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A TAXONOMIC STUDY OF SOME RED ALGAE COMMONLY GROWING ON THE COAST OF KARACHI

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ABSTRACT: Eighteen commonly occurring species of marine benthic red algae, *i.e., Asparagopsis taxiformis* (Delile) Trevisan, *Bangia atropurpurea* (Roth) C. Agardh, *Centroceras clavulatum* (C. Agardh) Montagne, *Calliblepharis fimbriata* (Greville) Kützing, *Coelarthrum muelleri* (Sonder) Børgesen, *Cottoniella filamentosa* (Howe) Børgesen, *Gracilaria foliifera* (Forsskål) Børgesen, *Halymenia porphyraeformis* (Børgesen) Parkinson, *Hypnea musciformis* (Wulfen) Lamouroux, *Hypnea valentiae* (Turner) Montagne, *Laurencia obtusa* (Hudson) Lamouroux, *Melanothamnus somalensis* Bornet *et* Falkenberg, *Porphyra vietnamensis* Tanaka *et* Pham-hoàng Hô, *Sarconema filiforme* (Sonder) Kylin, *Sebdenia flabellata* (J. Agardh) Parkinson, *Scinaia fascicularis* (Børgesen) Huisman, *Scinaia hatei* Børgesen, and *Solieria robusta* (Greville) Kylin were collected from coastal areas near Karachi (Pakistan) and taxonomically investigated. All the investigated seaweeds are taxonomically known species. During this study, *Melanothamnus somalensis* is reported for the first time from northern Arabian Sea and *Asparagopsis taxiformis, Bangia atropurpurea, Cottoniella filamentosa, Gracilaria foliifera, Halymenia porphyraeformis, Melanothamnus somalensis, Sarconema filiforme, Sebdenia flabellata, Scinaia fascicularis,* and *Solieria robusta* are taxonomically described for the first time from the coast of Pakistan.

KEY WORDS: Rhodophyta - morphology - anatomy - reproduction - ecological notes - marine algae - northern Arabian Sea - Pakistan.

INTRODUCTION

Karachi, has a coastline of about 100 km at the northern boundary of the Arabian Sea and includes a number of beaches, numerous islands, and mangrove swamps. The coastal belt around Manora, Sandspit, Hawkes Bay, Buleji, Paradise Point, Pacha, Nathiagali, and Cape Monze displays clear water with a variety of marine animals. A luxuriant growth of seaweeds is found at these beaches either as drift, attached to rocks or growing in pools (Shameel and Tanaka, 1992). Several taxonomic studies have been conducted on the Karachi seaweeds since 1930 (Børgesen (1931, 1932, 1933, 1934a,b, 1935, 1936, 1937a,b, 1938, 1939). Anand (1940,1943) not only provided a detailed taxonomy of the Karachi seaweeds, but also elaborated on their ecology, especially their zonation and belt formation. Salim (1965) presented a brief ecological account of the Karachi seaweeds.

Nizamuddin and Gessner (1970) investigated the seaweeds collected from the northern part of the Arabian Sea and the Persian Gulf including several species of red algae from the Karachi coast. Shameel and Nizamuddin (1972) described a new alga *Haloplegma anweri* and Farooqui and Begum (1978) a new species *Polysiphonia nizamuddinii*, both belonging to Ceramiales. Zahid *et al.* (1981) studied in detail the taxonomy of *Polysiphonia* species and Moazzam and Shameel (1985) the floristics of all the red algae belonging to the class Bangiophyceae of the Karachi coast. Afaq-Husain and Shameel (1991) and Afaq-Husain *et al.* (1991a) described two new species *Helminthocladia nizamuddinii* and *Dermonema abottiae*, respectively, both belonging to Nemaliales. Afaq-

Husain (1992) investigated in detail the morphology, anatomy, and postfertilization changes in the algae belonging to Nemaliales, Bonnemaisoniales, Gelidiales and Gigartinales from the coast of Karachi.

A few studies were made on the habitat, ecology and distribution of red algae from the neighbouring coast of Lasbela (Shameel, 1987a; Shameel and Afaq-Husain, 1987; Shameel *et al.*, 1989) and the Makran coast (Shameel *et al.*, 1996). Shameel and Tanaka (1992) recently presented a check-list describing in detail the distribution and habitat ecology of all the divisions of marine algae from the coast and inshore waters of Pakistan including red seaweeds occurring along the coast of Karachi.

Because the North Arabian Sea has rich seaweed flora due to upwellings (Thompson and Tirmizi, 1988), there is a luxuriant growth of seaweeds near Karachi and along adjacent coastal areas. An attempt has been made to investigate the commonly growing brown (Shaikh and Shameel, 1995) and coenocytic green algae (Aliya and Shameel, 1996) from the coast of Karachi. This paper presents a continuation of that work. This study was undertaken to investigate the predominant species of red algae occurring along the coast of Karachi to provide a better understanding of their morphology, anatomy, and reproduction.

MATERIALS AND METHODS

Seaweeds were collected from the coastal areas of Karachi, *i.e.*, Manora, Sandspit, Buleji, Paradise Point, Nathiagali, and Cape Monze from September 1986 to December 1994 (Fig. 1). The best time of collection for intertidal algae is during low tide, when the rocks are exposed along with the attached plants. For the collection of drift algae rising tides are more suitable, when large numbers of sublittoral plants may be obtained. Otherwise, they can only be collected by dredging, which requires a slow moving vessel. The details of the collection sites are given below.

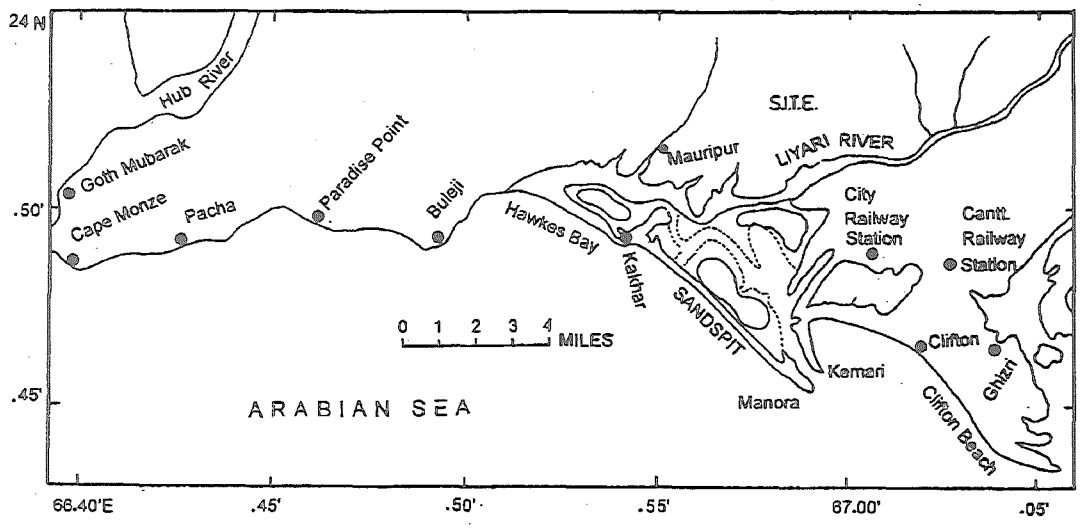

Fig. 1.Map showing collection sites on the coast of Pakistan.

Manora has a broad rocky ledge near PNS Himalaya. It is 5-6 furlong long and 1 furlong wide with a large number of tide pools of different depths having sandy or stony bottoms. It is totally submerged during high tide and is exposed only when the water recedes. The rock surfaces can be smooth or rough. Sandspit is purely a sandy beach, having no rocks. It is almost two km long and a half km wide. The plants collected from this area are usually drift algae. On the other side of the beach there is a wide swampy area of mangroves, where drift algae may also be found entangled with pneumatophores. At the beginning of Sandspit is a small rocky ledge near Kakkar Goth, where intertidal seaweeds may be collected.

The area of collection near Haji Ali Muhammad Goth at Buleji has two different sites: three rocky ledges with small bays in between and a broad sandy platform. These ledges have very large rocks, which are 3-4 meters high facing the rough sea and 2-3 km long. The surface of the rocks is very rough with several small and large stony ditches. The flat sandy platform spreads about 4-5 acres that, during emergence, provides an excellent site for large collections of drift algae. This area, commonly called French Beach, is guarded by a wall that prohibits entry. Therefore, the vegetation remains protected and collection may be made undisturbed. Most of the collections trips were made to these two sites.

Paradise Point exhibits both rocky as well as muddy areas, but no sandy beach. It is about one furlong long and half a furlong wide. The slanting rocks near Governor House, the flat platform of limy, soft, smooth stratified rocks, the vault-like large hole in a huge rock, and a range of calcarious rocks are various sites of collection that exhibit floristic variations. The Nathiagali collection site was down a hill beneath the first barrier of a Naval check post. It has a long sandy beach and three narrow rocky ledges. When water recedes, drift algae are left on the beach and benthic algae on the pebbles and rocks. Cape Monze has a long rocky area, which is 2-3 furlong long and 1-2 furlong wide. The rock surfaces are usually rough and it is a good site for collection of intertidal algae. It is very difficult to reach this spot due to a prohibited area lying in between, where a Naval base has been established.

Algal material was preserved in 4% formalin-seawater solution neutralized with hexamethylene tetramine. To investigate the anatomical features and reproductive structures, the hand sections and pieces of thin fronds were stained with 1% aniline blue in 5% HCl and mounted in 70% glycerine solution. Permanent slides were prepared using equal volumes of glycerine, acetic acid, and distilled water or 10% of Karo, a thick syrup normally used as baby food. Drawings were made with the help of camera lucida. The dried specimens were deposited in the Seaweed Herbarium (KUH-SW), Seaweed Biology and Phycochemistry Laboratory, M.A.H. Qadri Biological Research Centre, University of Karachi.

SYSTEMATIC ACCOUNT

The following 18 species of red seaweeds, belonging to 13 families and 6 orders, were collected from the coastal areas near Karachi and investigated taxonomically. Their external as well as internal features and reproductive structures were described.

Class Bangiophyceae Melichior 1954
Order Bangiales Schmitz *in* Engler 1892
Family Bangiaceae Nägeli 1847
1. *Bangia atropurpurea* (Roth 1806) C. Agardh 1824
(= *Bangia fuscopurpurea* (Dillwyn 1807) Lyngbye 1819)
(Figs. 2 a & b)

Feldmann, 1939: 247; Jaasund, 1965: 115; Joly, 1965: 103; Pankow, 1971: 218; Abbott and Hollenberg, 1976: 294; Kornmann and Sahling, 1977: 262; Moazzam and Shameel, 1985: 148; Shameel and Afaq-Husain, 1987: 296; Silva *et al.*, 1987: 17; Shameel *et al.*, 1989: 179, 1996: 227; Shameel and Tanaka, 1992: 43; Aleem, 1993: 58.

Thallus filamentous, unbranched, rose red or scarlet to almost black, usually aggregated into dense mats made up of numerous individuals. Plants flaccid when exposed and mucilaginous when moist, up to 100 mm in height and 2-3 mm in diameter at widest, often narrowing at base. Plants uniseriate when young with cylindrical to barrel-shaped cells, later becoming multiseriate by irregular longitudinal divisions resulting in wedge-shaped cells, as seen in surface view, rhizoids arising from the lower cells of the filaments. Cells 2.5-3.0 μm in diameter, containing a single, purple violet, stellate, radially lobed, chloroplast with a central pyrenoid.

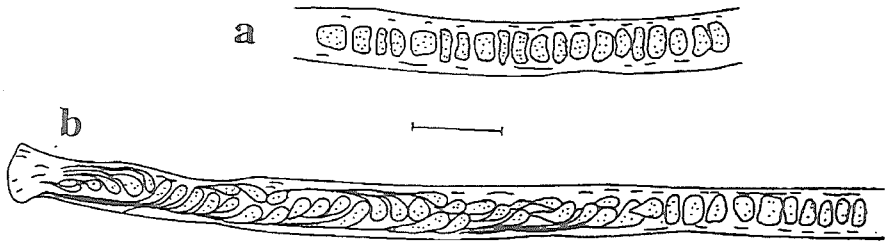

Fig. 2. *Bangia atropurpurea* (Roth) C. Agardh: a. young filament exhibiting uniseriate arrangement, b. old filament showing rhizoids and holdfast (scale: 12 μm).

Asexual reproduction by formation of monosporangia formed by the direct transformation of superficial vegetative cells. Sexual plants unisexual, the spermatangia formed from vegetative cells by repeated division. Carpogonia formed by the direct transformation of vegetative cells, forming 8-16 carposporangia after fertilization.

Generally epizoic on the shells of the limpet *Cellana radiata* (Born) Hornell, found in the upper littoral zone along the rocky shores, occasionally epilithic in small tufts at the same tidal height on flat rocks exposed to strong wave action (Buleji: *Leg.* A. Hayee-Memon 16-11-1988, 4-12-1988, 23-12-1988; Cape Monze: *Leg.* M. Shameel 18-12-1991, 7-11-1992, 26-12-1993). *Bangia atropurpurea* and *B. fuscopurpurea* are conspecific (den Hartog, 1972; Geesink, 1973; Nizamuddin, 1988). The former name has a priority over the latter one, although the latter name is in a common use.

2. *Porphyra vietnamensis* Tanaka et Pham-hoàng Hô, 1962
(Figs. 3 a - d)

Tanaka and Pham-hoàng Hô, 1962: 34; Moazzam and Shameel, 1985: 149; Shameel and Tanaka, 1992: 43; Shameel and Aftab, 1993: 13; Shameel, *et al.*, 1996: 227.

Thalli light purplish red, oblong, lanceolate, membranous, flattened, erect; 40-67 µm thick, 1.6-7.2 cm long, 0.5-3.5 cm broad with undulate margins having microscopic, spinulate processes; frond tightly adhering to the shell or rock by shortly stipitate, discoid holdfast, 0.5-2.5 mm in diameter.

Thallus monostromatic, having ellipsoidal cells arranged irregularly in surface view, but squarish, rectangular or bacillar in shape and radially arranged in transverse section; cells 25-40 µm long, 12.5-26.7 µm broad having 6.2-12.3 µm thick sheath on either side; single, purplish red, substellate rhodoplast in each cell with a central pyrenoid; lower cells of frond project rhizoidal filaments, 10-15 µm in diameter.

Plants monoecious; spermatangia and carpogonia occur on marginal region of the same thallus, may be seen closely arranged in the same monostromatic section; spermatangia usually found at the tip and marginal portion of the thalli; spermatangia 15.6-21.8 µm long and 10.1-15.6 µm broad, each spermatangium contains 64 spermatia arranged in four tiers of four each; spermatia 3.1-6.2 µm in diameter; carpogonia readily recognizable within the thallus due to their deep red colour, 24.9-43.4 µm long and 9.3-32.3 µm broad with 1.5-6.6 µm long colourless protuberance; first division of the fertilized carpogonium vertical, second one horizontal and third one again vertical, producing 8 carpospores in each sporocarp; carpospores 9.4-15.6 µm in diameter.

Restricted occurrence at Karachi and grows only in and around the vault of the rocky arch at Paradise Point during August and September. It is mostly seen attached to the shell of the limpet *Cellana radiata* (Born) Hornell, but also occurs as epilithon in cracks of clay-loam rocks and in small rocky pools of the upper littoral region. The number of plants (1-5, rarely more) attached to *C. radiata* vary from shell to shell and show no correlation with shell size (Paradise Point: *Leg.* A. Hayee-Memon 5-9-1987, 22-9-1987; M. Shameel 16-8-1990, 3-9-1991, 28-9-1992, 19-8- 1993).

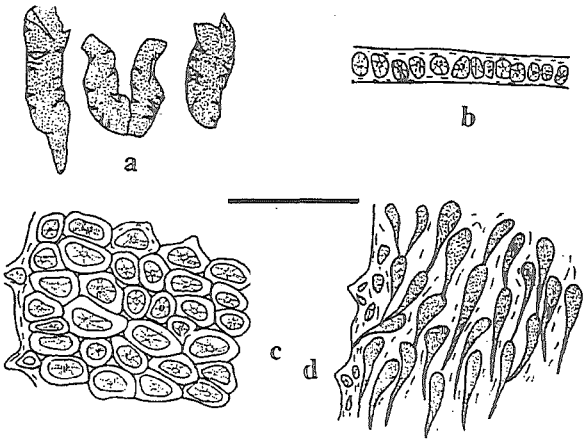

Fig. 3. *Porphyra vietnamensis* Tanaka et Pham-hoàng Hô: a. lanceolate thalli with undulate margins, b. transverse section of thallus, c. marginal portion of thallus exhibiting spinulate processes, d. lower most cells of thallus showing rhizoidal filaments (scale: a = 4 cm, b = 45 µm, c-d = 30 µm).

Class Florideophyceae Cronquist 1960
Order Bonnemaisoniales J. Feldman *et* G. Feldmann 1942
Family Bonnemaisoniaceae Schmitz *in* Engler 1892
3. *Asparagopsis taxiformis* (Delile 1813) Trevisan 1845
(= *Asparagopsis sanfordiana* Harvey 1855)
(Figs. 4 a & b)

Børgesen, 1933: 114, 1934b: 33; Anand, 1943: 43; Joly, 1965: 118; Abbott and Hollenberg, 1976: 340; Shameel, 1987: 514; Shameel and Afaq-Husain, 1987: 296; Silva *et al.*, 1987: 21; Shameel and Tanaka, 1992: 45; Aleem, 1993: 64.

Thalli 10-20 cm tall, with several to many erect, generally plumose fronds arising from creeping, cylindrical, entangled stoloniferous portions, these anchored by rhizoids; erect axes cylindrical, 1.5-2.0 mm diameter, base of branches in lower third, densely branched in pyramidal shape upwards; subtidal specimens soft and silky; low-intertidal specimens somewhat wooly and felted; spermatangia in clusters borne close to axis; cystocarps appear pedicellate, clavate in shape.

Tetrasporophytic thalli creeping, microscopic, filamentous, less than 1 cm tall, with disk-like holdfasts; prominent apical cell cutting off axial filament with 3 pericentral cells, the filament occasionally branched; trichoblasts lacking; minute, highly refractive glandlike cells lying between slender central filament and pericentrals; tetrasporangia cruciately divided, modified directly from a pericentral cell.

Occurs in the sublittoral region as epilithon and may be collected as drift material (Manora: *Leg.* M. Shameel 26-3-1989; Sandspit: *Leg.* M. Shameel 12-2-1991; Buleji: *Leg.* A. Hayee-Memon 7-3-1987, M. Shameel 15-2-1992; Paradise Point: *Leg.* M. Shameel 11-4-1993; Nathiagali: *Leg.* M. Shameel 18-3-1993).

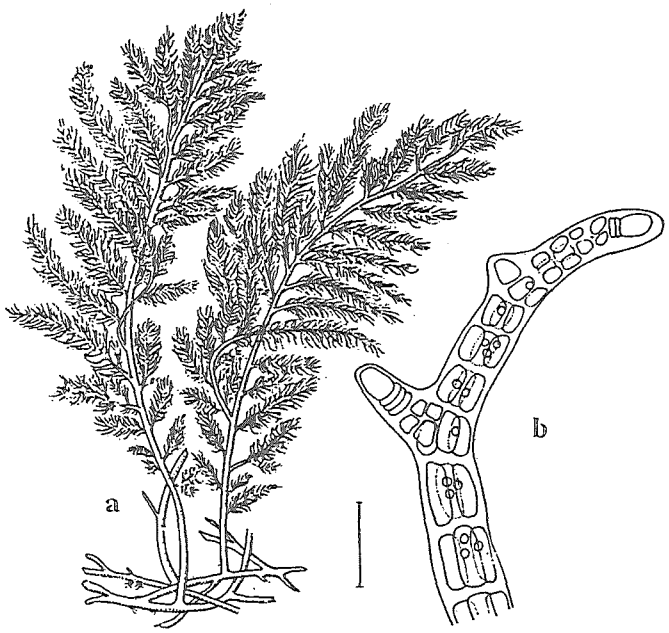

Fig. 4. *Asparagopsis taxiformis* (Delile) Trevisan: a. part of thallus, b. small part of tetrasporophytic thallus (scale: a = 2 cm, b = 50 μm).

Family Galaxauraceae Parkinson 1983
4. *Scinaia fascicularis* (Børgesen 1931) Huisman 1985
(= *Scinaia indica* Børgesen 1931)
(Figs. 5 a & b)

Børgesen, 1931: 4, 1934b: 32; Anand, 1943: 14; Shameel, 1987: 514; Shameel and Afaq-Husain, 1987: 296; Shameel and Tanaka, 1992: 45.

Plants bushy, cylindrical, up to 15 cm high, 2-3 mm broad, brownish red in colour, repeatedly dichotomously branched, only rarely constricted at the nodes, no visible axial strands; large epidermal cells 40-50 µm long, 16-20 µm broad, polygonal from above; assimilating cells about 16 µm broad, pyriform or globular with numerous rhodoplasts, filaments 3-10 µm thick. Cystocarps scattered over the surface, 220-260 µm in diameter, opening by a small ostiole.

Occurs as epilithon in quiet waters of lower littoral and sublittoral regions and may be collected as drift material (Manora: *Leg.* M. Shameel 11-2-1989; Sandspit: *Leg.* M. Shameel 15-3-1991; Buleji: *Leg.* A. Hayee-Memon 3-1-1987, 6-2-1987, M. Shameel 27-3-1992; Paradise Point: *Leg.* M. Shameel 11-4-1993; Nathiagali: *Leg.* M. Shameel 18-3-1993).

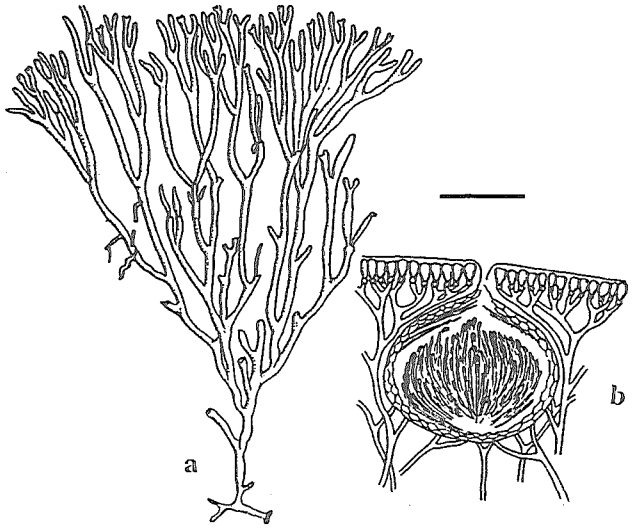

Fig. 5. *Scinaia fascicularis* (Børgesen) Huisman: a. habit of thallus, b. transverse section of thallus in the region of cystocarp (scale: a = 3 cm, b = 30 µm).

5. *Scinaia hatei* Børgesen 1931
(Figs. 6 a - e)

Børgesen, 1931: 5, 1934b: 32; Anand, 1943: 13; Shameel, 1987: 514; Shameel and Afaq-Husain, 1987: 296; Shameel and Tanaka, 1992: 45.

Plants up to 10 cm high, 3-4 mm broad, deep rose coloured, repeatedly forked, always constricted at the base of joints, cylindrical, sub-gelatinous or firm-gelatinous texture, axial strands clearly visible; composed of a medulla of slender filaments, obliquely giving off dichotomous filaments forming the middle layer, containing numer-

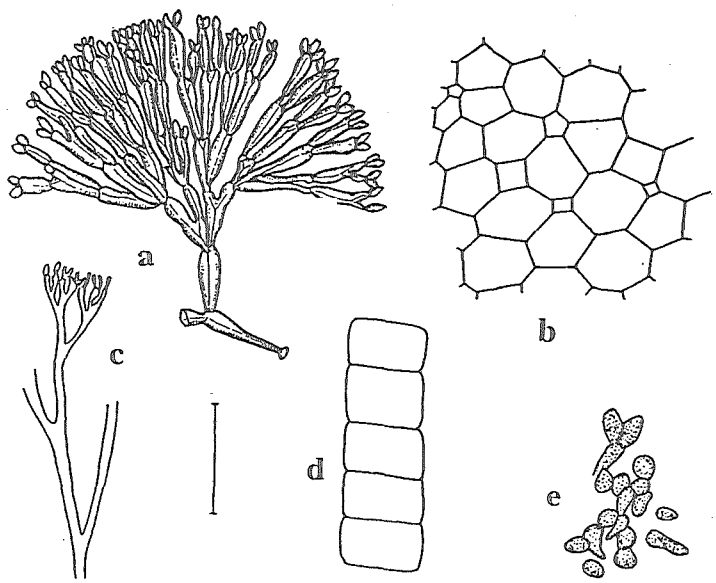

Fig. 6. *Scinaia hatei* Børgesen: a. habit of thallus, b. epidermal cells seen from above, c. filaments bearing antheridia, d. transverse section of thallus showing epidermal cells, e. assimilatory cells seen from above (scale: a = 2.5 cm, b,d,e = 25 µm, c = 60 µm).

ous rhodoplasts; epidermal cells large, colourless, 28 µm long and 20 µm broad, polygonal from above.

Assimilating cells pyriform, 25 µm long and 15 µm broad; axial strands composed of filaments, 2.5 µm broad, running in all directions in the central cavity filled with mucilage; antheridia spherical, in small sori, present in between the epidermal cells, filaments repeatedly forked; cystocarps scattered over the surface.

Occurs as benthos in the sublittoral region and can only be collected as drift material (Manora: *Leg.* A. Hayee-Memon 9-5-1987, M. Shameel 26-3-1989; Buleji: *Leg.* M. Shameel 27-3-1992; Paradise Point: *Leg.* M. Shameel 11-4-1993; Cape Monze: *Leg.* M. Shameel 14-5-1994).

Order Cryptonemiales Schmitz *in* Engler 1892
Family Halymeniaceae Bory 1828
6. *Halymenia porphyraeformis* (Børgesen 1932) Parkinson 1980
(= *Halymenia porphyroides* Børgesen 1932)

(Figs. 7 a & b)

Børgesen, 1932: 121, 1934b: 35; Anand, 1943: 16; Durairatnam, 1961: 53; Shameel, 1987: 514; Shameel and Afaq-Husain, 1987: 296; Shameel and Tanaka, 1992: 46; Shameel *et al.*, 1996: 227.

Thallus flat, tough, elastic, broadly cordate, soft, gelatinous, leaf-like, rosy-red, with sinuate margin, 20-30 cm in diameter; cells in the surface view rounded or oblong, 5-20 µm in diameter, usually 8-15 µm; transverse section of the thallus shows a peripheral limiting layer of short rounded cells in 3-4 radial rows, the innermost being the largest.

In the mucilaginous interior of the thallus numerous transversely placed anastomos-

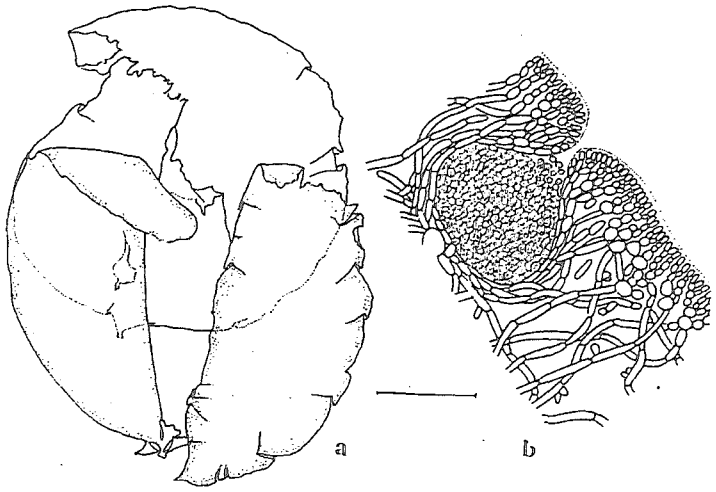

Fig. 7. *Halymenia porphyraeformis* (Børgesen) Parkinson: a. habit of thallus, b. portion of transverse section of thallus (scale: a = 10 cm, b = 100 μm).

ing filaments are found connecting the cortical layers on both sides, arising from the stellately divided cells lying below the cortical layer are thinner filaments, which run in all directions between the thicker cells; cystocarps and tetrasporangia in outer layers, cruciate, 24 μm long and 16 μm broad.

Børgesen (1932) proposed the name *Halymenia porphyroides* as an anowed substitute (*nomen novum*) for *Kallymenia harveyana* J. Agardh, on its transfer to *Halymenia* because the combination *Halymenia harveyana* was preoccupied by *Halymenia harveyana* J. Agardh. Børgesen (1932) indicated that he did not see Agardh's plant, but assumed that it was conspecific with an Indian plant from Okha. The Okha plant was studied by Balakrishnan (1961), who indicated that it had nothing to do with the real *Kallymenia harveyana* J. Agardh from South Africa, which is a *Pugetia* species (*Pugetia harveyana* (J. Agardh) Norris). The Indian plant appeared to be a new species, therefore, Parkinson (1980) proposed a new name, *Halymenia porphyriaeformis* to avoid confusion. The genitive of *Porphyra* is *Porphyrae* not *Porphyriae,* which is the genitive of the non-existent generic name *Porphyria.* Therefore, the correct specific epithet should be *H. porphyraeformis*, which means "having the form of *Porphyra*".

Grows in the sublittoral region and can only be collected as drift material (Manora: *Leg.* M. Shameel 18-3-1994; Sandspit: *Leg.* M. Shameel 26-2-1993; Buleji: *Leg.* A. Hayee-Memon 11-3-1990, M. Shameel 15-2-1992; Paradise Point: *Leg.* M. Shameel 20-3-1992, 11- 4-1993; Nathiagali: *Leg.* M. Shameel 8-2-1992).

Order Gigartinales Schmitz *in* Engler 1892
Family Sebdeniaceae Kylin 1932
7. *Sebdenia flabellata* (J. Agardh 1899) Parkinson 1980
(= *Halymenia polydactyla* Børgesen 1932)
(Figs. 8 a & b)

Børgesen, 1932: 122, 1934b: 35; Anand, 1943: 17; Durairatnam, 1961: 54; Joly,

1965: 149; Shameel, 1987: 514; Shameel and Afaq-Husain, 1987: 297; Shameel and Tanaka, 1992: 47.

Thallus repeatedly forked, fastigiate, but with a tendency to become flabellate; plants up to 30 cm long and attached by a small rounded disc, about 4 mm broad. Segments terete or little compressed below; in the basal portion distance between the forks less than 2 cm, higher up to 5 cm; apices blunt, colour dark purple below, lighter above, tough consistency. Wall of the thallus composed of thick-walled cells, polygonal from above, 5-9 μm in diameter, with larger cells underneath passing into stellate ones, gland cells here and there. Tetrasporangia roundish to oblong, 20-25 μm broad, 20-30 μm long, embeded in the cortex; tetraspores roundish to oblong, variable in size and shape, occur in epidermal tissue.

A transverse section shows that the cells underneath are larger and pass over into stellate cells. Cells near the periphery are short rayed, but the rays towards the interior are longer and form very lax tissue in the mucilaginous interior of the tubes. The length of the cells constituting the filaments is 120-140 μm and the breadth varies from 5-25 μm.

Occurs as epilithon on sublittoral rocks and may be collected as drift material (Manora: *Leg.* M. Shameel 14-12-1994; Buleji: *Leg.* A. Hayee-Memon 24-11-1990, M. Shameel 4-12-1993; Paradise Point: *Leg.* M. Shameel 13-1-1994; Cape Monze: *Leg.* M. Shameel 7-11-1992, 26-12-1993). Although various authors, beginning with Børgesen (1932), have noted the similarity of *Sebdenia polydactyla* (Børgesen) Balakrishnan to *S. flabellata*, the two species are conspecific. The oldest name in this connection is *Isymenia flabellata* J. Agardh, which is the basionym of *S. flabellata*; hence, this name is preferred.

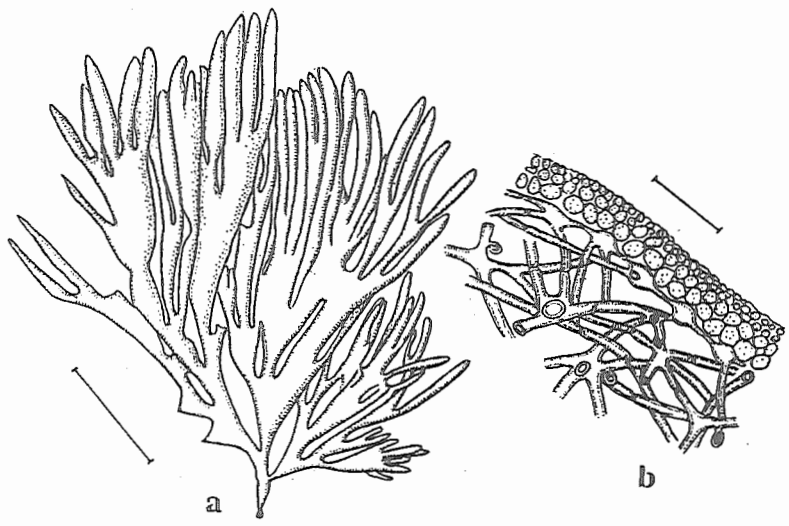

Fig. 8. *Sebdenia flabellata* (J. Agardh) Parkinson: a. habit of thallus, b. part of transverse section of thallus (scale: a = 6.5 cm, b = 150 μm).

Family Gracilariaceae Nägeli 1847
8. *Gracilaria foliifera* (Forsskål 1775) Børgesen 1932
(= *Gracilaria corticata* (J. Agardh 1841) J. Agardh 1852)
(Figs. 9 a & b)

Børgesen, 1932: 124, 1934b: 38, 1935: 55, 56, 1936: 85, 86, 1937a: 48, 1938: 225, 226, 1939: 109, 110; Anand, 1943: 57; Durairatnam, 1961: 63; Nizamuddin and Gessner, 1970: 9; Jaasund, 1976: 83; Shameel, 1987: 514; Shameel and Afaq-Husain, 1987: 297; Silva *et al.*, 1987: 42; Shameel *et al.*, 1989: 180, 1996: 228; Shameel and Tanaka, 1992: 47.

Thallus flat, 10-15 cm high, 2-3 mm wide, more or less dichotomously branched, rigid with cartilaginous consistency; upper portion and marginal ramuli less cartilaginous causing the thallus to adher firm to herbarium paper at these points; thickness of the frond more or less uniform throughout; margin of the thallus with irregular proliferations.

Frond composed of an inner core of large angular cells, surrounded by a cortex of small assimilating cells; in transverse section the cortex is composed of densely packed small cells 6-10 µm in diameter, surrounding the central portion of large rounded oblong cells, 170-200 µm in diameter, cells not vertically elongated.

Cystocarps large, sessile, external, roundish or subovate, with a subacute nipple, ostiole present, plentifully scattered over the branches; spores rounded or oblong, 20-26 µm in diameter; tetrasporangia formed from surface cells, cruciate.

Grows as epilithon firmly attached to the rocks of midlittoral and lower littoral regions (Manora: *Leg.* M. Shameel 15-10-1993; Buleji: *Leg.* A. Hayee-Memon 12-10-1986, M. Shameel 13-11-1992; Paradise Point: *Leg.* M. Shameel 13-1-1994; Cape Monze: *Leg.* M. Shameel 7-11-1992). *Gracilaria foliifera* and *G. corticata* appear to be conspecific.

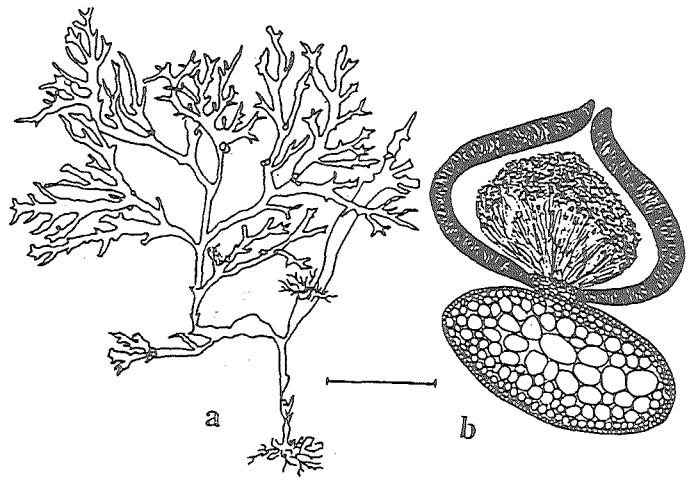

Fig. 9. *Gracilaria foliifera* (Forsskål) Børgesen: a. habit of thallus, b. transverse section of thallus in the region of cystocarp (scale: a = 3.2 cm, b = 20 µm).

Family Solieriaceae J. Agardh 1876
9. *Sarconema filiforme* (Sonder 1845) Kylin 1932
(= *Sarconema furcellatum* Zanardini 1858)

(Figs. 10 a - c)

Børgesen, 1932: 126, 1934a: 10, 11, 1934b: 36, 1935: 55, 1939: 111; Anand, 1943: 49, 52; Jaasund, 1976: 93; Basson *et al.,* 1989: 35; Shameel and Tanaka, 1992: 48; Shameel *et al.,* 1996: 228.

Thallus tufted, pinkish-red, fleshy, up to 15 cm high, 1-2 mm broad, repeatedly dichotomously branched, forming dense, broad, intricate tufts. Plants breaking quickly when handled, adhering firmly to paper on drying. Medulla of compactly arranged thick- walled filaments, 4-8 μm in diameter. Inner cortical cells 40-45 μm in diameter, outer ones 15-20 μm; epidermis of one or two layers of small cells 6-8 μm in diameter.

Cystocarps large, plentifully lodged in cortical tissue of branches, prominent to one side, as if hemispherical, mammilate or subconical, 700-750 μm broad, central placenta, 350-400 μm broad, bearing numerous filaments at ends having rounded or oval spores, 20-22 μm long, 15-20 μm broad, with a single ostiole.

Grows as epilithon attached to pebbles and rocks and also as epizoon attached to animal shells in the lower littoral region (Sandspit: *Leg.* M. Shameel 11-2-1989; Buleji: *Leg.* A. Hayee-Memon 7-3-1987; Paradise Point: *Leg.* M. Shameel 20-3-1992, 11-4-1993).

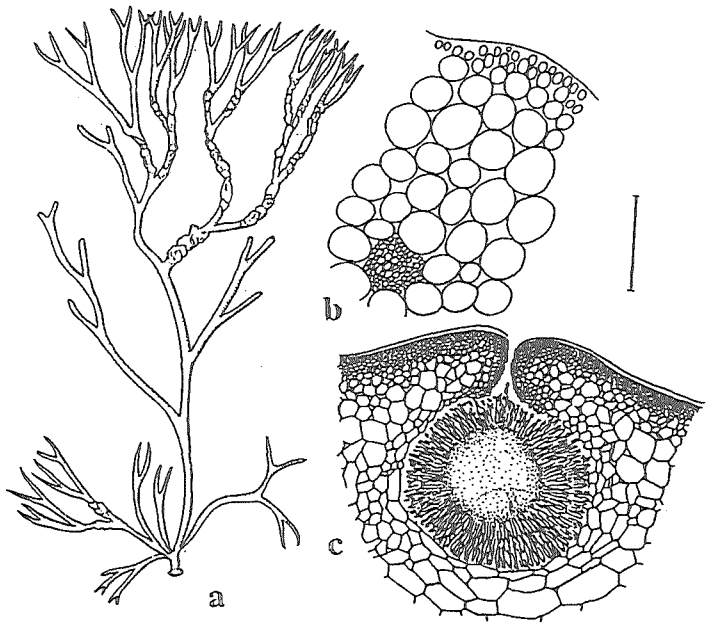

Fig. 10. *Sarconema filiforme* (Sonder) Kylin: a. habit of thallus, b. transverse section of thallus, c. transverse section through cystocarp showing central placenta bearing carpospores at periphery (scale: a = 4 cm, b = 86 μm, c = 368 μm).

10. *Solieria robusta* (Greville 1830) Kylin 1932
(= *Agardhiella rbusta* (Greville 1830) Børgesen 1932)
(Figs. 11 a - d)

Børgesen, 1932: 127, 1934a: 10, 1934b: 36, 1935: 54, 1937a: 47, 1937b: 325; Anand,1943:47;Jaasund,1976:93; Shameel and Tanaka,1992:48;Shameel *et al.*,1996:228.

Thallus tufted, bright red, very bushy, cylindrical, dendroid, tapering upwards, several fronds arising from the small basal disc, 10-25 cm high, main axis 2-3 mm wide. Plants adhere firmly to paper on drying and their colour fades with age and long preservation. Irregularly branched on all sides; usually alternate, occasionally polychotomous; branches, as a rule, are immediately constricted near the base to form short thin stipes; remain almost cylindrical until they taper slowly into the upper acute apex. Apices usually covered over by a tuft of short rudimentary branches; growth of the fountain type; rarely, the main filament may also be constricted at the intervals.

The thallus in transverse and longitudinal sections, is comprised of a lax network of longitudinal branching and anastomosing filaments, 6-8 µm in diameter, in the middle, embedded in jelly, forming the medulla. It is surrounded by a cortex of large rounded or polygonal cells, 110-130 µm in diameter, covered by a layer of small slightly elongated epidermal cells, 25-30 µm long, 15-20 µm broad, rounded and loosely placed in surface view. Tetrasporangia zonate, immersed in the cortex; cystocarps prominent, half immersed.

Grows as benthos in the sublittoral region and can only be collected as drift material from the bays between rocky ledges and sandy flats (Sandspit: *Leg.* A. Hayee-Memon 19-2-1989; Buleji: *Leg.* A. Hayee-Memon 21-3-1989, M. Shameel 15-2-1992; Nathiagali: *Leg.* M. Shameel 18-3-1993, 12-4-1994).

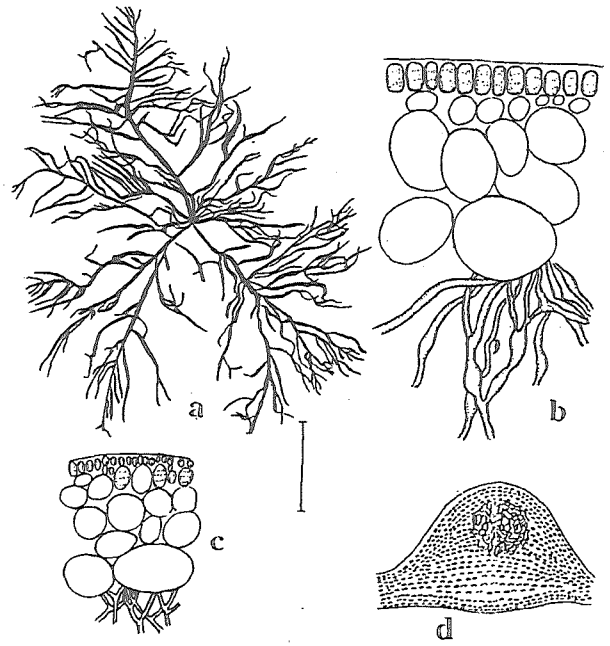

Fig. 11. *Solieria robusta* (Greville) Kylin: a. habit of thallus, b. transverse section of thallus, c. transverse section of thallus with tetrasporangia, d. cystocarp (scale: a = 7.5 µm, b = 120 µm, c = 188 µm, d = 450 µm).

Family Cystocloniaceae Kützing 1843
11. *Calliblepharis fimbriata* (Greville 1830) Kützing 1843
(Figs. 12 a & b)

Børgesen, 1932: 128, 1934b: 37; Anand, 1943: 58; Shameel and Tanaka, 1992: 49.

Plants purple red, flat, cartilagino-membranous, dichotomopinnate, attaining a height of about 30 cm, fixed to submerged stones by basal discs; growth by an apical cell; thallus divided into several lobes about 1 cm broad, flat, membranous; branches and main axis nearly equal in width, bearing along the margin dense, short, pointed, invariably branched horizontal proliferations giving a fringed appearance, 3/4 - 1 cm long and 0.3-0.6 cm broad, each usually having a short stipe and irregularly divided upper part.

In transverse section, thallus is 800-850 μm thick, cortical cells small, rounded or slightly vertically elongated, 40-50 μm in diameter, arranged in two rows bounding a central core of large rounded, oblong or angular cells, 180-200 μm in diameter. Cystocarps sessile on proliferations; tetrasporangia in the peripheral cells of the fronds or the proliferations, zonate.

Occurs as benthos in the sublittoral region and may be collected as drift material (Buleji: *Leg.* A. Hayee-Memon 25-5-1987, M. Shameel 10-4-1991; Paradise Point: *Leg.* M. Shameel 20-3-1992, 11-4-1993; Nathiagali: *Leg.* M. Shameel 12-4-1994; Cape Monze: *Leg.* M. Shameel 14-5-1994).

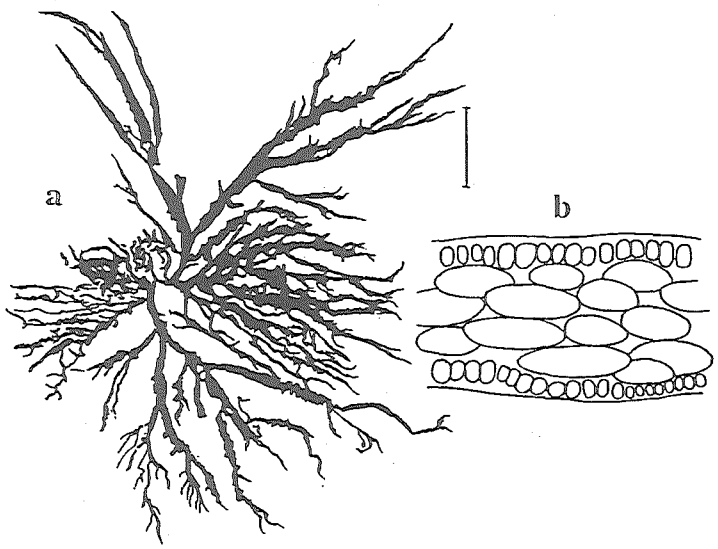

Fig. 12. *Calliblepharis fimbriata* (Greville) Kützing: a. habit of the thallus, b. transverse section of thallus (scale: a = 4 cm, b = 364 μm).

Family Hypneaceae J. Agardh 1851
12. *Hypnea musciformis* (Wulfen 1789) Lamouroux 1813
(Figs. 13 a - d)

Børgesen, 1943a: 17, 1934b: 37, 1935: 55, 1937a: 47, 1938: 221, 1939: 112;

Feldmann, 1941: 84; Anand, 1943: 59; Durairatnam, 1961: 55; Joly, 1965: 166; Nizamuddin and Gessner, 1970: 9; Jaasund, 1976: 97; Shameel and Afaq-Husain, 1987: 297; Silva *et al.*, 1987: 49; Shameel *et al.*, 1989:180, 1996: 228; Shameel and Tanaka, 1992: 49; Aleem, 1993: 84.

Plants bushy, spreading, cylindrical, 10-30 cm high, purplish green in colour, fronds filiform, cartilaginous, much branched; branches irregular, giving a bushy look to the plant. Tips of the main and principal lateral branches often elongate, typically swollen and crozier hooked. Hooked tendrils cause plants to entangle to other large seaweeds. At point of contact, haptera may be formed, establishing a firm intimate connection. The hooked and swollen tendrils are the characteristic feature of this species.

In transverse section, a few central cells, 16-18 µm in diameter, are surrounded by a group of 6-7 large angular cells, 25-38 µm in diameter, becoming smaller 10-11 µm in diameter, towards the periphery.

Occurs as epilithon on rocks of lower littoral and sublittoral and may also be collected as drift material (Buleji: *Leg.* A. Hayee-Memon 12-10-1986; Paradise Point: *Leg.* A. Hayee-Memon 29-10-1986, M. Sahmeel 16-8-1990, 3-9-1991; Cape Monze: *Leg.* M. Shameel 7-11-1992).

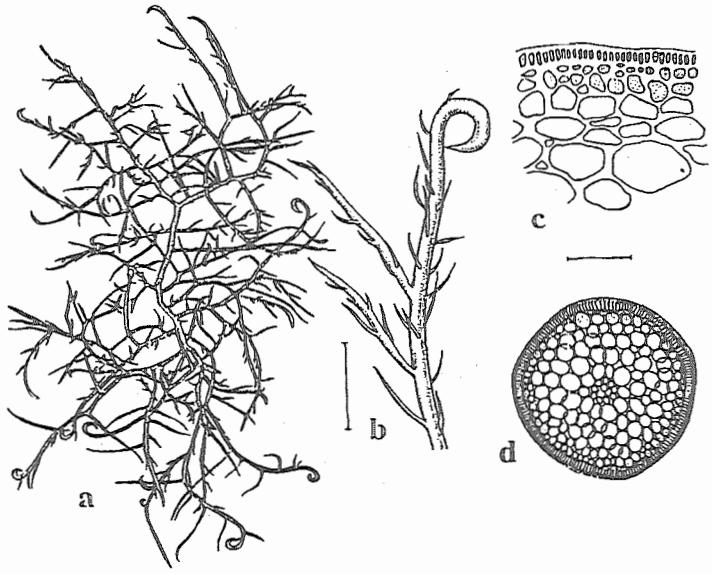

Fig. 13. *Hypnea musciformis* (Wulfen) Lamouroux: a. habit of thallus, b. enlarged view of a branch showing swollen and crozier hook like tip, c. enlarged view of transverse section of thallus, d. general view of transverse section of thallus (scale: a = 3 cm, b = 12 cm, c = 40 µm, d = 150 µm).

13. *Hypnea valentiae* (Turner 1809) Montagne 1843
(Figs. 14 a & b)

Børgesen, 1934a: 17, 1934b: 37, 1935: 55, 1937a: 47, 1938: 221, 1939: 112; Anand, 1943: 60; Durairatnam, 1961: 56; Abbott and Hollenberg, 1976: 489; Basson,

1979: 70; Shameel and Afaq-Husain, 1987: 297; Silva *et al.*, 1987: 50; Basson *et al.*, 1989: 35; Shameel *et al.*, 1989: 180, 1996: 228; Shameel and Tanaka, 1992: 49; Aleem, 1993: 85.

Plants erect to slightly decumbent, bushy, virgate, slender, greenish in colour, 10-25 cm tall; characterised by having densely placed short branchlets along the main axis, straight to uncinate, 3-10 mm long; branches numerous, with acute apices, developing from an apical cell, main erect branches to 2 mm diam., gradually reduced in lateral branches; determinate ramuli simple to compound; internally composed of a medulla of longitudinal filaments surrounded by a cortex of large cells, having at the periphery a layer of small assimilating cells.

Cystocarps and tetrasporangia grouped in separate short branchlets, tetrasporangia zonate, ramuli bearing tetrasporangial and spermatangial nemathecia at or near their bases; sexual plants rare, cystocarps somewhat globose, conspicuous.

Grows as epilithon on sand covered rocks of lower littoral and sublittoral regions and may also be collected as drift material (Buleji: *Leg.* A. Hayee-Memon 4-12-1988, 23-12-1988; Paradise Point: *Leg.* M. Shameel 13-11-1993; Cape Monze: *Leg.* M. Shameel 7-11-1992, 26-12-1993).

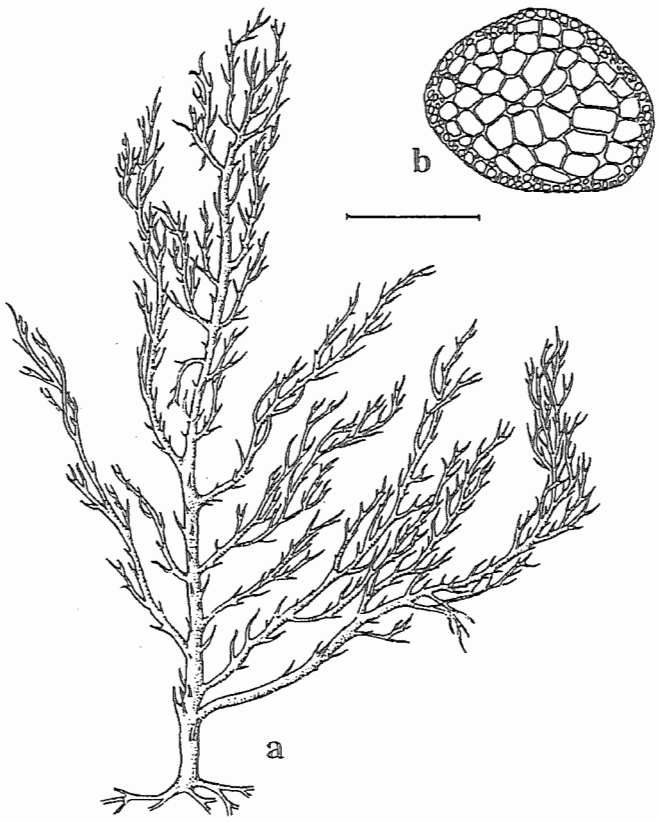

Fig. 14. *Hypnea valentiae* (Turner) Montagne: a. part of thallus, b. transverse section of thallus (scale: a = 4.7 cm, b = 96 μm).

Order Rhodymeniales Schmitz *in* Engler 1892
Family Rhodymeniaceae Harvey 1849
14. *Coelarthrum muelleri* (Sonder 1852) Børgesen 1931
(Figs. 15 a - c)

Børgesen, 1931: 9; Anand, 1943: 61; Shameel, 1987: 514; Shameel and Afaq-Husain, 1987: 297; Shameel and Tanaka, 1992: 50.

Plants erect, bright red, up to 15 cm high, attached by solid, creeping, cylindrical stolons, 2-3 mm in diameter; thallus jointed and fairly regularly di- and trichotomously branched. Lower portion of basal segment solid and hard, segments hollow, solid at articulations, lower ones cuneate, 1.5-2.5 cm long, 4-5 mm wide, upper ones relatively broader and more or less oval, ultimate segments rounded, 2-3 mm in diameter; plants adhere firmly to paper.

Walls of thallus composed of 2-3 layers of large cortical cells, abutting on the hollow cavity, oblong or polygonal in surface view, up to 300 µm long, 200-250 µm broad, some bear small irregularly stellate cells carrying glands, surrounded on the outside by one or two layers of small cells, 8 µm in diameter. Many-layered diaphragm present at the articulations. In transverse section, stolon shows large polygonal cells in the centre, 100-150 µm in diameter and smaller, slightly elongated pyriform cells towards the periphery. Lower solid portion of the basal segment has the same structure.

Cystocarps hemispherical, with an apical pore, scattered upon the thallus, each having a basal placenta bearing radiating sporogenous filaments; spores 20-40 µm in diameter; tetrasporangia in cortical cells, cruciate.

Occurs as benthos in the sublittoral region and can be collected only as drift material from sandy beaches (Manora: *Leg.* A. Hayee-Memon 26-10-1988, 16-11-1988; Buleji: *Leg.* M. Shameel 13-11-1992; Cape Monze: *Leg.* M. Shameel 26-12-1993).

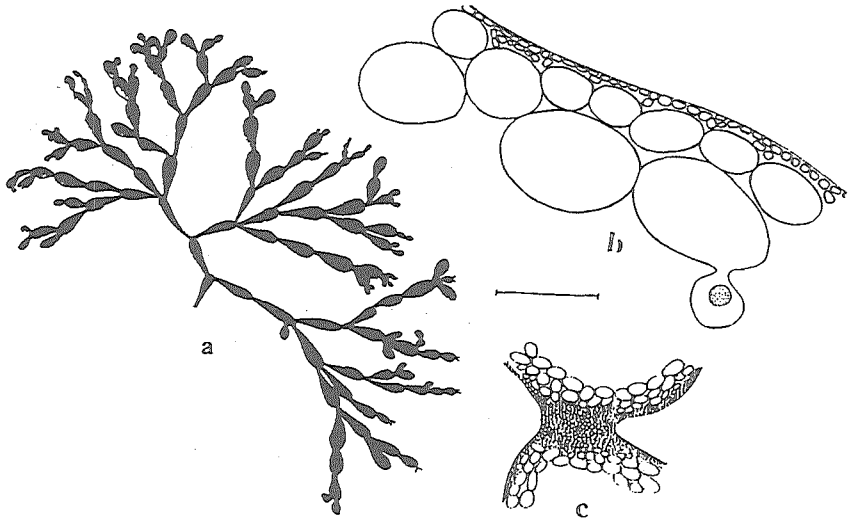

Fig. 15. *Coelarthrum muelleri* (Sonder) Børgesen: a. habit of thallus, b. transverse section of thallus, c. longitudinal section through articulation (scale: a = 6 cm, b = 105 µm, c = 25 µm).

Order Ceramiales Oltmanns 1904
Family Ceramiaceae Dumortier 1822
15. *Centroceras clavulatum* (C. Agardh 1822) Montagne 1846
(Figs. 16 a - d)

Børgesen, 1934a: 18, 1934b: 41, 1935: 57, 1936: 92, 1937a: 49, 1939: 118; Anand, 1943: 25; Durairatnam, 1961: 66; Joly, 1965: 193; Nizamuddin and Gessner, 1970: 11; Abbott and Hollenberg, 1976: 604; Jaasund, 1976: 109; Basson, 1979: 72; Shameel, 1987: 514; Shameel and Afaq-Husain, 1987: 297; Silva *et al.*, 1987: 54; Basson *et al.*, 1989: 36; Shameel *et al.*, 1989: 180; Shameel and Tanaka, 1992: 51; Aleem, 1993: 91.

Thalli tufted, dark red, filiform, articulated, corticated, matted together forming very low cushions, up to 2 mm high, attached firmly to substratum by rhizoids given off from nodes, each ending in a broad disc. Plants rigid, harsh; brittle on drying, easily loosened at nodes and breaking into small pieces; irregularly dichotomously branched, branching alternate, sometimes almost ternate, each dichotomy of equal length. Ultimate ramuli usually of unequal lengths, slightly curved inwards, apices broadly obtuse.

Completely corticated with coloured cells in longitudinal rows, cells near the nodes quadrate, 12 µm in diameter, lower down rectangular, 18-21 µm long, 12-14 µm broad. Each node crowned with whorl of small spine like processes, usually 2-celled, which are gradually obliterated by age, very prominent in the youngest branches, 9-10 articulations in each ramification, 300-450 µm long, 120-150 µm broad.

Tetrasporangia tetrahedrally divided, in rings at nodes, sometimes on specialized branches. Spermatangia in terminal clusters from tufted, adventitious branchlets, these arising from pericentral cells at nodes. Gonimoblasts borne at nodes, usually terminating further growth there but initiating several sterile branchlets from below, mature gonimoblasts surrounded by several sterile branches.

Grows on sand covered rocks and in sandy bottom pools of rocky ledges at littoral as well as on muddy flats (Manora: *Leg.* M. Shameel 18-3-1994; Sandspit: *Leg.* M.

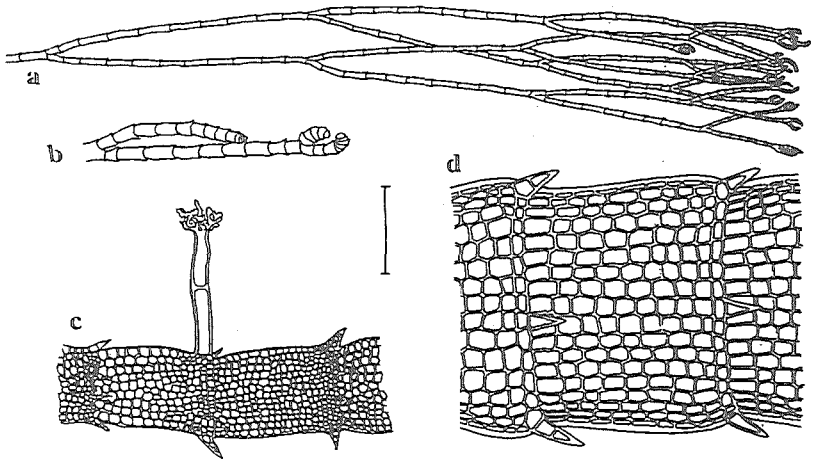

Fig. 16. *Centroceras clavulatum* (C. Agardh) Montagne: a. part of thallus, b. thallus showing ultimate branches incurved in pairs, c. thallus exhibiting longitudinally arranged cortical cells, nodes and a rhizoid, d. thallus showing nodes crowned with a whorl of small spine-like processes (scale: a = 1.4 mm, b = 0.1 mm, c = 160 µm, d = 55.5 µm).

Shameel 26-2-1993; Buleji: *Leg.* A. Hayee-Memon 7-3-1987, 28-3-1987, M. Shameel 15-2-1992; Paradise Point: *Leg.* M. Shameel 20-3-1992, 11-4-1993; Nathiagali: *Leg.* M. Shameel 8-2-1992, 18-3-1993).

Family Delesseriaceae Bory 1828

16. *Cottoniella filamentosa* (Howe 1905) Børgesen 1920

(= Cottoniella fusiformis Børgesen 1930)

(Figs. 17 a - e)

Børgesen, 1931: 20, 1934b: 45; Anand, 1943: 41; Shameel and Afaq-Husain, 1987: 298; Silva *et al.*, 1987: 58; Shameel *et al.*, 1989; Shameel and Tanaka, 1992: 52.

Plants rose red in colour, irregularly branched, up to 12 cm high, in the upper end branches usually more or less curved, young branches markedly fusiform. Thallus with basal portion of decumbent filaments fixed to substratum by rhizoids. Erect filaments near the upper end bear a series of branches with limited growth in two rows along the dorsal convex sides, growth by an apical cell. Filaments composed of a central cell surrounded by four pericentral cells, older parts corticated, ramuli monosiphonous. The hemispherical apical initial cuts off segments, which divide to form 4 pericentral cells. The abaxial pericentral cell is first formed, followed by the 2 lateral pericentral cells, and finally the adaxial pericentral cell.

Monosiphonous filaments are formed from the adaxial face of the branches, cells of the filaments contain rhodoplasts. Filaments are conspicuous near the branch apices but fall off away from the tip. They develop endogenously from the central cell, at the anterior end of the adaxial pericentral cell, which is shorter in length than the other pericentral cells. They arise very shortly after the adaxial pericentral cell is formed. These filaments tend to emerge from the branch in 2 rows, alternately to either side. When the filaments are shed the basal cell only is retained. Monosiphonous filaments are not formed near the base of lateral branches; here, the adaxial pericentral cell is about as long as the other pericentral cells.

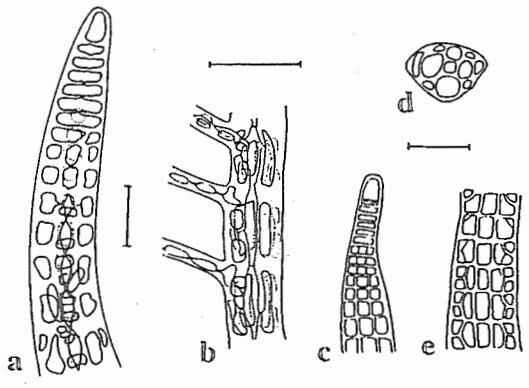

Fig. 17. *Cottoniella filamentosa* (Howe) Børgesen: a. apex of an older branch showing segmentation and formation of monosiphonous filaments anterior to the small adaxial pericentral cell, b. side view of older part of a branch exhibiting origin of monosiphonous filaments, c. apex of a young filament, d. transverse section of thallus showing 4 pericentral cells, 2 marginal cells and cortical cells, e. part of thallus exhibiting formation of marginal cells (scale: a = 25 µm, b = 100 µm, c-e = 75 µm).

Lateral branches arise endogenously from the central cells and cortication commences some distance from the apex and develops extensively. Thallus is attached by means of several-celled rhizoids from prostrate branches.

Occurs attached with the pebbles and rocks in the lower littoral (Buleji: *Leg.* A. Hayee-Memon 15-9-1988, 30-9-1988, M. Shameel 17-8-1992; Nathiagali: *Leg.* M. Shameel 10-9-1993, 23-8-1994).

Family Rhodomelaceae J.E. Areschoug 1847

17. *Laurencia obtusa* (Hudson 1778) Lamouroux 1813

(Figs. 18 a - d)

Børgesen, 1933: 135, 1934a: 20, 1934b: 46, 1938: 230, 1939: 120; Feldmann, 1942: 81; Anand, 1943: 31; Durairatnam, 1961: 73; Joly, 1965: 244; Nizamuddin and Gessner, 1970: 41; Jaasund, 1976: 143; Shameel, 1987: 514; Shameel and Afaq-Husain, 1987: 298; Silva *et al.*, 1987: 66; Shameel and Tanaka, 1992: 54; Aleem, 1993: 101; Shameel *et al.*, 1996: 228.

Thallus erect, cartilaginous, brittle, yellowish red, 6-12 cm high, cylindrical of more or less uniform diameter throughout, tapering towards the base into a small disc for attachment. Branching as a rule alternate, rarely opposite or spiral, diminishing in length from base to apex, ramuli short with obtuse or slightly truncate apices, bearing two or more processes.

Internally thallus composed of an epidermis of small rounded cells, 25-32 μm in diameter with a central tissue of large isodiametric cells, 75-80 μm in diameter. The inner most largest cells attaining diameter of up to 100 μm, central cell is only clearly seen in sections of young branches.

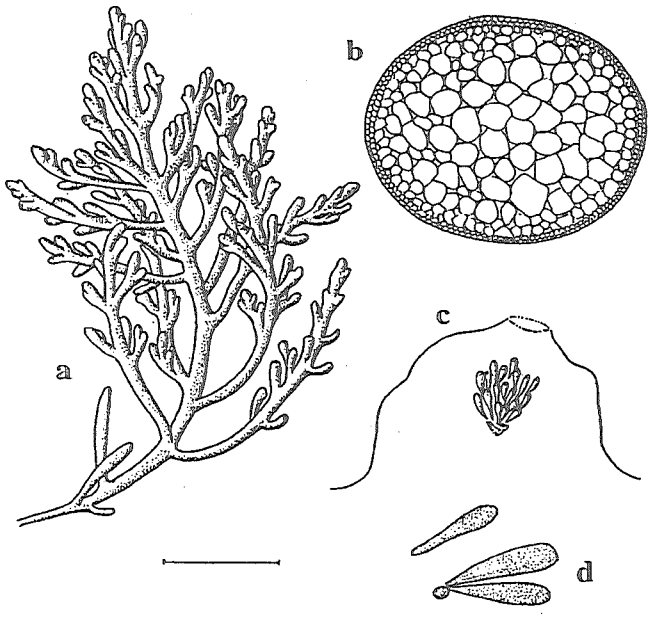

Fig. 18. *Laurencia obtusa* (Hudson) Lamouroux: a. part of thallus, b. transverse section of thallus, c. cystocarp, d. carpospores (scale: a = 7.5 mm, b = 300 μm, c = 142 μm, d = 39 μm).

Cystocarps conspicuous, distributed on ramuli and branches, mammilate, up to 270 µm broad at the widest portion, opening by an orifice, 50-60 µm in diameter. Spores clavate, 120-130 µm long, 12-15 µm broad at the greatest width. Tetrasporangia near tips of the ramuli.

Occurs as epilithon in shallow rock pools at shaded localities on lower littoral region of rocky ledges and as epizoon on shells of barnacles on sandy beaches (Manora: *Leg.* A. Hayee-Memon 14-11-1989; Buleji: *Leg.* A. Hayee-Memon 18-12-1989, M. Shameel 13-11-1992; Paradise Point: *Leg.* M. Shameel 7-12-1991, 13-11-1993, 13-1-1994).

18. *Melanothamnus somalensis* Bornet *et* Falkenberg *in* Falkenberg 1901 (= *Odonthalia washingtoniensis* Kylin 1925)

(Figs. 19 a - d)

Kylin, 1956: 554; Wynne and Banaimoon, 1990: 216; Shameel and Tanaka, 1992: 54; Shameel *et al.*, 1996: 228.

Thalli erect, freely branched, terete axes, up to 30 cm in height, with several long, terete to markedly flattened branches. Plants become dark reddish-black upon drying and have tough consistency. Thalli coarse, cartilaginous, prominently distichous, attached by means of a large, hapteroid holdfast with soft rocks constituting large bushes. Axes radially organized and produce branches in spiral arrangement from every fifth segment. Segments from apical cell cut off four pericentral cells, each of which cuts off several smaller cells to the outside. Later these latter cells cut off still smaller cells to the outside, such that two discrete layers of cells lie outside of the ring of pericentral cells.

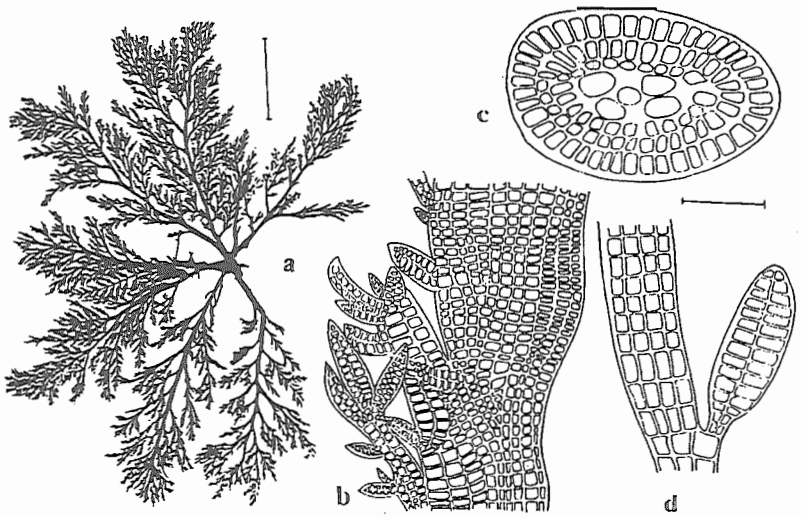

Fig. 19. *Melanothamnus somalensis* Bornet et Falkenberg: a. part of thallus, b. axes with propagule like bodies, c. transverse section of axis showing 4 pericentral cells surrounding axial cell, d. propagule like body (scale: a = 2.6 cm, b = 167 µm, c = 86 µm, d = 53 µm).

Multicellular propagule-like bodies, up to 210 μm in length, 68-84 μm in diameter, produced in abundance in distal portions of plants. Consist of 13-15 tiers of cells situated on a narrow stalk of three very reduced tiers of cells. Each tier of propagule consists of four pericentral cells with very dense contents surrounding a smaller axial cell. Lower most tier of cells above the stalk are often protruding, being incipient rhizoids; the stalk is very narrow and delicate.

Occurs as epilithon in the form of dense bushes on lower littoral rocks exposed to strong wave action (Manora: *Leg.* M. Shameel 15-10-1993; Buleji: *Leg.* A. Hayee-Memon 10-10-1990, 27-10-1990, M. Shameel 13-11-1993; Paradise Point: *Leg.* M. Shameel 28-9-1992; Cape Monze: *Leg.* M. Shameel 7-11-1992). This plant was misidentified earlier by Shameel and Tanaka (1992) as *Odonthalia washingtoniensis,* which is a cold-water alga.

CONCLUDING REMARKS

During this research programme, 18 commonly occurring species of marine benthic red algae, have been taxonomically determined. These seaweeds were collected from intertidal regions and obtained as drift material from rocky ledges and sandy bays of different coastal areas near Karachi, Pakistan. The studies were based on several collections made during different seasons from 1987 to 1994. All the investigated seaweeds are taxonomically known species. While large numbers of them were known from the Pakistan coast (Anand, 1943; Moazzam and Shameel, 1985; Shameel and Tanaka, 1992; Shameel *et al.,* 1996), some were not taxonomically described. In this study, *Melanothamnus somalensis* was reported for the first time from this region and *Asparagopsis taxiformis, Bangia atropurpurea, Cottoniella filamentosa, Gracilaria foliifera, Halymenia porphyraeformis, Melanothamnus somalensis, Sarconema filiforme, Sebdenia flabellata, Scinaia fascicularis,* and *Solieria robusta* taxonomically described for the first time from the coast of Pakistan.

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