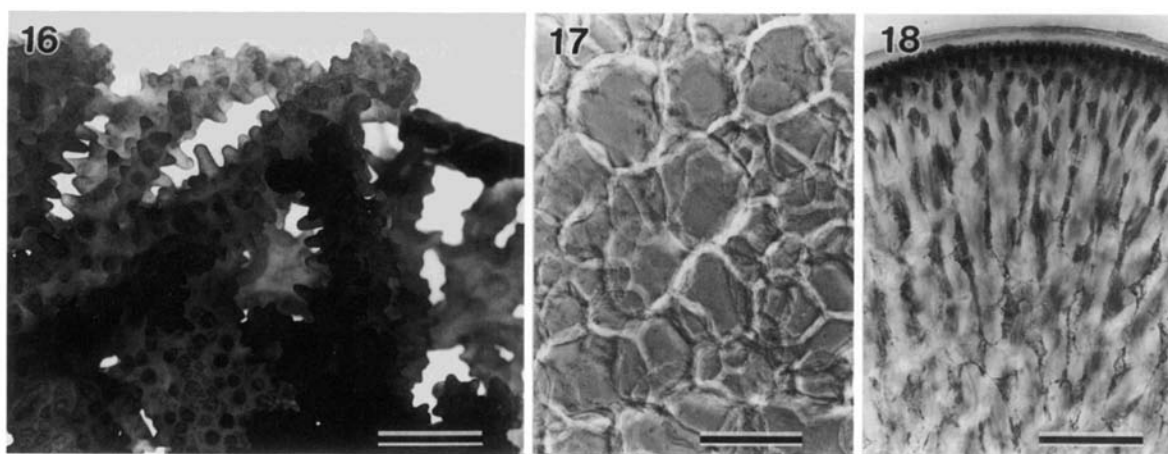
The thallus is multiaxial. The medulla is devoid of rhizoidal filaments and entirely pseudoparenchymatous (Fig. 17). It consists of unpigmented cells that are 80–250 µm in diameter and have thick walls of 10–20 µm. Contiguous medullary cells are frequently linked by secondary pit-connections (Fig. 18). These medullary cells merge outwards with anticlinally oriented cortical cells that form a tightly packed cortex of various depths according to parts of the thallus. The outer, one to three cortical cells are conspicuously pigmented, 5–8 µm wide and 10–16 µm high in transverse sections. No reproductive structures were found in our collections.

Our Malaysian specimens are characterised by prostrate thalli with abundant papilliform protuberances. Some specimens of this species with a few papilliform protuberances are similar in gross morphology to *Gracilaria eucheumoides* Harvey that is distributed in tropical and subtropical regions of the north-western Pacific (Yoshida and Yamamoto 1998) and grows together with *Kappaphycus cottonii* at Tanjung Kaitan (our observation). However, *K. cottonii* is distinguished from *Gracilaria eucheumoides* by its slippery thalli with frequent anastomoses between adjacent branches in the field.

Gracilaria multifurcata Børgesen 1953: 42, f. 15, 16 (Figs 19–26)

Distribution: Tropical regions in the Pacific (Millar 1997) and Indian Ocean (Silva *et al.* 1996).

Specimens examined: Penang: Sungai Batu (5°16'23" N, 100°14'36" E; 31.xii.1997; SAP 070788); Batu Ferringhi (5°28'55" N, 100°15'18" E; 1.i.1998; SAP 070789, 070790); Pasir Pandak (5°16'27" N, 100°10'24" E; 2.i.1998; SAP 070791–070793); Pasir Panjang (5°17'33" N, 100°10'54" E; 2.i.1998; SAP 070794); Teluk Kerachut (5°18'18" N, 100°11'01" E; 2.i.1998; SAP 070795).



Figs 16–18. *Kappaphycus cottonii*.

Fig. 16. Wet habit of the marginal portion of a plant (scale bar = 1 cm). Fig. 17. Centre of the medulla in the upper portion of an axis in TS (scale bar = 200 µm). Fig. 18. LS of the apex of an axis (scale bar = 100 µm).

Plants grow on dead coral or pebbles together with *Gracilaria edulis* (S. Gmelin) P. Silva in the lower intertidal zone in reef flats and on fish-cage nets. Several thalli 4–16 cm long (Fig. 19) arise from a small discoid holdfast and have prostrate rhizomes (Fig. 20), forming an entangled mass. They are cartilaginous and reddish brown to purplish brown in colour and do not adhere to herbarium paper in drying. Axes divide dichotomously or trichotomously (Fig. 21) up to 4 times and are flattened throughout (Fig. 22), reaching up to 2 mm wide. Anastomoses between adjacent branches are frequently present.

The thallus is multi-axial. The medulla consists of 8 layers of unpigmented, abundantly vacuolated, spherical cells that increase gradually in size towards the centre and reach up to 250 µm in diameter (Fig. 22). Contiguous medullary cells are frequently linked by secondary pit-connections. The cortex consists of 1 or 2 layers of globular cells up to 6 µm long and 4 µm wide (Fig. 23). Cortical cells are filled with dense cytoplasm and connected with only their parental cells by primary pit-connections.

Spermatangial conceptacles are formed over the entire surface (Fig. 21) of male gametophytes except for apical and basal parts. They are multicavitated, 120–160 µm deep and 100–200 µm wide (Fig. 23). Fully mature spermatangial conceptacles become conspicuously elevated (Fig. 23). Cystocarps are formed also over the entire surface of female gametophytes except for basal and apical parts. Mature cystocarps protrude prominently from the bearing axes and branches. They are globose, up to 0.8 mm high by 1 mm wide, each having a single rostrated ostiole and a slightly constricted base (Fig. 24). Gonimoblasts consist of large cells 60–120 µm wide (Fig. 24). Basal traversing filaments arise from the bottom of the gonimoblasts and penetrate into the tissue of the cystocarpic floor and that of the proximal portion of the pericarp (Fig. 25), fusing to cells in these portions by secondary pit-connections.

Tetrasporangia are formed over the entire surface of tetrasporophytes except for basal and apical portions. Crucially divided tetrasporangia are up to 45 µm high by 30 µm wide (Fig. 26).

Our Malaysian plants agree well with *Gracilaria multifurcata*, which was originally described by Børgesen (1953) on the basis of material collected at Mauritius, in having flattened thalli that are repeatedly irregularly furcated and in having multicavitated *Hydropuntia*-type (*Polycavernosa*-type) spermatangial conceptacles (Børgesen, 1953, p. 43, fig. 16). They are similar in basal habit and reproductive organs to *G. edulis*. However, our plants with flattened thalli are clearly distinguished from *G. edulis* which has entirely terete (sometimes compressed) thalli (Yamamoto 1978).

Umamaheswara Rao (1972) reported *Gracilaria foliifera* (Forsskål) Børgesen from India. However, the multicavitated spermatangial conceptacles of his

alga (Umamaheswara Rao 1972, fig. 2 b) shows that his alga should be referred not to *G. foliifera* but to *G. multifurcata*, because *G. foliifera* is known to produce shallowly depressed *Textorii*-type spermatangial conceptacles (McLachlan and Edelstein 1977).

Gracilaria multifurcata was transferred to *Polycavernosa* Chang et Xia by Chang and Xia (1963) on the basis of its characteristic spermatangial conceptacles and later to *Hydropuntia*, which has nomenclatural priority over *Polycavernosa* Montagne (1842), by Wynne (1989). However, Abbott et al. (1991) reduced *Hydropuntia* to the synonymy of *Gracilaria* because both *Hydropuntia*- and *Verrucosa*-type spermatangial conceptacles are present in the same thallus of some *Hydropuntia* species. This treatment has been supported by 18S rDNA nucleotide sequence data (Bird et al. 1992), although the generitype *H. urvillei* Montagne has not been analysed yet. Citing a paper of Fredericq and Hommersand (1990), Wynne (1998) claimed that *Hydropuntia* can still be distinguished from *Gracilaria* by its cystocarpic characteristics. According to Fredericq and Hommersand (1990), traversing filaments (as tubular nutritive cells) of *Hydropuntia* are restricted to the floor of the cystocarp, whereas those of *Gracilaria* are present in both the floor of the cystocarp and the pericarp. However, some species are known to produce both *Hydropuntia*-type spermatangial conceptacles and cystocarps that are similar to those formed in *Gracilaria sensu stricto* (Bird 1995), which supports the conclusion of Abbott et al. (1991).

Gracilaria tenuistipitata Chang et Xia 1976: 102, f. 6, 7, pl. I(3) (Figs 27, 28)

Distribution: Tropical and subtropical regions in the western Pacific (Zhang and Xia 1988) and Indian Ocean (present paper).

Specimens examined: Kedah: Kuah (6°18'32" N, 99°51'15" E; 19.xii.1997; SAP 070796, 070797), Langkawi.

Plants grow on pebbles or shells in a calm, narrow, muddy canal in the lower intertidal zone on Langkawi Island. Several thalli arise from a small discoid holdfast and are 5–15 cm high. They are terete throughout, cartilaginous, deep purple and do not adhere to herbarium paper when dried. Main axes are 0.5–1.0 mm wide and bear densely and irregularly arranged first-order branches 5–10 cm long by 0.2–0.3 mm wide that bear progressively shorter and more slender branches which branch up to three orders (Fig. 27).

The internal structure of thalli is similar to that of *Gracilaria multifurcata*, but some differences are found. The medulla consists of 5 layers of cells which increase markedly in size towards the centre and reach up to 350 µm in diameter, and the cortex consists of 2 layers of cells up to 4 µm long and 8 µm wide (Fig. 28).

Our Malaysian alga is in agreement with the var. *liui* Zhang *et al.* (1988) of *Gracilaria tenuistipitata* that was originally described from Hainan Island, China, and distinguished from the typical variety *tenuistipitata* by the slender thalli bearing numerous, delicate, short to long flagelliform lateral branches. The var. *liui* is known to occur in fish ponds and in the shallow intertidal zone (Zhang and Xia 1988), whereas the var. *tenuistipitata* is known to occur in the subtidal region of lower salinity (Chang and Xia 1976). Zhang and Xia (1988) reported the presence of intermediates between the var. *tenuistipitata* and var. *liui*. There is a possibility that the var. *liui* is an ecad growing in quiet water.

Gracilaria firma Chang *et al.* 1976: 143, f. 38, 39, pl. II(4) (Figs 29–32)

Distribution: Tropical and subtropical regions in the western Pacific (Chang and Xia 1976, Abbott 1994, Yamamoto *et al.*, 1994, Lewmanomont 1994) and Indian Ocean (Phang 1994).

Specimens examined: Sabah: Tanjung Aru (5°20'51" N, 115°14'04" E; 1.vi.1998; SAP 070798), Pulau Labuan.

Plants grow on pebbles or shells in the lower intertidal zone in a reef flat. Several thalli arise from a small discoid holdfast and are 10 cm high. They are terete throughout, cartilaginous, greenish brown to yellowish brown in colour and do not adhere to herbarium paper when dried. Axes are up to 2 mm in diameter and bear alternately or irregularly arranged first-order branches that produce progressively shorter branches of up to 3 orders (Fig. 29). Branches of all orders are generally constricted at the bases (Fig. 30), tapering gradually towards acute or blunt apices.

The internal structure of thalli is similar to that of *Gracilaria multifurcata*. However, some differences are found: the medulla consists of 7 layers of cells up to 400 µm in diameter; the cortex consists of 2 layers of cells up to 7 µm long and 12 µm wide.

Spermatangia are formed in deep pot-shaped conceptacles up to 60 µm deep and 40 µm wide (Figs 31, 32) over the entire surface of male gametophytes except for apical and basal parts.

Gracilaria firma was originally described by Chang and Xia (1976) based on material from Guangdong Province, China, and has been characterised by small gonimoblast-cells, a few traversing filaments in the

cystocarp and deep pot-shaped (*Verrucosa*-type) spermatangial conceptacles (Chang and Xia 1976, Yamamoto *et al.* 1994). Although this species closely resembles *G. blodgettii* Harvey in gross morphology, it entirely differs from *G. blodgettii* which has more abundant traversing filaments and shallowly depressed *Textorii*-type spermatangial conceptacles (Yamamoto 1978; Fredelicq and Norris 1992). Although this species was already reported from Sungei Merbuk (facing the Straits of Malacca), Perak (Phang 1994), on the basis of cystocarpic and tetrasporangial plants, its presence in Malaysian waters is confirmed here by finding male gametophytes with the *Verrucosa*-type spermatangial conceptacles.

Gracilariopsis bailinae (as *bailinae*) Zhang *et al.* 1991: 290 (Figs 33–37)

Distribution: Tropical and subtropical regions in the western Pacific (Zhang and Xia 1988, Yamamoto *et al.* 1994, both as *Gracilaria heteroclada* Zhang *et al.* and Indian Ocean (present paper).

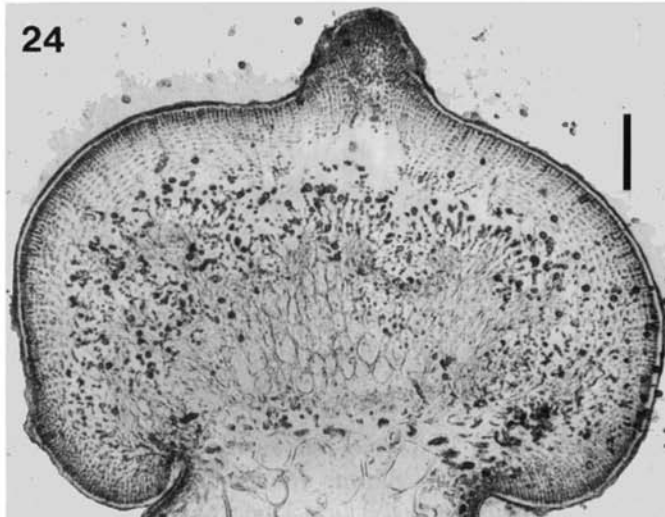
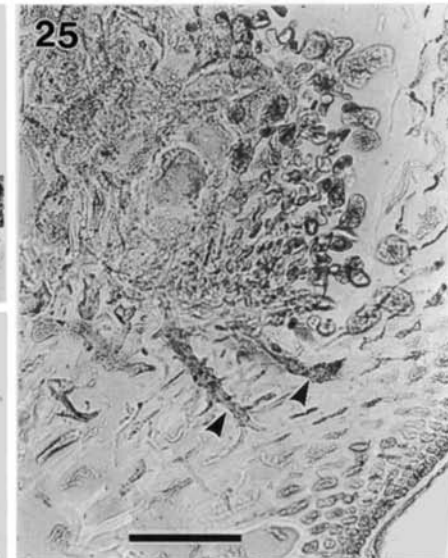
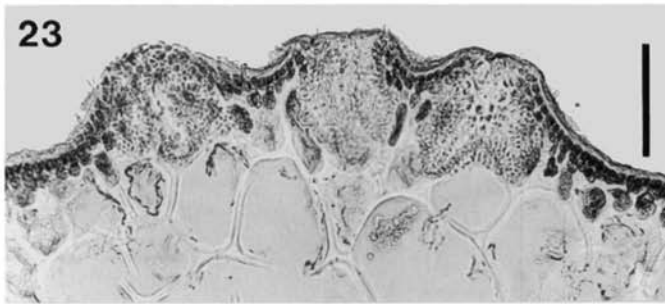
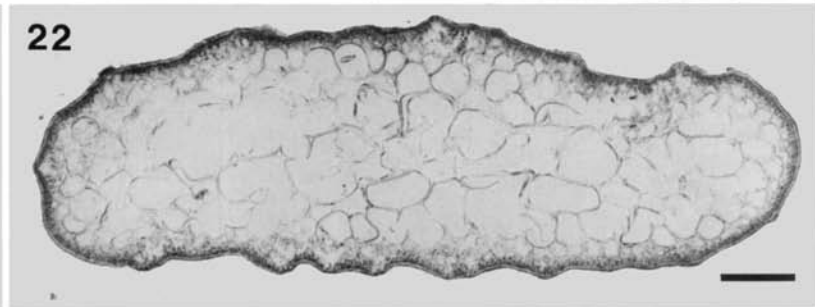
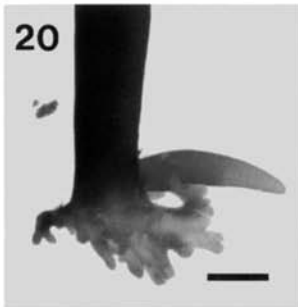
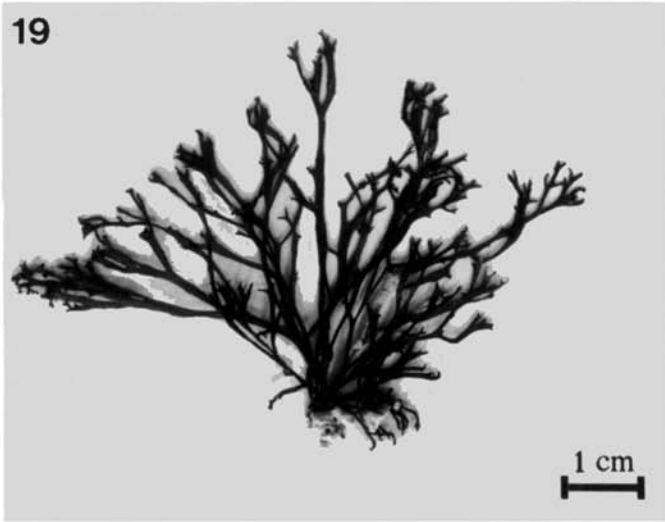
Specimens examined: Penang: an island (5°21'47" N, 100°19'38" E; 1.i.1998; SAP 070799, 070800) in the Middle Banks. Sabah: Pulau Bai (5°46'22" N, 118°06'53" E; 19.v.1998; SAP 070801), Sandakan.

Plants grow on shells or pebbles in a calm, muddy canal between Penang Island and Malay Peninsula in the lower intertidal zone and on fish-cage nets in Sandakan. Several thalli arise from a small discoid holdfast and are 10–20 cm high. They are terete throughout, fleshy, light green or dark brown in colour and firmly adhere to herbarium paper in drying. The main axes are 0.8–2.0 mm in diameter and produce irregularly alternately or secondly arranged first-order branches 8–14 cm long that bear also irregularly arranged, short, spinous branches which branch up to four orders (Fig. 33).

The thallus is multiaxial. The medulla consists of 5 layers of unpigmented, abundantly vacuolated, spherical cells that increase in size towards the centre and reach up to 500 µm in diameter. Contiguous medullary cells are frequently linked by secondary pit-connections. The cortex consists of 2 layers of globular cells up to 10 µm long and 6 µm wide. Cortical cells are filled with the dense cytoplasm and connected with only their parental cells by primary pit-connections.

Figs 19–26. *Gracilaria multifurcata*.

Fig. 19. Herbarium cystocarpic specimen (SAP 070790). Fig. 20. Base of a thallus issuing prostrate rhizomes (scale bar = 1 mm). Fig. 21. Surface view of a male plant, showing trichotomous branching and numerous, pale-coloured spermatangial conceptacles formed over the entire surface (scale bar = 1 mm). Fig. 22. TS of the middle portion of a male plant (scale bar = 200 µm). Fig. 23. Multicavitated spermatangial conceptacles raised above the thallus surface in TS (scale bar = 100 µm). Fig. 24. LS of a mature cystocarp with a rostrate ostiole and gonimoblasts consisting of large cells (scale bar = 200 µm). Fig. 25. Basal traversing filaments (arrowheads) arising from the gonimoblast and penetrating into the proximal portion of a pericarp in LS (scale bar = 100 µm). Fig. 26. Tetrasporangia in TS (scale bar = 20 µm).

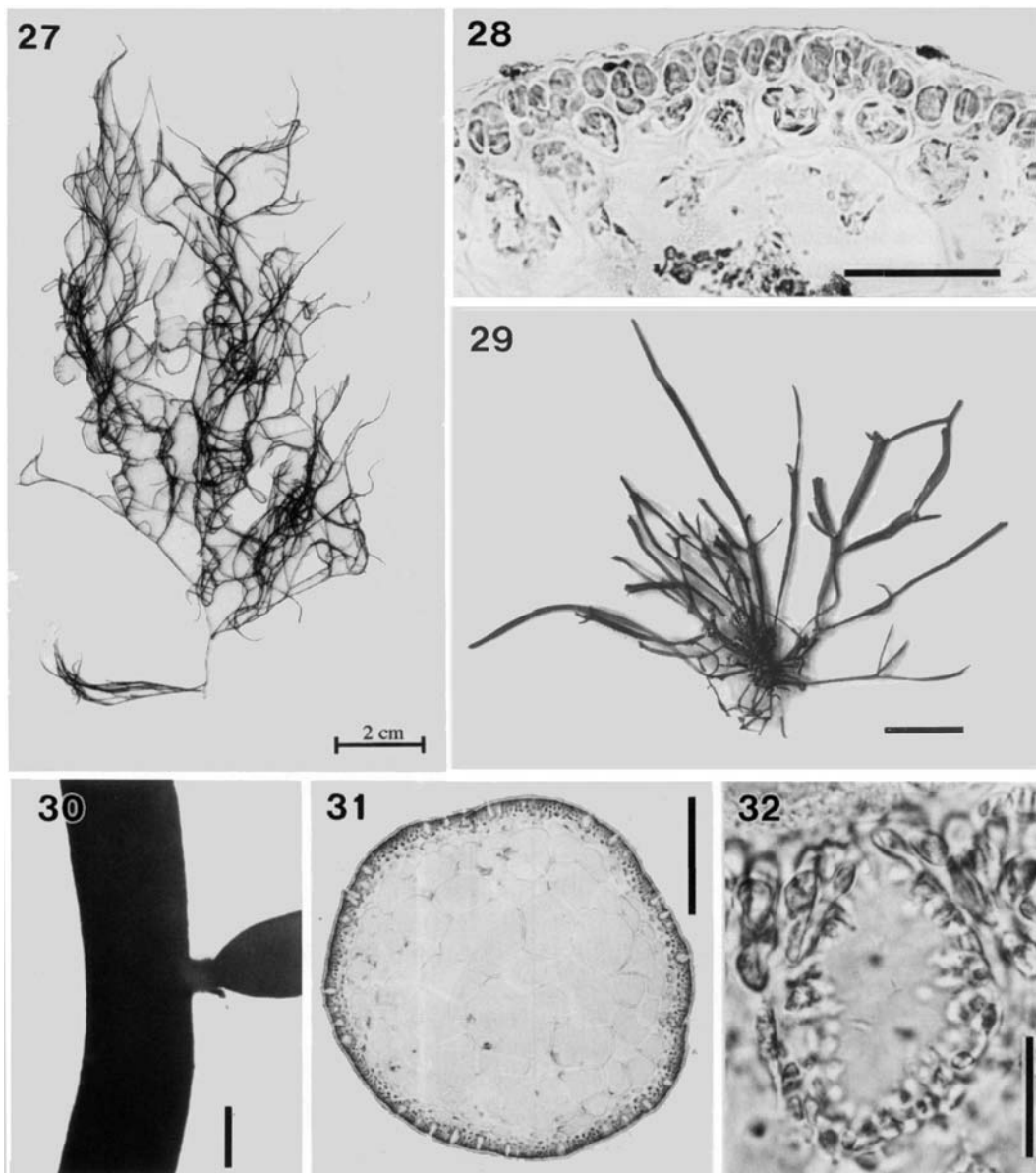


Spermatangia are continuously superficial (Fig. 34) over the entire surface of male gametophytes except for the basal and apical portions and are 5 μm in diameter. Cystocarps are formed also over the entire surface of female gametophytes except for the basal and apical parts. Mature cystocarps protrude prominently from the bearing axes and branches (Figs 35, 36). They are globose, up to 1.5 mm high and 2 mm wide, each having a slightly constricted base and a slightly rostrated ostiole (Fig. 36), the pericarp consisting of 6–8 layers of cells. Gonimoblasts consist

of small cells 40 μm in diameter. Traversing filaments are absent in the cystocarp (Fig. 36).

Tetrasporangia are formed over the entire surface of tetrasporophytes except for basal and apical portions. Crucially divided tetrasporangia are up to 30 μm high by 20 μm wide (Fig. 37).

Zhang and Xia (1988) described *Gracilaria heteroclada* Zhang *et* Xia from material collected at Guangdong Province, China. It was later transferred to *Gracilariopsis* as *Gracilariopsis heteroclada* (Zhang *et* Xia) Zhang *et* Xia (*in* Abbott *et al.* 1991). As *Gracila-*

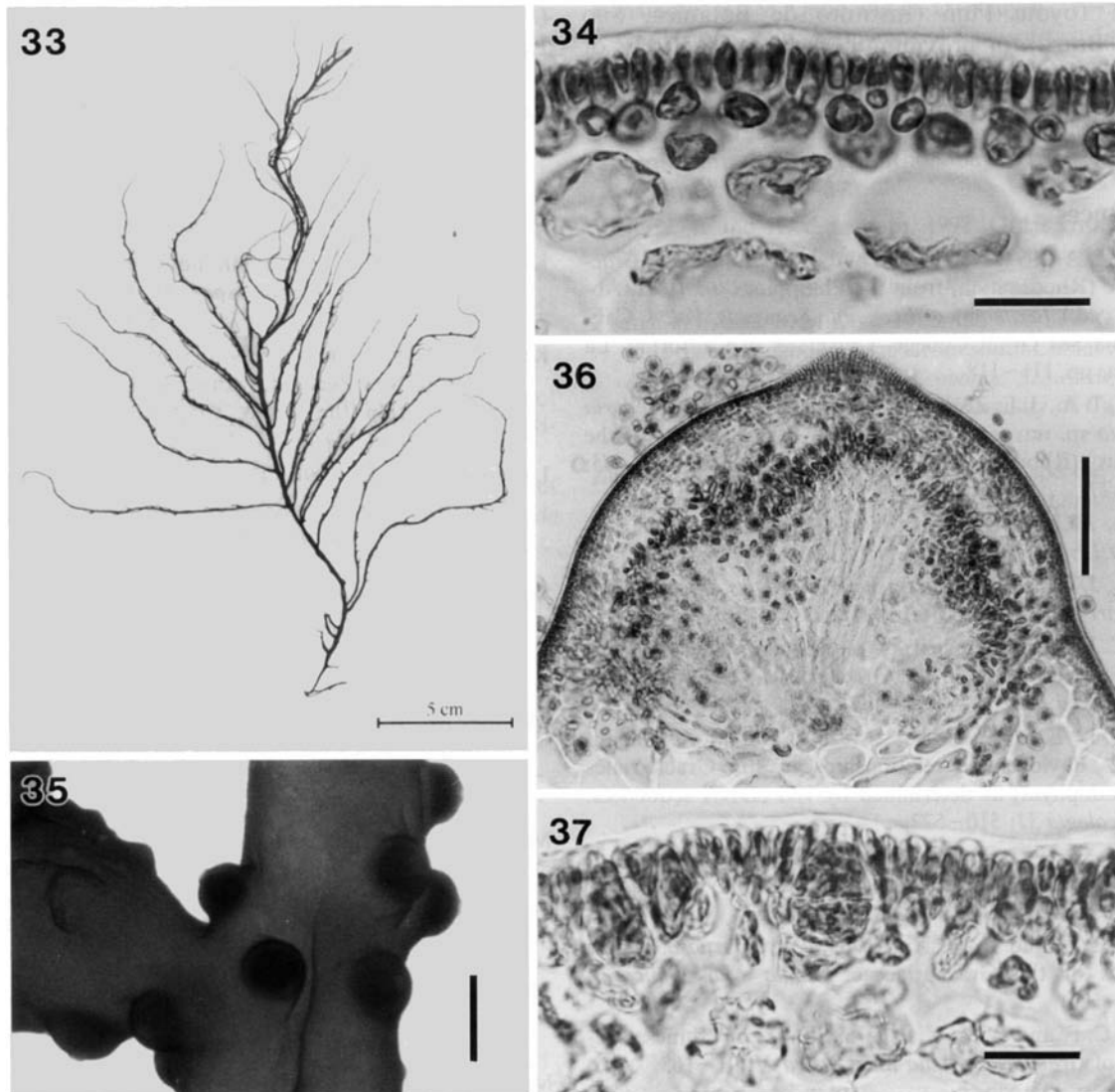


Figs 27, 28. *Gracilaria tenuistipitata*.

Fig. 27. Herbarium vegetative specimen (SAP 070797). Fig. 28. TS of a main axis, showing the cortex consisting of 2 layers of cells (scale bar = 50 μm).

Figs 29–32. *Gracilaria firma*.

Fig. 29. Herbarium male specimen (SAP 070798) (scale bar = 1 cm). Fig. 30. Middle portion of a tetrasporophyte, showing a conspicuous constriction at the branch base (scale bar = 1 mm). Fig. 31. TS of a main axis of a male plant, showing numerous spermatangial conceptacles (scale bar = 500 μm). Fig. 32. Close up of a spermatangial conceptacle in TS (scale bar = 20 μm).



Figs 33–37. *Gracilariopsis bailinae*.

Fig. 33. Herbarium male specimen (SAP 070801). Fig. 34. Superficial spermatangia in TS (scale bar = 20 µm). Fig. 35. Cystocarps protruding prominently from the axis in surface view (scale bar = 1 mm). Fig. 36. LS of a cystocarp, showing gonimoblasts consisting of small cells (scale bar = 200 µm). Fig. 37. Tetrasporangium in TS (scale bar = 25 µm).

ria heteroclada is a later homonym of *Gracilaria heteroclada* (Montagne) J. Feldmann *et* G. Feldmann (1943), the new name *Gracilariopsis bailinae* was proposed by Zhang and Xia (1991, as *bailinae*). The presence of long first-order and short (sometimes spine-like) second-order branches, both of which are not constricted proximally, the size of medullary cells, the absence of traversing filaments in the cystocarp and the presence of the *Chorda*-type superficial spermatangia in our Malaysian alga are entirely compatible with those of *G. bailinae* from China (Zhang and Xia 1988 as *Gracilaria heteroclada*).

Gracilariopsis bailinae is similar in gross morphology to *Gracilaria gigas* Harvey that has been chiefly reported from warm-temperate regions in the western Pacific (Yamamoto 1978). However, *G. gigas* is clearly distinguished from *Gracilariopsis bailinae* by

the production of both *Textorii*-type spermatangial conceptacles and traversing filaments in the cystocarp (Yamamoto 1978). An Indian Ocean record (Delft in Sri Lanka) of *Gracilaria gigas* is in need of confirmation, as no such reproductive features were described (Durairatnam 1961).

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