

## ON THE GRACILARIAEAE OF THE SEAS AROUND INDIA\*

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### ABSTRACT

Taxonomic investigations of members of the family Gracilariaceae of the seas around India are very limited and many of the *Gracilaria* species hitherto reported from this area are inadequately described. During the course of studies on the agar-yielding seaweeds, different species of *Gracilaria* and *Gracilariopsis* were collected from the east and west coasts of India, Laccadives, Andaman and Nicobar Islands. In this paper seventeen species and two varieties of *Gracilaria* and two species of *Gracilariopsis* are described in detail. The species of these two genera are as follows: *Gracilaria arcuata* v. *typica* Zanardini, *G. arcuata* v. *attenuata* var. nov., *G. cacalia* (J. Agardh) Dawson, *G. canaliculata* (Kuetzing) Sonder, *G. corticata* v. *typica* J. Agardh, *G. corticata* v. *cylindrica* var. nov., *G. cylindrica* Boergesen, *G. disticha* J. Agardh, *G. edulis* (Gmelin) Silva, *G. foliifera* (Forsskal) Boergesen, *G. indica* sp. nov., *G. kanyakumariensis* sp. nov., *G. mannarensis* sp. nov., *G. millardetii* (Montagne) J. Agardh, *G. obtusa* (Kuetzing) De Toni, *G. opuntia* (Svedelius) Durairatnam, *G. textorii* (Suringer) J. Agardh, *G. verrucosa* (Hudson) Papenfuss, *Gracilaria* sp., *Gracilariopsis megaspora* Dawson and *Gr. sjoestedtii* (Kyllin) Dawson.

Of the 21 algae reported in this paper, three species and two varieties of *Gracilaria* are new taxa and *G. cylindrica*, *G. millardetii*, *G. opuntia* and *Gracilariopsis megaspora* are the first records from the Indian waters. Cystocarps of *G. canaliculata*; antheridia of *G. corticata*, *G. foliifera*, *G. canaliculata*, *G. obtusa*, *G. edulis*, *G. cylindrica*, *Gracilariopsis megaspora* and tetrasporangia of *Gr. megaspora* and other species were observed and these have been described here for the first time. Details regarding the habitats of the species and their distribution in India and other geographical areas are also included here.

### INTRODUCTION

STUDIES on the species of *Gracilaria* and other genera reported earlier from the Indian Ocean region and in particular from the seas around India are incomplete. Only three genera of the family Gracilariaceae namely *Gracilaria*, *Gracilariopsis* and *Ceratodictyon* have been reported from India till now. Of these, the genus *Ceratodictyon* is known by a single species, *C. spongiosum* Zanardini (Umamaheswara Rao, 1969; Devanesan and Chacko, 1941). The genus *Gracilaria* is well represented in Indian Seas. Boergesen (1933, 1934, 1937a, b and 1938) reported the following eleven species and one variety of *Gracilaria* from different localities. *G. compressa* (Agardh) J. Agardh, *G. confervoides* (Linnaeus) Greville, *G. corticata* J. Agardh, *G. corticata* var. *ramalinoidea* J. Agardh, *G. crassa* (Harvey) J. Agardh, *G. debilis* (Forsskal) Boergesen, *G. disticha* J. Agardh, *G. fergusonii* J. Agardh, *G. foliifera* (Forsskal) Boergesen, *G. lichenoides* (Linnaeus) Harvey, *G. pygmaea* Boergesen and *Corallopsis cacalia* J. Agardh (*G. cacalia* (J. Agardh) Dawson). The nomenclature of some of these species has been changed in recent years (Papenfuss, 1950; Silva, 1952; Newton, 1953 and Dawson, 1954) and Boergesen also revised

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the names of some Indian plants, while working on the algae of Mauritius. Recently, *G. textorii* (Suringer) J. Agardh and *Gracilariopsis sjoestedtii* (Kylin) Dawson were recorded from Visakhapatnam and Mandapam on the east coast of India (Umamaheswara Rao, 1969; and Umamaheswara Rao and Sreeramulu, 1970). In view of the economic importance of *Gracilaria* and *Gracilariopsis*, detailed taxonomic studies were undertaken by the author and the present account deals with the species of these two genera collected from the seas around India.

Collections were made since 1964 from the coral islands and rocky areas in the vicinity of Mandapam and from other localities on the east and west coasts of India, extending from Tuticorin to Kovalam. In addition to the collections made by the author, samples obtained from the Chilka Lake on the east coast, the Andaman and Nicobar Islands, the Laccadive Islands and some herbarium specimens available in the algal collections of the Central Marine Fisheries Research Institute have been examined in this study. Information on 17 species and 2 varieties of *Gracilaria* and 2 species of *Gracilariopsis* (Table I) is given in this paper.

Among the two genera studied, the genus *Gracilariopsis* was established in recent years by Dawson (1949), considering the striking differences observed in the cystocarp of *Gracilaria sjoestedtii* Kylin, such as the absence of nutritive filaments and the presence of broad based gonimoblast. The gonimoblast of this genus is dome-like and occupies most part of the cystocarpic cavity. The cells of the gonimoblast are small and densely filled with protoplasm. Studies on *G. millardetii* (Montagne) J. Agardh revealed another interesting variation (Boergesen, 1950, p. 33) in the structure of the cystocarp, wherein the cells of the gonimoblast are large and vacuolated as in *Gracilaria*, but the connecting filaments penetrate the tissue below the gonimoblast. In the present study also similar variation in the structure of the cystocarp was observed in the same species as well as in *G. edulis* (Gmelin) Silva, *G. corticata* J. Agardh and *G. foliifera* (Forsskal) Boergesen. All these plants were not considered here as a distinct group of this genus as indicated by Boergesen (1950, p. 33), since both types of nutritive filaments were seen in species such as *G. edulis* and *G. millardetii*. The species of *Gracilariopsis* are also not reduced to *Gracilaria* as suggested by Papenfuss (1966), because of the apparent differences (other than the presence or absence of nutritive filaments) in the structure of the cystocarp as outlined by Dawson (1949).

Of the 17 species and 2 varieties of *Gracilaria* (Table I) dealt with in this paper, *G. mannarensis*, *G. kanyakumariensis*, *G. indica*, *G. arcuata* var. *attenuata* and *G. corticata* var. *cylindrica* are new taxa and *G. cylindrica*, *G. opuntia*, *G. millardetii* and *Gracilariopsis megaspora* are new records from Indian waters. Antheridia, tetrasporangia and cystocarps have been observed for the first time for a number of species already reported from the Indian Ocean region and other parts of the world and information obtained on different species is summarised in Table 1. Based on the observations made by the author and from the earlier records, the distribution of the species of *Gracilaria* and *Gracilariopsis* along the Indian coast and other geographical areas is given. All the type specimens (CMFRI Nos. 170-174) and fixed materials are deposited in the Reference Collections at the Regional Centre of the Central Marine Fisheries Research Institute, Mandapam Camp.

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lections of Prof. M. O. P. Iyengar and his own collections available in the herbarium ; to Prof. Ohmi, Hokkaido University, Japan and to Dr. J. B. Hansen, Curator of Botanical Museum, Copenhagen, for the loan of valuable herbarium specimens of *Gracilaria*. He wishes to express his sincere thanks to Prof. K. M. Matthew, S.J., St. Joseph's College, Tiruchirapalli, for the latin diagnoses of the new taxa. He is thankful to Shri Ali Manikfan for the materials collected from Andaman and Nicobar Islands, to Orissa State Fisheries authorities for the *Gracilariopsis* material collected from Chilka Lake area and to Shri C. Mukundan and Shri P. Raghavan for the photographs.

TABLE 1. Information obtained on the sexual and asexual stages of *Gracilaria* and *Gracilariopsis*

	Tetrasporangia	Cystocarp	Antheridia
1. <i>Gracilaria arcuata</i> v. <i>arcuata</i> ..	—	—	—
2. <i>G. arcuata</i> v. <i>attenuata</i> ..	+	+	+
3. <i>G. canaliculata</i> ..	—	+	+
4. <i>G. cacalia</i> ..	*	—	*
5. <i>G. corticata</i> v. <i>corticata</i> ..	—	—	+
6. <i>G. corticata</i> v. <i>cylindrica</i> ..	+	+	+
7. <i>G. cylindrica</i> ..	—	—	+
8. <i>G. disticha</i> ..	+	+	*
9. <i>G. edulis</i> ..	—	—	+
10. <i>G. foliifera</i> ..	—	—	+
11. <i>G. indica</i> ..	+	+	+
12. <i>G. kanyakumariensis</i> ..	+	+	+
13. <i>G. mannarensis</i> ..	*	+	+
14. <i>G. millardetii</i> ..	—	—	—
15. <i>G. obtusa</i> ..	—	—	+
16. <i>G. opuntia</i> ..	*	—	*
17. <i>G. textorii</i> ..	—	—	—
18. <i>G. verrucosa</i> ..	—	*	*
19. <i>Gracilaria</i> sp. ..	+	—	+
20. <i>Gracilariopsis megaspora</i> ..	+	—	+
21. <i>Gr. sjoestedtii</i> ..	—	—	—

+ New report                      — already reported                      \* not reported so far

### GRACILARIA Greville

*Gracilaria arcuata* Zanardini var. *arcuata* (=typica Zanardini) Fig. 1a, b; Pl. IIA

Zanardini, 1858, p. 57, tab. 3, fig. 2; Feldmann, 1931, p. 14, figs. 4-6; Boergesen, 1934, p. 9, pl. 3; 1950, p. 38; *G. compressa* (Agardh) J. Agardh-Boergesen, 1937a, p. 48.

Plants reach a height of 22 cm with several fronds arising from a discoid hold fast. Fronds are alternately, secundly branched at the upper parts (Pl. IIA) and the branches and branchlets are slightly constricted near the bases. The cortex is one cell thick in the sterile parts of the thallus and it is well modified in tetrasporic and antheridial plants with 3-4 rows of anticlinally elongated cells (Fig. 1a, b). Tetrasporangia are 19-22  $\mu$  broad, and antheridia are borne in conceptacular cavities which are 67-75  $\mu$  deep and 33-45  $\mu$  broad (Fig. 1b). Cystocarps are prominent on the thallus and strongly rostrate.

While comparing my specimens with Prof. M. O. P. Iyengar's collection of *Gracilaria* determined by Boergesen, it has been found that the plants agree with

*G. compressa* (Agardh) J. Agardh [= *G. bursa-pastoris* (Gmelin) Silva] collected from Cape Comorin in September, 1924 (Nos. 296 B, C and E) and reported by Boergesen (1937a, p. 48). Ohmi (1958) gave a detailed description of *G. bursa-pastoris* and a specimen of this species sent by Prof. Ohmi has also been examined. In this species the antheridia are developed in shallow or saucer-like cavities (Ohmi, 1958) and in external habit and internal characters the Indian plant agrees fairly well with *G. arcuata* var. *typica*. The south Indian plants identified as *G. compressa* by Boergesen has, therefore, been placed under *G. arcuata* var. *typica* reported from Karachi and Mauritius (Boergesen, 1934; 1950, p. 38).

**Habitat:** Attached to rocks in sheltered areas of the infralittoral fringe zone and also in the sublittoral zone. The external appearance of the plants growing in the intertidal region and sublittoral zone varies to some extent. Plants collected near Kilakarai from the sublittoral region are longer and sparsely branched.

**Distribution in India:** Kilakarai, Tuticorin, Manapad, Idindakarai and Kanyakumari (Cape Comorin).

**Geographical distribution:** Red Sea, Karachi, Mauritius, Ceylon, Japan, Mediterranean Sea, Malayan Archipelago.

***Gracilaria arcuata* Zanardini var. *attenuata* var. *nov.***

Fig. 1 c-f; Pl. II B & C

Plantae 15-20 cm altae, brunneolo-rubrae ad viridulae, frondibus numerosis cylindricis et ramosissimis e disco parvo ortis; frondes 2-3 mm vel ultra diametro, irregulariter, alternatim vel unilateraliter ramosae; rami infra non constricti, interdum arcuati, supra vero attenuati apicibus acutis terminantibus, saepe ramulis brevibus indutis; thallus in sectione transversali ex medulla cellulis magnis tenuidermicis 120-400  $\mu$  diametro, infracortice cellulis parvis 30-80  $\mu$  diametro et cortice menostromatico cellulis pigmentosis et anticlinaliter prolatis 10  $\mu$  longis constantibus et 4-7  $\mu$  latis; uno vel duabus stratis cellulorum subcorticalium etiam pigmentosis; transitione gradato e medulla ad corticem; tetrasporangia ovoidea vel oblonga, 30-37  $\mu$  longa et 22  $\mu$  lata, per totam superficiem frondis dispersa, inter cellulas corticales anticlinaliter elongatas et modificatas inclusa; antheridia in cavitatibus marsupiiiformibus 45-65  $\mu$  latis et 60-100  $\mu$  profundis portatis, circumcinctisque cellulis corticalibus modificatis vel leviter elongatis; soris antheridialibus cum aperturis circularibus vel irregularibus per superficiem thalli dispersis; cystocarpia globoidea, super frondes conspicua, non-rostrata, 1.0-1.6 mm diametro; gonimoblasto, cellulis magis et vacuolatis, pericarpio pluribus filis nutritivis, 8-10  $\mu$ , latis, connexo; carposporae rotundae, 15-25  $\mu$  diametro, corpore pigmentoso ad centrum.

**Typus:** Planta tetrasporica (t. II B) lecta die 10, martii, 1970, prope Mandapam (versus Palk Bay), CMFRI No. 173.

Plants 15-20 cm tall, brownish red to light green in colour with many cylindrical and much branched fronds arising from a small disc; fronds 2-3 mm or more in diameter, irregularly, alternately and secundly branched; branches not constricted below, sometimes arcuately bent, attenuated above, ending with pointed apices, often provided with short branchlets, thallus in transverse section consisting of a medulla of large thin walled cells, 120-400  $\mu$  in diameter, an infracortex of small cells,

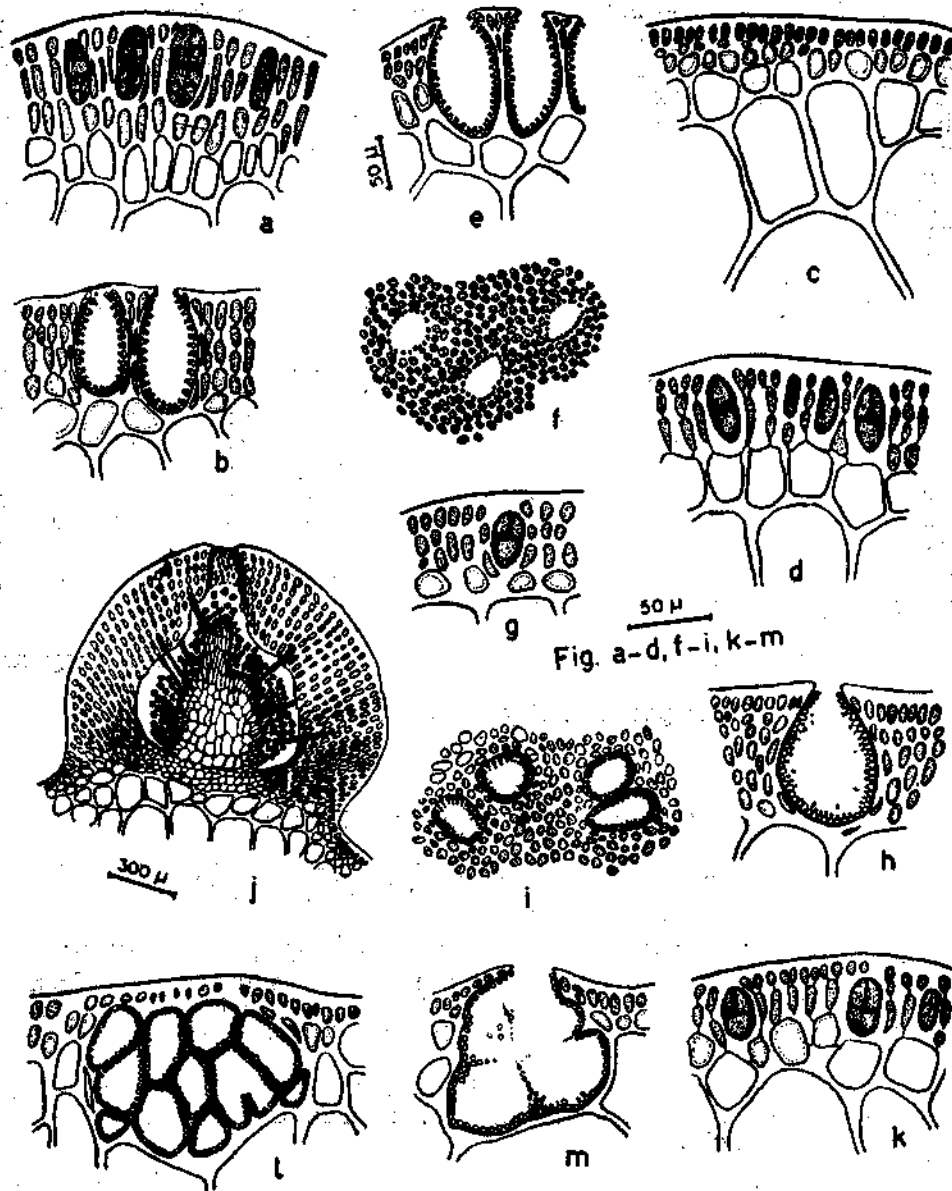


Fig. 1. a, b. *Gracilaria arcuata* var. *typica*: a. transverse section of the tetrasporic thallus; b. Sectional view of the male frond showing antheridial cavities; c-f. *Gracilaria arcuata* var. *attenuata*: c. transverse section of part of the thallus; d. transverse section of the tetrasporic frond; e, f. sectional and surface views of the antheridial sori; g-j. *Gracilaria canaliculata*: g. transverse section of tetrasporic cortex with sporangia; h, i. sectional and surface views of the antheridial sori; j. section of a cystocarp; k-m. *Gracilaria corticata* var. *typica*: k. transverse section of the tetrasporic cortex; l. antheridial sorus showing antheridia in the enlarged subcortical cells; and m. old antheridial sorus with an irregular cavity.

30-80  $\mu$  in diameter and a cortex of one cell thick, pigmented and anticlinally elongated cells, upto 10  $\mu$  long 4-7  $\mu$  wide, one or two layers of the subcortical cells also pigmented and transition from medulla to cortex gradual; tetrasporangia scattered over the entire surface of the frond, ovoid or oblong, 30-37  $\mu$  long, 22  $\mu$  wide and embedded among anticlinally elongated and modified cortical cells; antheridia borne in deep pocket-like cavities, 45-65  $\mu$  wide and 60-100  $\mu$  deep surrounded by unmodified or slightly elongated cortical cells, antheridial sori scattered over the surface of the thallus with circular or irregular openings; cystocarps globoid, prominent on the fronds, non-rostrate, 1.0-1.6 mm in diameter, gonimoblast with large vacuolated cells, connected to pericarp by a number of nutritive filaments of 8-10  $\mu$  thick; carpospores round, 15-25  $\mu$  in diameter with a pigmented body at centre.

This alga shows some resemblance to *G. bursa-pastoris* (Gmelin) Silva, especially in the external appearance of the thallus with attenuated branches and branchlets and hence it was reported in an earlier communication as *G. bursa-pastoris* (Umamaheswara Rao, 1968). A critical study of the male, cystocarpic and tetrasporic individuals has revealed that in the internal structure of the thallus (Fig. 1c) and reproductive morphology, the present species closely agrees with *G. arcuata* (Fig. 1 d-f). However, it differs in many respects from the variety *typica*. The plants are light green to brownish red in colour with irregular branching and the branches and branchlets are very much attenuated with unconstricted bases (Pl. II B & C). Furthermore, the cystocarps are non-rostrate and the antheridial sori are large and surrounded by unmodified (Fig. 1e) cortical cells. Considering these differences, the present plant is described here as a new variety of *G. arcuata*.

*Habitat* : Plants grow on dead coral pieces in the shallow sublittoral regions.

*Localities* : Mandapam (Palk Bay side) and Pamban.

#### *Gracilaria cacalia* (J. Agardh) Dawson

Dawson, 1954, p. 5, fig. 3; Durairatnam, 1961, p. 63; 1962, p. 13, figs. 4a, b; *Corallopsis cacalia* J. Agardh-Agardh, 1852, p. 583; 1876, p. 409; De Toni, 1900, p. 459; Weber van Bosse, 1928, p. 439; Boergesen, 1934, p. 8, figs. 6a, b.

Plants small, irregularly ramified at their bases; main branches cylindrical or unconstricted at base, strongly constricted at upper parts with one or two branchlets arising from depressions of swollen ends of branches; branchlets elongate, clavate in shape about 0.5 mm thick below and 2.0-2.5 mm thick at summits.

This species has not been collected by the author. As this was reported by Boergesen (1934) from Okha on the west coast of India, a brief description of the vegetative thallus is given here.

*Distribution in India* : Okha.

*Geographical distribution* : Red Sea, North coast of Java, Thursday Island and Indian Ocean.

**Gracilaria canaliculata** (Kuetzing) Sonder

Figs. 1g-j, Pl. I A &amp; B

Newton, 1953, p. 413; *Gracilaria crassa* (Harvey) J. Agardh-Agardh, 1876, p. 417; De Toni, 1900, p. 439; Weber van Bosse, 1928, p. 431; Boergesen, 1936, p. 86, fig. 8; 1952, p. 33; Dawson, 1954, p. 5; Ohmi, 1958, p. 25; pl. 5 D-E, fig. 11; Durairatnam, 1961, p. 59, p. 14, fig. 6; 1962, p. 12; *Corallopsis opuntia* J. Agardh-Agardh, 1876, p. 409; Okamura, 1933-42, p. 13, pl. 308, figs. 6-11; Boergesen, 1937b, p. 328.

Plants of this alga form dense cushions on the substratum with dichotomously and irregularly branched fronds. Branches are upto 4.00 mm in diameter, cylindrical and sometimes constricted with club-shaped or oblong articulations as shown in Pl. II A. Tetrasporangia occur in irregular patches at the upper parts of the branches and they are surrounded by slightly modified cortical cells (Fig. 1g). Antheridial and cystocarpic plants have been found in the material collected (Pl. I A & B). Antheridia are borne in ovoid cavities of 70-92  $\mu$  deep and 50-66  $\mu$  broad (Fig. 1h) as reported in *G. verrucosa* and *G. arcuata* and the antheridial cavities are surrounded by 4-5 rows of cortical cells (Fig. 1h). Cystocarps are dome-shaped; constricted below and the gonimoblast tissue is connected to pericarp by many nutritive filaments of 10-15  $\mu$  in diameter (Fig. 1j).

**Habitat:** Mostly confined to the infralittoral fringe zone and sometimes extends down to the upper part of the sublittoral zone. It grows on rocks and dead coral debris as large tufts.

**Distribution in India:** Coral islands near Mandapam, Rameswaram and Tuticorin.

**Geographical distribution:** Indian Ocean, Red Sea, Malayan Archipelago, Vietnam, Japan and Mauritius.

**Gracilaria corticata** J. Ag. var. *corticata*, (= v. *typica* J. Agardh)

Figs. 1 k-m; 2a-b; Pl. II E

Agardh, 1852, p. 602; 1876, p. 423; Boergesen, 1933, p. 124; 1936, p. 86; 1938, p. 225; Durairatnam, 1961, p. 10; 1962, p. 14, fig. 1.

Plants collected from different localities agree well with the herbarium specimens of Dr. Boergesen (No. 5353, dated 19-1-28, Dwarka) and Prof. M. O. P. Iyengar (No. 266, Madras harbour, 30th August, 1924). Regularly dichotomous fronds (Pl. II E), thick and cartilaginous nature of the thallus are the distinguishing features of this typical variety. Sterile plants of this alga have been described in detail in the publications of Boergesen (1938) and Durairatnam (1962).

In this species and a few others investigated in the present study, the nutritive filaments penetrate the parenchymatous tissue below the gonimoblast (Fig. 2 a & b) as reported in *G. millardetii* (Boergesen, 1950). Tetraspores are 30-37  $\mu$  long, 15-18  $\mu$  wide and embedded in modified cortex (Fig. 1k). The antheridia are formed on the inner walls of a group of enlarged subcortical cells. The sori are irregular in outline, 75-90  $\mu$  broad and 75-100  $\mu$  deep and resemble the 'gobular caves' of *Gracilaria multifurcata* Boergesen reported from Mauritius (Boergesen, 1953). Their structure (Fig. 1 l & m) is quite different from the cup-shaped and conceptacular

cavities found in many other species of *Gracilaria* and *Gracilariopsis*. Mature or old antheridial sori appear as irregular cavities due to dissolution of the walls between the enlarged cells as shown in Fig. 1 m and the spermatia are liberated through a definite pore. Same type of antheridial sorus has been found in *G. foliifera* and *G. edulis*.

*Habitat*: This alga is confined to the infralittoral fringe zone in the intertidal regions. Attached to rocks in areas that are not exposed to heavy surf action.

*Distribution in India*: Visakhapatnam, Madras, Mahabalipuram, Mandapam, Pudumadam, Kilakarai, Tuticorin, Tiruchendur, Manapad, Idindakarai, Kanyakumari (Cape Comorin), Muttam and Kadiapatnam, Colachel, Vizhinjam, Kovalam, Karwar, Bombay and Dwaraka.

*Geographical distribution*: Indian Ocean and Red Sea.

*Gracilaria corticata* var. *cylindrica* var. *nov.*

Fig. 2 c & d; Pl. I C & E

Plantae 61-0 cm altae vel ultra, discis ortis ex frondium basibus affixis, atro-rubrae ad flavido-rubrae, saepe cum maculis super frondes; frondes dichotome, alternatim vel irregulariter ramosae, applanatae vel compressae infra, subteretae ad cylindricae et arcte ramosae supra, apicibus acutis vel spineis; thallus in sectione transversali medullam cellulis magnis 90-220  $\mu$  diametro, subcorticem parvulis pigmentosisque cellulis 10-30  $\mu$  diametro, corticem 1-2 stromaticem 7-10  $\mu$  longam et 4-7  $\mu$  latam cellulis pigmentosis praebens. Tetrasporangia, 30-34  $\mu$  longa 18-22  $\mu$  lata, super ramos cylindricos dispersa circumcinctaque cellulis corticalibus modificatis; sori antheridiales super ramos supernos dispersos, 80-130  $\mu$  diametro aspectu sectionali, antheridia secus parietes interiores turmarum cellularum dilatatum subcorticalium; cystocarpia tholiformia, leviter rostrata, 1.0-1.4 mm diametro; gonimoblastus cellulis magnis et vacuolatis filis nutritivis texturam infra gonimoblastum penetrantibus; carposporae rotundae vel ovaes, 18-22  $\mu$  diametro, contentu crasso.

*Typus*: Tetrasporophyta lecta die 7, Novembris, 1964, prope Mandapam (versus Gulf of Mannar) (t. I, C), CMFRI No. 174.

Plants 6-10 cm tall or more, attached by discs arising from the basal parts of fronds, dark red to yellowish red in colour, often with variegated spots on fronds; fronds dichotomously, alternately and irregularly branched, flat or compressed at lower parts, subterete to cylindrical and closely branched above with pointed or spinous apices; thallus in section showing a medulla of large cells, 90-220  $\mu$  in diameter, a subcortex of small and pigmented cells, 10-30  $\mu$  in diameter and 1-2 cells thick cortex of pigmented cells, 7-10  $\mu$  long and 4-7  $\mu$  broad; tetrasporangia scattered on cylindrical branches 30-34  $\mu$  long, 18-22  $\mu$  wide and surrounded by modified cortical cells; antheridial sori scattered on upper branches, 80-130  $\mu$  in diameter in sectional view, antheridia lining inner walls of a group of enlarged subcortical cells; cystocarps dome-shaped, slightly rostrate, 1.0-1.4 mm in diameter, gonimoblast with large vacuolated cells, nutritive filaments penetrating tissue below gonimoblast; carpospores round or oval, 18-22  $\mu$  in diameter with thick contents.



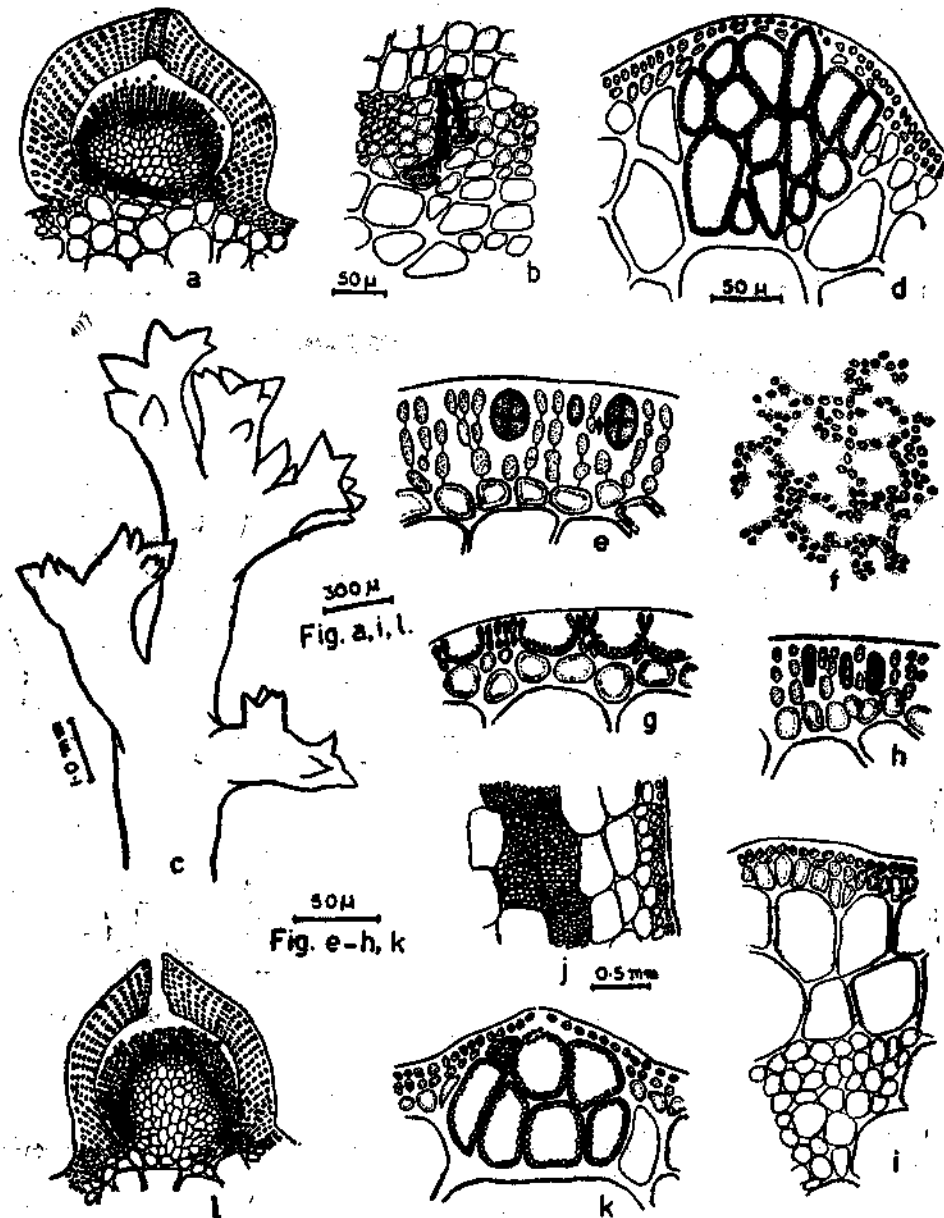


Fig. 2. a, b. *Gracilaria corticata* var. *typica*: a. Section of cystocarp with nutritive filaments below the gonimoblast tissue; b. enlarged part of the tissue below the gonimoblast showing nutritive filaments; c, d. *Gracilaria corticata* var. *cylindrica*: c. upper part of the thallus showing cylindrical branches; d. sectional view of an antheridial sorus; e-g. *Gracilaria cylindrica*: e. transverse section of the tetrasporic frond; f, g. surface and sectional views of male frond showing confluent and cup-shaped sori; h. *Gracilaria disticha*: transverse section of tetrasporic frond with immature sporangia; i-l. *Gracilaria edulis*: i, j. transverse and longitudinal sections of old frond with small cells at the centre; k. antheridial sorus; and l. section of a cystocarp.

Although the present variety was found associated with *G. corticata* var. *corticata*, it is quite distinct from the narrow and broad forms of it, which are flabellately branched in one plane. This new variety can easily be distinguished by the cylindrical and multifariously branched fronds with pointed apices (Fig. 5c; Pl. I C & E). Variegated spots were often seen on these plants. The internal characters are similar in both the varieties of *G. corticata*, but for the differences in the size of the antheridial sori (Fig. 2d). In plants collected from the sublittoral regions, the cylindrical branches are not profusely and closely branched as observed in the plants of the intertidal habitats.

*Habitat* : Collected from the sublittoral fringe and sublittoral zones. Plants grow on rocks protected from wave wash and also in rock pools of the intertidal region.

*Localities* : Mandapam and Pudumadam.

#### *Gracilaria cylindrica* Boergesen

Fig. 2 e-g ; Pl. I D

Boergesen, 1915-20, p. 376, figs. 364-365 ; Weber van Bosse, 1928, p. 432 ; Taylor, 1960 p. 450, pl. 56, fig. 3 ; Durairatnam, 1961, p. 59.

Plants collected are upto 25 cm tall, sparingly branched with blunt as well as pointed apices. They closely agree with the description given by Boergesen (1915-20), but antheridial plants of *G. cylindrica* were not examined by him while describing this species. In the male plants collected by the author, the antheridia are borne in cup-like cavities of 25-30  $\mu$  deep and 25-35  $\mu$  wide (Fig. 2g). The antheridial sori appears as irregular patches in surface view and are surrounded by modified and elongated cortical cells as shown in Fig. 1 f, g. Cortex of the tetrasporophytes is also well modified in the Indian material (Fig. 2e), unlike in the Mauritius plant (Boergesen, 1915-20, Fig. 365 C).

The scarcer ramification of the plants (Pl. I D) and obtuse apices of the branches are the main characters given by Boergesen to separate *G. cylindrica* from the closely related *G. blodgettii* Harvey. From the above description of the male thallus it is clear that the structure of the antheridial sorus (Fig. 2 f & g) is another important character to distinguish *G. cylindrica* from *G. blodgettii*, since antherida occur in deep, ovoid and closely spaced cavities in the latter species (Ohmi, 1958).

*Habitat* : Collected from the cast ashore vegetation. Plants are attached to small shells and coral pieces.

*Distribution in India* : Mandapam (Gulf of Mannar side) and Tuticorin.

*Geographical distribution* : West Indies, Florida, Columbia, Gaudelope, Ceylon and Malayan Archipelago.

#### *Gracilaria disticha* J. Agardh

Fig. 2h, Pl. II D

Agardh, 1852, p. 594 ; 1876, p. 416 ; Boergesen, 1938, p. 222.

This species has not been collected by me and the figures given here (Fig. 1h, Pl. II D) are based on the dried and formalin preserved specimens available in the

collections of the Central Marine Fisheries Research Institute. Male plants are not available and only young tetrasporangia (Fig. 1h) were seen in the plants examined. Cystocarps are 1-1.7 mm in diameter, often strongly rostrate and constricted below.

The material at hand agrees with plants of *G. disticha* J. Agardh in the herbarium of Prof. M. O. P. Iyengar (No. 261, May, 1924) collected from Pamban and Krusadai Island and in the herbarium of Dr. Boergesen (No. 403, collected by K. Rangachary). Boergesen determined the Indian specimens as *G. disticha* J. Agardh with a query (No. 403) and the present plant shows some resemblance to *G. coronopifolia* J. Agardh (Dawson, 1949; Ohmi, 1958).

*Habitat* : Attached to coral heads in the sublittoral zone.

*Distribution in India* : Krusadai Island and Pamban.

*Geographical distribution* : Red Sea, Indian Ocean.

#### *Gracilaria edulis* (Gmelin) Silva

Fig. 2 i-l, Pl. I F

Silva, 1952, p. 293, Ohmi, 1958, p. 16, fig. 6, pl. 3B; Durairatnam, 1961, p. 62, pl. 14, figs. 4, 5; *G. lichenoides* (Linnaeus) Harvey-Agardh, 1852, p. 588; 1876, p. 412; De Toni, 1900, p. 430; Okamura, 1929-32, p. 39, pl. 271, figs. 1-5; Boergesen, 1937b, p. 327.

Plants collected from different localities were compared with the specimens of *G. edulis* sent by Prof. Ohmi. In fully grown and old fronds of this species groups of small cells were seen inside the medullary cells. Transverse and longitudinal sections of these are shown in Fig. 2 i & j. Antheridial sori are similar to those observed in *G. corticata* and *G. foliifera* (Fig. 2 k) and they are slightly elevated from the surface of the thallus. In the cystocarps two types of nutritive filaments were seen as reported in *G. millardetti* (Fig. 2 l). Tetrasporangia are surrounded by unmodified cortical cells.

*Habitat* : It occurs abundantly in shallow lagoons formed between the shore and the fringing coral reefs. Attached to small stones and shells on sandy and muddy areas.

*Distribution in India* : Coral islands around Mandapam, Rameswaram and Tuticorin. This species has also been reported from Chilka Lake on the east coast of India (Ahmed, 1966) but a re-examination of the plants is necessary to confirm the identification.

*Geographical distribution* : India, Australia, Japan, East Indies, Pacific Ocean.

#### *Gracilaria foliifera* (Forsskal) Boergesen

Fig. 3 a-b; Pl. IV A

Boergesen, 1932, p. 7, fig. 1; 1937a, p. 48; 1938, p. 226; 1939, p. 109; Durairatnam, 1961, p. 63, pl. 31, fig. 2; *G. lacinulata* (Vahl) Howe-Howe, 1920, p. 562; *G. lacinulata* (Vahl) Boergesen-Boergesen, 1915-20, p. 379, fig. 316; Weber van Bosse, 1928, p. 434; *G. multipartita* (Clem.) J. Agardh-Agardh, 1852, p. 600; 1876, p. 432.

Plants are bushy with di- or polychotomously, alternately and pinnately branched fronds (Pl. IV A). Fronds are thin when compared with *G. corticata*

and have proliferous margins. The structure of the tetrasporic cortex with sporangia and the antheridial sorus are shown in Fig. 2 a, b respectively. As observed in *G. corticata* the nutritive filaments arise from the lower side of the gonimoblast tissue.

Working on the specimens collected from the Indian Ocean region Boergesen (1938, p. 225) and others (Durairatnam, 1961) have found it difficult to separate certain growth forms of *G. foliifera* and *G. corticata*. The present study on the structure and reproduction of these two species also indicated the close relationship between these two algae (Figs. 1 k-m & 2 a, b; Fig. 3 a, b) and the differences in the thickness of the thallus and branching of the fronds are the only characters by which these two plants can be distinguished. Besides these morphological characters, the habitats in which the plants grow and their geographical distribution also vary. But in an illustrated guide to the seaweeds of Texas area, Edwards (1970, Fig. 153) has given a photograph showing the surface view of the male plant of *G. foliifera* (Forsskal) Boergesen and the antheridial sori of this plant closely resemble the cup-shaped and confluent sori observed in *G. textorii* and other algae. In this respect the Indian and Texas plants differ markedly and if more details of the alga reported from Atlantic coasts of Europe and America are available, *G. foliifera* reported from the Indian Ocean region can be treated as a variety of *G. corticata* J. Agardh.

In the collections examined by the author both slender and flattened forms, as reported by Kim and Humm (1965), were seen. Two herbarium specimens of Dr. Boergesen collected from Bombay (No. 5117, 4-1-28 and No. 5300, 16-1-28) and identified as *G. corticata* var. *ramalinoides* J. Agardh (Boergesen, 1933) have been examined and they seem to agree well with the narrow and much branched forms of *G. foliifera* (Forsskal) Boergesen. Another specimen (No. 5153, 4-1-28) identified as *G. corticata* J. Agardh also agrees with *G. foliifera*.

*Habitat* : It grows very rarely in the infralittoral fringe zone and abundantly in shallow lagoons and submerged coral reefs.

*Distribution in India* : Coral islands around Mandapam, Rameswaram and Tuticorin, Kanyakumari, Bombay, Gopnath, Gujarat and Minicoy Island.

*Geographical distribution* : Atlantic coasts of Europe and America, Mediterranean Sea, Red Sea, Indian Ocean and Malayan Archipelago.

*Gracilaria indica* sp. nov.

Fig. 3 c-h ; Pl. IV B

Plantae 4-15 cm altae, compressae, ad substratum parvo haptero affixae, brunneo-rubrae ad flavido vel virido-rubrae; frondes subcylindrici ad basim, supra vero in thallum latum expansae 0.3-1.5 cm vel ultra latae; dichotome, palmatum et irregulariter ramosae, apicibus acutis, marginibus integris ad prolificis; thallus 195-413  $\mu$  crasso, in sectione transversali medullam cellulis pachydermicis 50-200  $\mu$  diametro, subcorticem cellulis parvis et corticem 1-2 stromaticem cellulis pigmentosis 8-9  $\mu$  longis et 8-11  $\mu$  latis, quadratis et aliquantum latioribus quam longis; tetrasporangia portata utrinque thalli in mematheciis irregularibus et lumbricalibus bene evolutis 30-34  $\mu$  longis et 25-34  $\mu$  latis circumcinctisque seriebus cellularum corticalium immo modificatis et ramosis; antheridia in soris valde vadosis

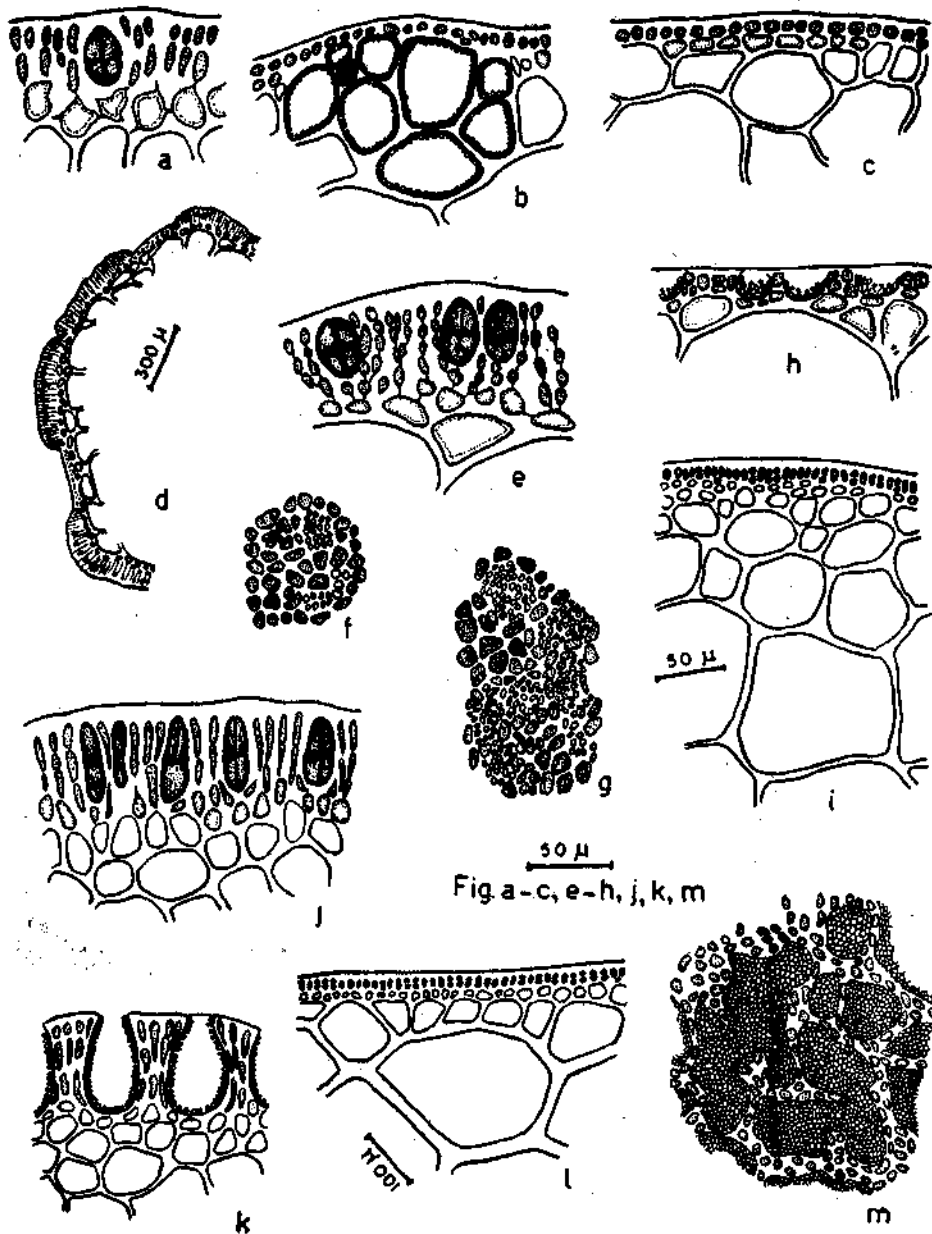


Fig. 3. a, b. *Gracilaria foliifera* : a. transverse section of the tetrasporic frond ; b. antheridial sorus ; c-h. *Gracilaria indica* : c. transverse section of part of the thallus ; d. sectional view of the tetrasporic thallus showing nemathecially modified sori and vegetative patches ; e. enlarged part of the tetrasporic cortex with branched rows of cortical cells and sporangia ; f. surface view of the male frond showing division of the cortical cells, g. male thallus with irregular and confluent sori ; h. transverse section of the male thallus showing antheridial pits and unmodified cortical cells ; i-k. *Gracilaria kanyakumariensis* : i. transverse section of part of the thallus ; j. tetrasporic cortex showing elongated sporangia and cortical cells ; k. transverse section of the antheridial plant showing conceptacular cavities ; l, m. *Gracilaria mannarensis* : l. transverse section of part of the thallus ; and m. surface view of the antheridial plant with confluent sori.

et confluentis 15  $\mu$  profundis, 25-37  $\mu$  latis, circumcinctisque cellulis corticalibus immo modificatis; cystocarpia per superficiem frondis dispersa, leviter rostrata 1.0-2.0 mm diametro; gonimoblastus cellulis vacuolatis, pericarpio filis nutritivis 7-10  $\mu$  diametro connexus; carposporae rotundae vel angulares, 18-22  $\mu$  diametro, chromatophoro stellatim labato ad centrum.

*Typus*: Tetrasporophyta lecta die 20, februarii, 1970 prope Pamban (t. IV B), CMFRI No. 172.

Plants 4-15 cm high, compressed, attached to substratum by means of a small hold fast, light brownish-red to yellowish or greenish red in colour, fronds sub-cylindrical near base and soon expanded to a broad thallus above 0.3-1.5 cm or more in width, dichotomously, palmately and irregularly branched with pointed apices; margins entire to proliferous; thallus 195-413  $\mu$  in thickness, showing in transverse section a medulla of thin walled cells, 50-200  $\mu$  in diameter, subcortex of small cells and one or two cells thick cortex of pigmented cells 8.0-9.0  $\mu$  long and 8.0-11.0  $\mu$  broad, quadrate and somewhat broader than long; tetrasporangia borne on both sides of thallus in well developed nemathecium which are irregular or worm-shaped, 30-34  $\mu$  long and 25-34  $\mu$  wide, surrounded by unmodified and branched rows of cortical cells; antheridia produced in very shallow and confluent sori, 15  $\mu$  deep, 22-37  $\mu$  broad, surrounded by unmodified cortical cells; cystocarps scattered over surface of frond, slightly rostrate, 1.0-2.0 mm in diameter, gonimoblast with vacuolated cells, pericarp connected by nutritive filaments of 7-10  $\mu$  diameter; carpospores round or angular, 18-22  $\mu$  in diameter with a stellately lobed chromatophore at centre.

*G. indica* is closely related to *G. textorii* (Suringer) J. Agardh, but it can be distinguished from the latter by the structure of the antheridial sori and other internal characters. In the vegetative thallus of this species the cortical cells are broader than long (Fig. 3c) and from the different stages in the development of antheridia shown in fig. 3 f, g, it is clear that only the superficial cortical cells are involved in the production of antheridia in this new species. The antheridial sori are very shallow (15  $\mu$  deep). The cortical cells surrounding the sori are not modified (Fig. 3 h) as in *G. textorii*. Irregular and somewhat worm-shaped nemathecium sori separated by vegetative parts of the thallus (Fig. 3d) were seen on both sides of the fully grown tetrasporic fronds and the tetrasporangia are embedded in branched rows of cortical cells (Fig. 3e).

In the worm-shaped nemathecium, branching and general appearance of the vegetative thallus (Pl. IV B), this alga shows some resemblance to *Rhodymenia indica* described by Weber van Bosse (1928, p. 460) based on the tetrasporic plants.

*Habitat*: Attached to dead coral pieces in shallow sublittoral regions.

*Locality*: Pamban.

***Gracilaria kanyakumariensis* sp. nov.**

Fig. 3 i-k; Pl. III B

Plantae 10-12 cm altae, complanatae vel subteretae, carnosae, brunneo-rubrae ad roseae, frondibus pluribus ex haptero discoideo basali ortis; frondibus principalibus bi-vel tri-pinnatim ramosis, ramulis longibus infra, bre vibus vero

supra, rarissime ramulis pectinatim ramis lateralibus dispositis; thallus in sectione medullam latam cellulis parvis et pachydermicis 50-165  $\mu$  diametro, granis amyliis pluribus exhibens, subcorticem cellulis parvulis 8-22  $\mu$  diametro marginatis et corticem 1-2 stromatico cellulis pigmentosis, quadratis vel elongatis 7.5-15  $\mu$  longis et 4-7.5  $\mu$  latis; tetrasporangia superficie thalli portata, angusta et elongatissima, 37-56  $\mu$  longa et 18-22  $\mu$  late et in seriebus cellularum corticalium bene modificatarum et anticlinaliter elongatarum; antheridia in cavitatibus conceptacularibus profundis et arcte contiguis 65-75  $\mu$  profundis et 30-40  $\mu$  latis; sori antheridiales cum orificio circulari vel ovali circumcinctique 2-3 seriebus cellularum corticalium elongatarum et modificatarum; cystocarpia per thallum dispersa, globosa, non-rostrata vel leviter rostrata, inconstricta infra, 1.4 - 4.8 mm diametro; gonimoblastus aliquantum lobatus, cellulis vacuolatis; fila nutritiva 11-15  $\mu$  diametro, pericarpio abundanter connexa; carposporae rotundae vel ovaes, 22-26  $\mu$  diametro, chromatophoro ad centrum.

*Typus*: Planta tetrasporica prope Kanyakumari lecta die 17, Decembri, 1969 (t. III B) CMFRI No. 171.

Plants 10-12 cm in height, compressed or subterete, fleshy, brownish-red to pink in colour with several fronds arising from basal discoid holdfast; main fronds bi- or tri-pinnately branched with longer branches below and shorter ones above, very rarely branchlets pectinately arranged on lateral branches; thallus in section showing a broad medulla of small and thin-walled cells with numerous starch grains, 50-165  $\mu$  in diameter, bordered by a sub-cortex of small cells, 8-22  $\mu$  in diameter, and a cortex of one or two layers of pigmented and quadrate or elongated cells, 7.5-15  $\mu$  long and 4.0-7.5  $\mu$  wide; tetrasporangia borne on surface of thallus, narrow and much elongated, 37-56  $\mu$  long and 18-22  $\mu$  wide, embedded in well modified and anticlinally elongated rows of cortical cells; antheridia in deep and closely packed conceptacular cavities, 65-75  $\mu$  deep, 30-40  $\mu$  wide, antheridial sori opened by a circular or oval pore and surrounded by 2-3 rows of elongated and modified cortical cells; cystocarps scattered over thallus, globular, non-rostrate or slightly rostrate, unconstricted below, 1.4-1.8 mm in diameter, gonimoblast somewhat lobed, with vacuolated cells, nutritive filaments 11-15  $\mu$  in diameter, connecting abundantly the pericarp; carpospores round or oval, 22-26  $\mu$  in diameter with a chromatophore at centre.

Based on the pinnate nature of branching Setchell and Gardner (1924) described a species known as *G. pinnata*, which was later included under *G. subsecundata* by Dawson (1961). From the description and figures given by Dawson it is evident that this Mexican species does not agree with the new species described here. The structure of the tetrasporic cortex and the antheridial sori (Fig. 3 j, k) of *G. kanyakumariensis* is similar to that observed in *G. arcuata* var. *arcuata*. The medullary cells are very small (Fig. 3 i) and the tetrasporangia are very much elongated (Fig. 3 j) as seen in *G. obtusa*. But the compressed and feather-like appearance of the plants (Pl. III B) with bi- or tri-pinnate branching suggests that it is an undescribed species of *Gracilaria*.

*Habitat*: Growing on rocks in the sublittoral fringe and sublittoral zones. Specimens were also collected from the cast ashore vegetation.

*Localities*: Kanyakumari (Cape Comorin), Chinnamuttam, Idindakarai and Manapad.

***Gracilaria mannarensis* sp. nov.**

Fig. 3 l-m ; 4 a-c ; Pl IV E

Plantae foliatae, atroroseae, rigidae et coriaceae, ex 1-3 frondibus constantibus ex haptero discoideo ; frondes 12.0 cm altae, 5-6 cm latae, sparsim lobatae, marginibus integris vel leviter serratis ; thallus in sectione transversali 460-560  $\mu$  crassus, medullam cellulis magnis polygonalibus vel rotundis, 130-280  $\mu$  diametro, subcorticem cellulis parvulis cum granis amyliis multis, 65-100  $\mu$  diametro, et corticem 1-2 stromaticam cellulis pigmentosis 5-7  $\mu$  crassis et 7-10  $\mu$  longis exhibens ; sori antheridiales per totam superficiem frondis dispersi initio solitarii, postea vero confluentes marginibus irregularibus ; antheridia in cavitatibus vadosis 30-35  $\mu$  profundis et 35-45  $\mu$  latis ; sori antheridiales cellulis corticalibus modificatis circumcincti ; cystocarpia per utramque superficiem frondis, aliquantum ambitu conicalia 0.8-1.2 mm diametro ; gonimoblastus cellulis vacuolatis constantibus connexisque pluribus filis nutritivis 8-12  $\mu$  diametro ; carposporae rotundae vel ovaes, 26-30  $\mu$  diametro, chromatophoro stellato ad centrum ; tetrasporophytae non lectae.

*Typus* : Planta cystocarpica prope Pudumadam lecta, dis 27, Martii, 1968 (t. IV E), CMFRI No. 170.

Plants foliose, dark pink in colour, stiff and coriaceous, consisting of 1-3 fronds from a discoid hold fast ; fronds 12.0 cm tall, 5-6 cm broad, sparingly lobed with entire or slightly serrate margin ; thallus in transverse section 460-560  $\mu$  thick, showing a medulla of large polygonal or round cells, 130-380  $\mu$  in diameter, a subcortex of small cells with numerous starch grains, 65-100  $\mu$  in diameter, and a cortex of 1-2 layers of pigmented cells, 5-7  $\mu$  thick and 7.10  $\mu$  long ; antheridial sori scattered all over surface of frond, solitary at first, latter joined to form confluent sori with irregular outlines, antheridia borne in shallow cavities of 30-35  $\mu$  deep and 33-45  $\mu$  wide, antheridial sori surrounded by modified cortical cells ; cystocarps scattered on both surfaces of frond, somewhat conical in outline, 0.8-1.2 mm in diameter, gonimoblast consisting of large vacuolated cells, connected by many nutritive filaments of 8-12  $\mu$  diameter, carpospores round or oval, 26-30  $\mu$  in diameter, containing a stellate chromatophore at centre, tetrasporophytes not collected.

Only cystocarpic and male plants of this new taxon were collected from Pudumadam on the Gulf of Mannar side. As far as the author is aware, *G. sublittoralis* Yamada and Segawa and *G. punctata* (Okamura) Yamada are the foliose species of *Gracilaria* reported with very broad thalli. Plants of *G. sublittoralis* have thalli of 3-6 cm in width. They are well branched and grow upto 20 cm in height (Ohmi, 1958), whereas in *G. mannarensis* the plants are unbranched or rarely lobed (Pl. IV E) and the antheridia occur in shallow cavities (Fig. 3 m ; 4 a), unlike in *G. sublittoralis* (Yamamoto, 1969). Specimens of the present species were compared with the plants of *G. punctata* sent by Prof. Ohmi. Although the structure of the antheridial sorus is more or less similar in both these species, they differ markedly in the external form.

*Habitat* : Attached to small stones in the sublittoral region. Specimens were collected from the shore seines operated along the shore.

*Locality* : Pudumadam (Gulf of Mannar).



**Gracilaria millardetii** (Montagne) J. Agardh

Fig. 4 d-f; Pl. IV D

Agardh, 1884, p. 64; Boergesen, 1943, p. 72, figs. 36-40; 1950, p. 26, figs. 11-19.

Plants are 4-7 cm tall, complanate and foliose with irregularly and subdichotomously divided fronds (Pl. IV D). Tetraspores are scattered in slightly elongated cortical cells (Fig. 4 d) and antheridia occur in ovoid conceptacles, which are separated by 3-4 rows of cortical cells (Fig. 4 e).

Vegetative variability is very common in this species and the Indian plants (Pl. IV D) come near to forma *millardetii* and other forms with broad lobes (Boergesen, 1950). Material collected closely agrees with the description and figures of Boergesen (1943, 1950) and two types of nutritive filaments were seen as reported by him (Boergesen, 1943) in the cystocarps of this species (fig. 4 f). The vegetative plants of *G. millardetii* resemble *G. purpurascens* (Harvey) J. Agardh reported from Japan (Ohmi, 1958) Malayan Archipelago and Ceylon (Weber van Bosse, 1928) and these two species can only be separated by the differences in the structure of male reproductive organs.

Boergesen (1937b, p. 327) reported a new species of *Gracilaria* namely, *G. pygmaea*, from the cystocarpic material collected at Krusadai Island, South India. But, while working on the algae of Mauritius, he (Boergesen, 1943, p. 75) considered it as a form of *G. millardetii* (f. *linearifolia*). Plants resembling *G. pygmaea* Boergesen were collected by the author from Pamban area (Kuntagal point). They were found growing on rocks along with *G. foliifera* and in the structure of the thallus, cystocarps and male reproductive organs these plants agreed with *G. foliifera*. Anand (1943) collected two forms of *G. pygmaea* from Karachi and he has also come to the same conclusion that 'the larger form shows a certain resemblance to *G. multipartita* (= *G. foliifera*) and it is probable that it may be any intermediate form and the two species may have to be merged into one later on.'

*Distribution in India*: Pamban, Mandapam and Pudumadam.

*Geographical distribution*: Mascarene Island, Indian Ocean.

**Gracilaria obtusa** (Kuetzing) De Toni

Fig. 4 g-j, Pl. III A, C

De Toni, 1900, p. 433; *Sphaerococcus obtusus* Kuetzing-Kuetzing, 1869, p. 8, tab. 21; *Gracilaria fergusonii* J. Agardh-Agardh, 1901, p. 60, Boergesen, 1938, p. 222, figs. 5, 6.

Plants are cartilaginous, 15 cm tall with many erect shoots arising from a discoid hold fast. Erect shoots are cylindrical or slightly compressed, sometimes constricted here and there and di- or subdichotomously ramified at the distal ends (Pl. III A, C). Tetrasporangia and male reproductive organs are confined to upper parts of the branches or branchlets. The internal structure of the tetrasporic cortex and antheridial sori are shown in Fig. 4 h and j. Cystocarps are 1.0-2.2 mm in diameter and the gonimoblast tissue is connected to pericarp by many nutritive filaments.

The colour and external form varies considerably in the plants collected from different habitats. Plants growing in the intertidal region are greenish, dark red or

pink in colour and they have cylindrical and irregularly branched fronds with constrictions at the distal ends (Pl. III A). But, the specimens collected from the sublittoral and coral reef areas are bright pink or orange red in colour with regularly branched and slightly compressed fronds (Pl. III C). Plants collected by me near Kanyakumari and other intertidal habitats closely agree with the herbarium specimens of Prof. M. O. P. Iyengar (No. 285, Sept., 1924, Cape Comorin) and Boergesen (No. 314, Sept., 1924, Cape Comorin by M.O.P.I.) determined as *G. fergusonii*.

Weber van Bosse (1928), Boergesen (1938, p. 223) and Newton (1953, p. 411) discussed about the nomenclatural problems and the correct application of names of the closely related species of *Gracilaria* reported from the Indian Ocean region. Newton (1953) included *G. obtusa* and *G. fergusonii* under *G. debilis* (Forsskal) Boergesen. Based on the earlier descriptions, photographs of *G. fergusonii* and *G. obtusa* given by Newton (1953, Pl. III) and also from the collections examined by me, I agree with Dr. Newton that *G. obtusa* and *G. fergusonii* are one and the same species. But Forsskal's specimen is not available for examination, except for a photograph of part of a specimen obtained from the Botanical Museum, Copenhagen. Further, the species described by Taylor (1960) as *G. debilis* (Forsskal) Boergesen is quite different from the two species mentioned above. In view of this uncertainty, the Indian plant is reported here as *G. obtusa* (Kuetzing) De Toni. A reinvestigation of all the succulent and poorly described species of the Indian Ocean region, collecting the plants from the type localities is absolutely necessary to solve these nomenclatural problems.

As suggested by Setchell and Gardner (1924, p. 753), *G. obtusa* (Fig. 4 g-j) shows some resemblance to *G. pachydermatica* Setchell and Gardner reported from the Gulf of California. Detailed description of this species, given by Dawson (1949, 1961), clearly indicates the similarities in the structure of the thallus, antheridial sori and other characters. In old plants and particularly at the basal parts of the plants collected, the cortex is several cells thick (Fig. 4 g) as figured by Setchell and Gardner (1924).

**Habitat :** Grows on rocks in the infralittoral fringe and sublittoral zones. In the intertidal habitats dense growth of this alga was observed in semi-exposed and sheltered areas.

**Distribution in India :** Shingle Island, Pudumadam, Kilakarai, Tuticorin, Tiruchendur, Manapad, Idindakarai, Kanyakumari (Cape Comorin), Muttam, Kadiapatnam, and Colachel.

**Geographical distribution :** Indian Ocean and Red Sea.

#### ***Gracilaria opuntia* (Svedelius) Durairatnam**

Fig. 4 k, Pl. III D

Durairatnam, 1962, p. 11, fig. 3.

Only sterile specimens (Pl. III D) agreeing with the above species, are available with colourless and slightly elevated spots on the surface of the thallus. In sectional view the cortical and subcortical cells are somewhat elongated near these spots.

This species can be easily distinguished from *G. canaliculata* (= *G. crassa*) by the external appearance of the thallus and the dichotomous branching without

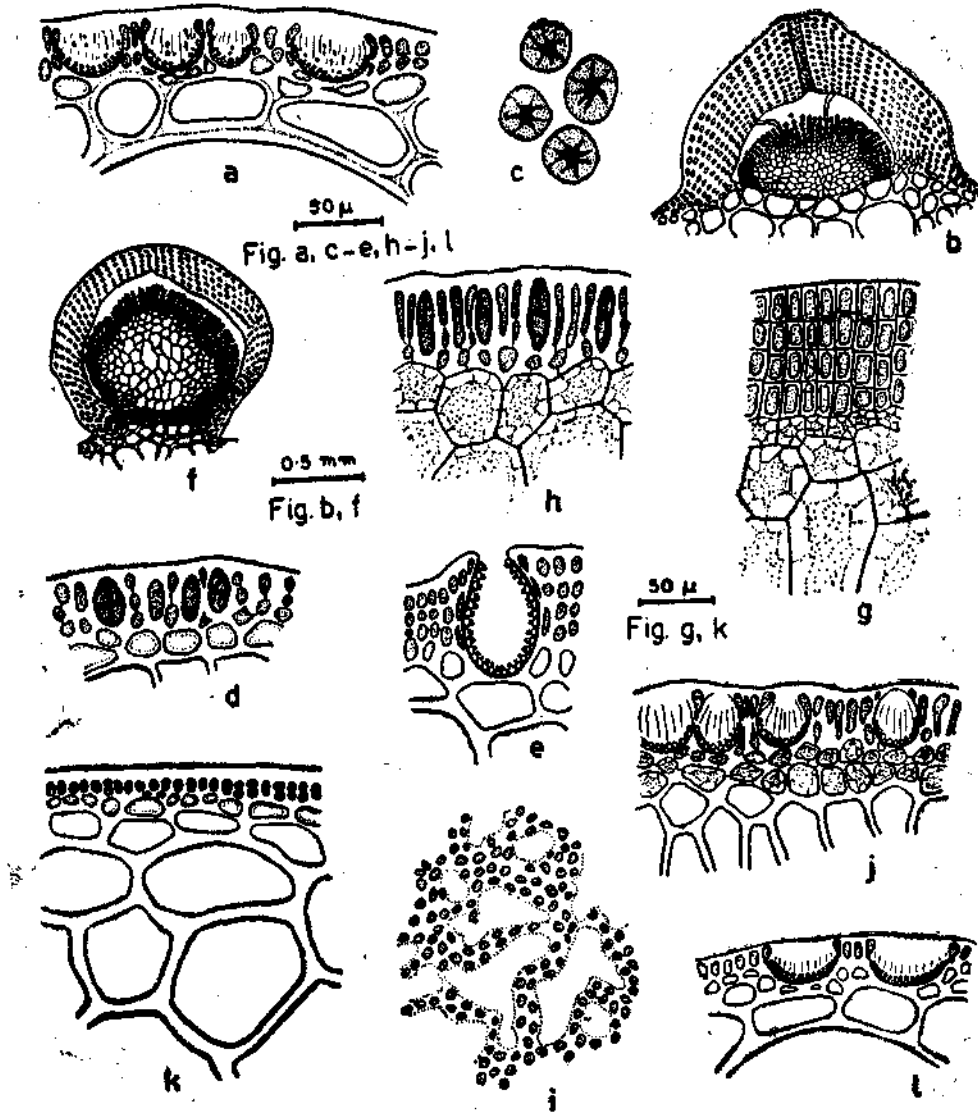


Fig. 4. a-c. *Gracilaria mannarensis* : a. transverse section of the male plant ; b. longitudinal section of a cystocarp ; c. carpospores with stellate chromatophores ; d-f. *Gracilaria millardetti* : d. tetraporic cortex with sporangia ; e. antheridial sorus ; f. section of a cystocarp showing nutritive filaments below the gonimoblast tissue, g-d. *Gracilaria obtusa* : g. transverse section of basal part of the thallus showing multilayered cortex, h. transverse section of the tetrasporic frond ; i, j. surface and sectional views of the antheridial thallus ; k. *Gracilaria opuntia* : transverse section of part of the thallus, and l. *Gracilaria textorii* : section of the male frond with antheridial pits.

any constrictions. As pointed out by Durairatnam (1962) the medullary cells of the thallus (Fig. 4 k) are  $1\frac{1}{2}$  to 2 times smaller than in *G. canaliculata* and the transition from medulla to corex is gradual.

*Distribution in India* : Andaman and Nicobar Islands.

*Geographical distribution* : Ceylon.

#### *Gracilaria textorii* (Suringer) J. Agardh

Fig. 4 l, Pl. III F

Agardh, 1876, p. 426 ; De Toni, 1900, p. 449 ; Ohmi, 1958, p. 40, figs. 20, 21 ; Dawson, 1961, p. 211, pl. 10, figs. 8 ; pl. 11, fig. 2 ; pl. 12, figs. 13, 14 ; pl. 18 ; Durairatnam, 1961, p. 62 ; Umamaheswara Rao and Sreeramulu, 1970, p. 39, figs. 41, 42, 51, 52 ; *G. vivesii* Howes-Dawson, 1949, p. 34, pl. 2, figs. 4-6, pl. 14, figs. 1-6, pl. 15, figs. 1-6 ; *G. Johnstonii* Setchell and Gardner-Setchell and Gardner, 1924, p. 752, pl. 22, figs. 11-14, pl. 60 ; *G. sinicola* Setchell and Gardner-Setchell and Gardner, 1924, p. 752, pl. 62 ; *G. vivipara* Setchell and Gardner-Setchell and Gardner, 1924, p. 750, pl. 24, fig. 28, 29, pl. 63.

Detailed descriptions of this species is given by Dawson (1949, 1961), Ohmi (1958) and other workers. The size and external form of the specimens collected from different localities and habitats varied considerably. Sublittoral plants collected along the Indian coast thin and delicate with entire or proliferous margins. They are upto 25 cm tall and 2-3 cm broad (Pl. III F) and resemble the specimens of *G. vivesii* available in the herbarium of Prof. Desikachary. While the specimens collected from the intertidal regions are smaller and they have thick and coriaceous thalli with proliferous and wavy margins. Indian plants collected so far agree with the variety *textorii* (Dawson, 1961).

*Habitat* : It is found attached to rocks in the infralittoral fringe and sublittoral zones.

*Distribution in India* : Visakhapatnam, Mandapam, Tuticorin, Tiruchendur, Manapad, Idindakarai and Kanyakumari (Cape Comorin).

*Geographical distribution* : Japan, North-east Pacific.

#### *Gracilaria verrucosa* (Hudson) Papenfuss

Figs. 5 a, b

Papenfuss, 1950, p. 195, Ohmi, 1958, p. 6, pl. I A-D, figs. 1, 2 ; Dawson, 1961, p. 214, pl. 20 ; Durairatnam, 1961, pl. 61, pl. 15, fig. 7 ; *G. confervoides* (Linnaeus) Greville-Greville, 1830, p. 123 ; Agardh, 1852, p. 587 ; 1876, p. 413 ; De Toni, 1900, p. 431 ; Okamura, 1916-23, p. 1, pl. 151 ; Boergesen, 1938, p. 221, Dawson, 1949, p. 13, pl. 15, fig. 9.

Plants are 15-25 cm high, with several cylindrical fronds arising from the hold fast. Erect fronds are irregularly and multifariously branched and the branches are sometimes loaded with small and unbranched ramulai. In the herbarium specimens examined the tetrasporangia are surrounded by slightly elongated cortical cells (Fig. 5 a) and stellate chromatophores were not observed in the carpospores as illustrated by Ohmi (1958).

Male plants were not seen separately and the antheridial cavities (Fig. 5 b) were found on short ramulai of the tetrasporic specimens. Occurrence of antheridial

sori on tetrasporophytes was reported by Ohmi (1958) in *G. blodgettii* Harvey, *G. bursa-pastoris* (Gmelin) Silva and *Gracilariopsis vermiculophylla* Ohmi and by Boergesen (1950) in *G. millardetii*.

**Habitat :** Attached to coral pieces in the shallow sublittoral regions.

**Distribution in India :** Krusadai Island, Pamban (Kuntagal Point), Tuticorin and Okha.

*G. verrucosa* is morphologically similar to the members of *Gracilariopsis*. Detailed studies are, therefore, necessary on the plants reported earlier from Chilka Lake (Ahmed, 1966), Pulicat Lake (Chacko *et al.*, 1953) and other places along the Indian coast.

**Geographical Distribution :** In all the warmer seas.

### **Gracilaria sp.**

Fig. 5 c-h ; Pl. IV C

Plants forming prostrate and entangled cushions, succulent, compressed, greenish-red on dorsal side and pink on ventral side of thallus, attached to coral pieces by small rhizoids and discoid hold fasts arising from ventral side of fronds ; fronds dichotomously, alternately and pinnately branched ; branches about 3-4 cm long, 0.5-1.2 cm broad with dentate margins, adjacent branches attached by means of discoid hold fasts ; thallus upto 0.5 mm thick in transverse section, composed of a medulla of uniform cells. 100-247  $\mu$  in diameter, a subcortex of small cells with stellately contracted protoplast and a cortex of pigmented cells, cortical cells one cell thick in young fronds, 11.0  $\mu$  long, 4-7  $\mu$  broad and 3-4 cells thick in older fronds.

Only a single specimen (Pl. IV C) with young tetrasporangia is available. Undivided tetrasporangia were seen in small colourless and slightly elevated patches (Fig. 5 g, h) occurring on both sides of the thallus. These are surrounded by quadrate or anticlinally elongated cells. The structure of the thallus (Fig. 5 e, f) is similar to the other succulent members of *Gracilarias* such as *G. opuntia*, but differs markedly in the dorsiventral nature of the thallus, branching and other characters.

This seems to be an undescribed plant and it does not agree with other prostrate and succulent species like *G. crassissima* Grouan (Howe, 1920) and *G. eucheumoides* Harvey (Weber van Bosse, 1928). As cystocarpic specimens are not available, a brief description of this interesting specimen is given here without naming the plant at present.

**Habitat :** Attached to coral pieces in the sublittoral region.

**Locality :** Nicobar Island (Nan-cowry).

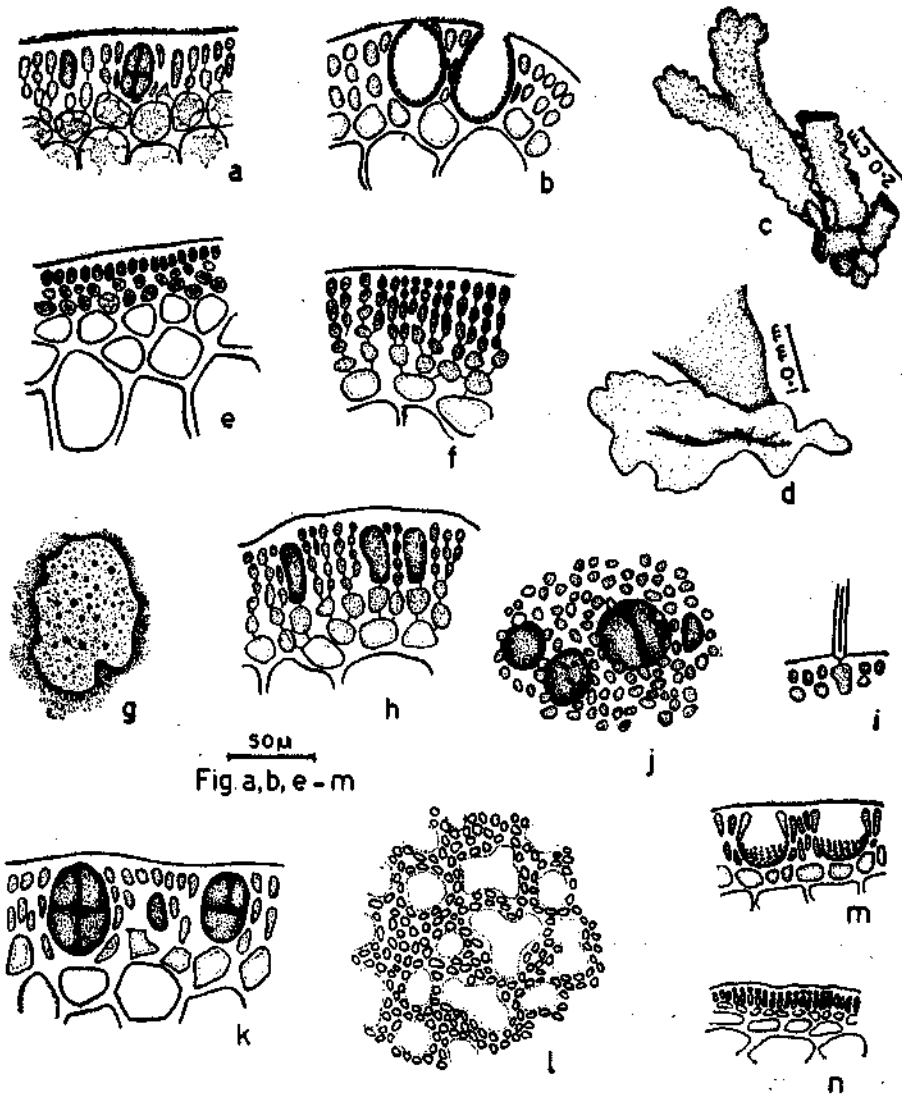


Fig. 5. a, b. *Gracilaria verrucosa* : a. transverse section of the tetrasporic thallus ; b. antheridial sori ; c-h. *Gracilaria* sp : c. habit of a portion of the thallus ; d. rhizoid arising from the ventral side of the thallus ; e, f. transverse sections of young and old fronds showing variations in the number of cortical cells ; g. surface view of the tetrasporic sorus ; h. sectional view of the sorus with immature tetrasporangia ; i-m. *Gracilarlopsis megaspora* : i. sectional view of the thallus showing hair ; j, k. surface and sectional views of the tetrasporic frond, l. surface view of the male thallus with confluent sori, m. longitudinal section of the male frond ; and n. *Gracilarlopsis sjoestedtii* : longitudinal section of the male frond showing superficial antheridia.

**Gracilariopsis Dawson****Gracilariopsis megaspora Dawson**

Fig. 5 i-m ; Pl. III, E

Dawson, 1949, p. 45, pl. 18, figs. 1-3 ; 1961, p. 217, pl. 11, fig. 3, pl. 22, fig. 2

Plants are 18-25 cm tall, cylindrical and mutifariouly branched with long and thin branches. In external appearance *Gr. megaspora* Dawson shows some resemblance to slender forms of *Gracilaria verrucosa*. Dawson (1946, 1961) reported this species from cystocarpic specimens collected from Mexico. Indian plants (Pl. III E) are larger than the Mexican plants and as shown in Fig. 5 i hairs present on the surface of the thallus are very long. Male and tetrasporic plants have been examined in the present study. The tetrasporangia (Fig. 5 j, k) are bigger in size, when compared with other species of *Gracilariopsis* and they are surrounded by slightly elongated cortical cells. Antheridia were seen in sunken and confluent pits (Fig. 5 l, m) which are separated by modified and anticlinally elongated cortical cells. The structure of the antheridial sorus (Fig. 5 m) differs from other species of the genus, especially from the nearest relative, *Gr. costaricensis* Dawson, and it is similar to that observed in *Gracilaria gigas* Harvey (Yamamoto, 1969).

**Habitat :** Attached to small stones in shallow areas of the lake.

**Distribution in India :** Balugaon (Chilka Lake).

**Geographical distribution :** Mexico.

**Gracilariopsis sjoestedtii (Kylin) Dawson**

Fig. 5 n

Dawson, 1949, p. 40, pl. 50, fig. 10, pl. 6, figs. 5-8, pl. 17, figs. 1-9, pl. 18, fig. 4 ; 1961, p. 218, pl. 10, fig. 14 ; pl. 11, fig. 10, pl. 23 ; Umamaheswara Rao and Sreeramulu, 1970, p. 39, Figs 43, 53.

Dawson (1949) reported thin and robust forms of this species from the collections of Gulf of California. Similar types were seen in the material collected from different localities of the Indian coast. The robust form collected near Mandapam and Pamban is more succulent or fleshy with 2.5-3.0 mm thick fronds and very conspicuous cystocarps. Male plants of this type are very small and only two plants were seen in many samples examined in this study. Antheridia developed from the cortical cells are shown in Fig. 5 n. Plants reported earlier from Visakhapatnam coast are of slender type and they were collected from the rock pools and sheltered areas of the infralittoral fringe zone (Umamaheswara Rao and Sreeramulu, 1970).

In Rameswaram plants reaching a height of 2.0 m have been collected. Though the external and internal characters of these plants agree well with the slender form of *Gr. sjoestedtii*, male plants were not seen in hundreds of specimens collected and examined so far in different months of the year.

**Habitat :** Attached to rocks and small coral pieces in the infralittoral fringe zone and in the shallow sublittoral zone. It also grows luxuriantly in calm bays attached to rhizomes of sea grasses, shells and other hard substrata.

*Distribution in India*: Visakhapatnam, Mandapam, Pamban, Rameswaram, Kilakarai and Tuticorin.

*Geographical distribution*: Pacific and Atlantic coasts of United States, Mexico, India.

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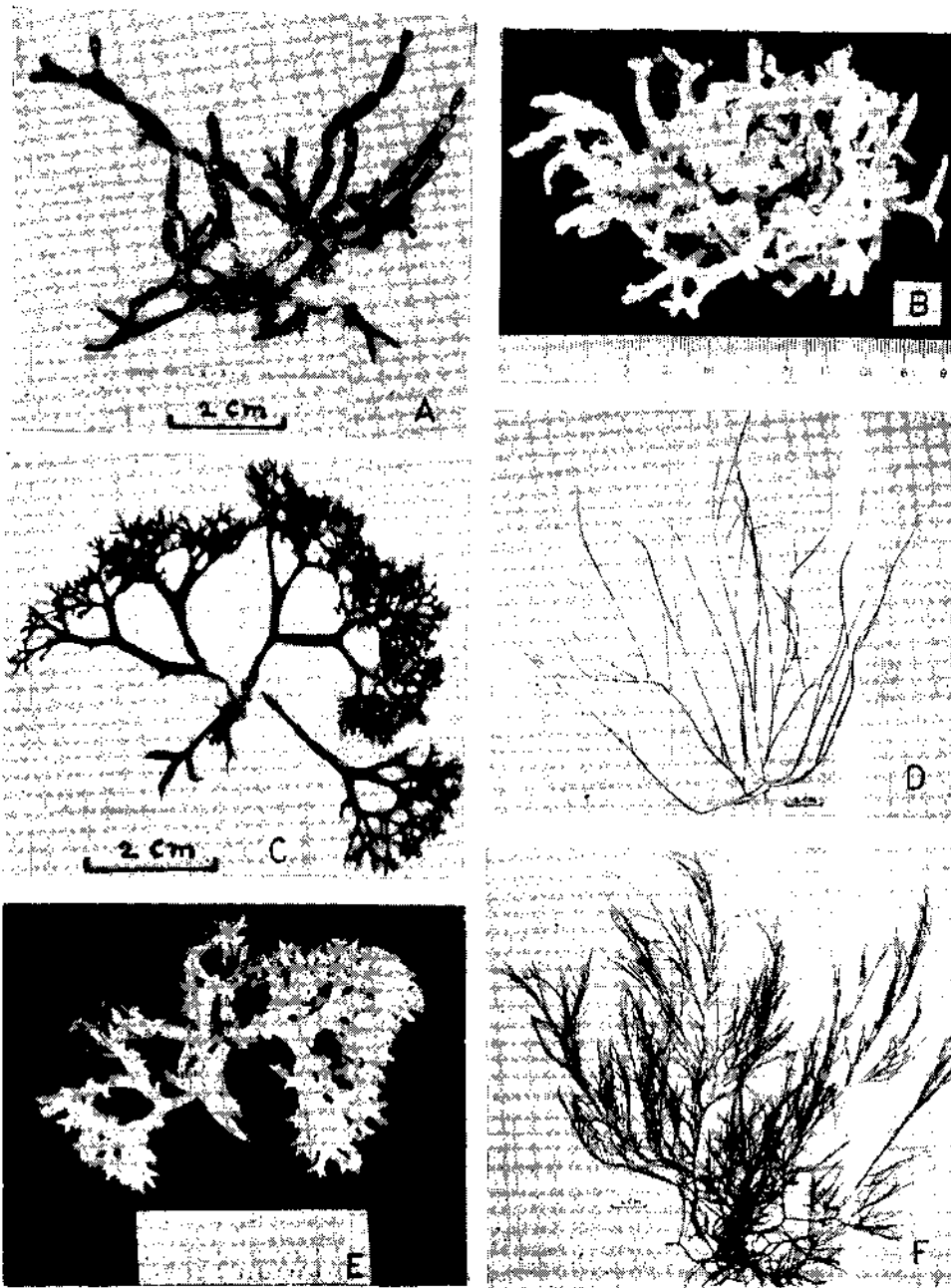


PLATE I. A and B. *Gracilaria canaliculata*: A. habit of an articulated specimen (male plant); B. cystocarpic plant; C. *G. corticata* var. *cylindrica*, habit of a tetrasporophyte; D. *G. cylindrica*, habit of a tetrasporic plant; E. *G. corticata* var. *cylindrica*, cystocarpic specimen; and F. *G. edulis*, habit of a vegetative plant.

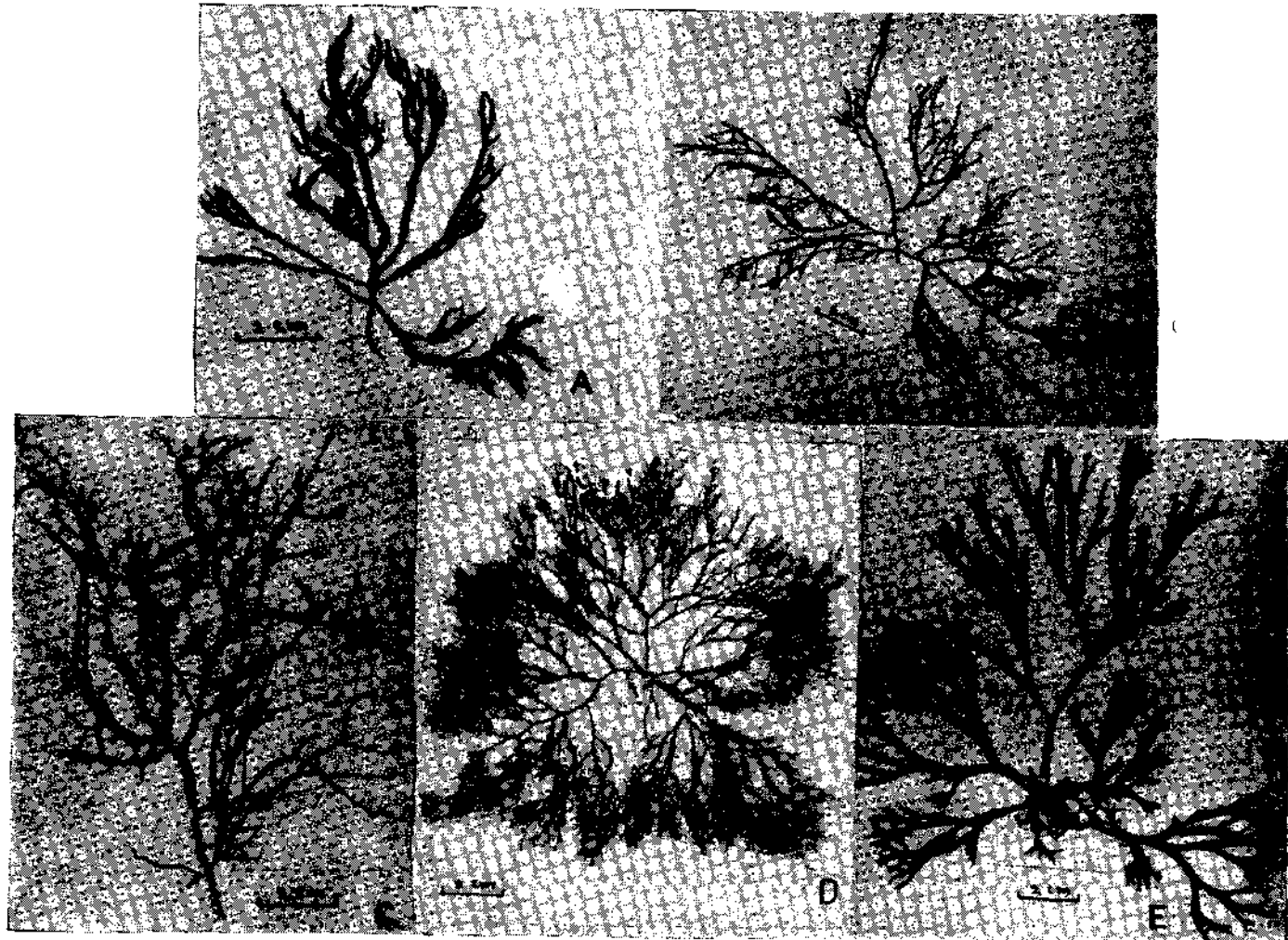


PLATE II. A. *Gracilaria arcuata* var *typica*, habit of a male plant ; B and C. *G. arcuata* var *attenuata*, B. habit of a tetrasporophyte ; C. cystocarpic plant ; D. *G. disticha*, plant habit ; and E. *G. corticata* var *typica*, habit of male plant.

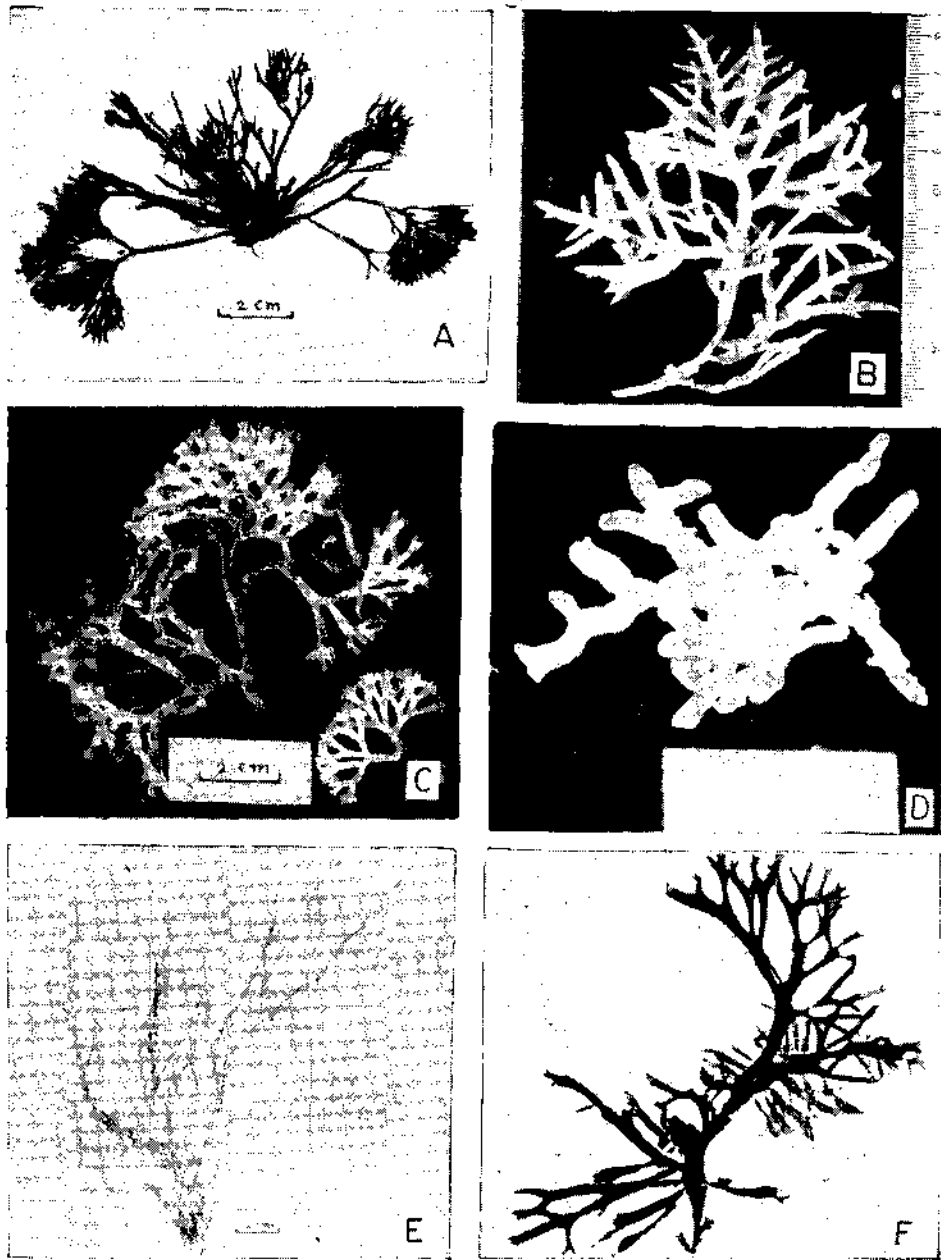


PLATE III. A. *Gracilaria obtusa*, habit of a tetrasporophyte collected from the intertidal region ; B. *G. kanyakumariensis*, habit of a tetrasporophyte ; C. *G. obtusa*, habit of portions of two sublittoral plants ; D. *G. opuntia* ; plant habit ; E. *Gracilariaopsis megaspora*, habit of a cystocarpic specimen ; and F. *G. textorii*, a cystocarpic specimen collected from the sublittoral region.

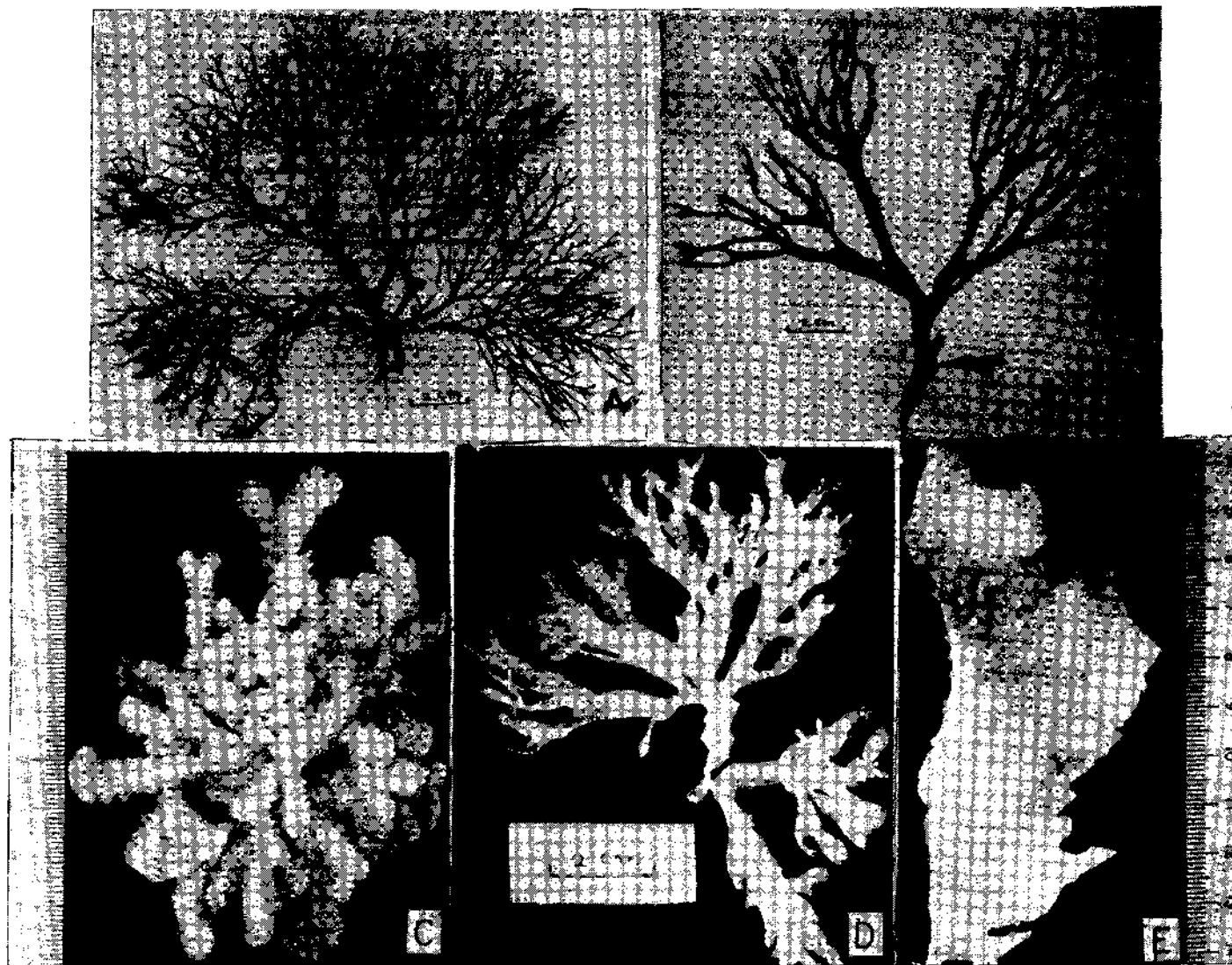


PLATE IV. A. *Gracilaria foliifera*, habit of a tetrasporic plant ; B. *G. indica*, habit of a tetrasporophyte ; C. *Gracilaria* sp., plant habit ; D. *G. millardetii*, habit of a tetrasporic plant ; and E. *G. mannarensis*, habit of a cystocarpic plant.

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