

TAXONOMIC STUDY OF COENOCYTIC GREEN ALGAE COMMONLY GROWING ON THE COAST OF KARACHI

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ABSTRACT: Twelve commonly occurring coenocytic and siphonaceous species of marine benthic algae, *i.e.*, *Bryopsis pennata* Lamouroux, *Caulerpa chemnitzia* (Esper) Lamouroux, *Ca. faridii* Nizamuddin, *Ca. manorensis* Nizamuddin, *Ca. racemosa* (Forsskål) J. Agardh, *Ca. taxifolia* (Vahl) C. Agardh, *Chaetomorpha antennina* (Bory de Saint-Vincent) Kützing, *Cladophora uncinella* Harvey, *Codium decortcatum* (Woodward) Howe, *Co. flabellatum* Nizamuddin, *Co. iyengarii* Børgesen, and *Valoniopsis pachynema* (Martens) Børgesen, belonging to four different orders of the class Bryopsidophyceae, division Chlorophyta, were collected from the intertidal region of different coastal areas near Karachi (Pakistan) and investigated taxonomically. *Codium decortcatum* is a new report from this region and *Co. decortcatum*, *Co. flabellatum* and *Co. iyengarii* are described for the first time from the coast of Pakistan.

KEY WORDS: Chlorophyta - Bryopsidophyceae - morphology - cell structure - reproduction - ecological notes - marine algae - northern Arabian Sea - Pakistan.

INTRODUCTION

The green seaweeds occupy a large area of the Karachi coast and show great variation in type and species. It was not until the 1930s that any systematic taxonomic study was carried out on the marine algal flora of the Karachi coast. Børgesen (1934) provided the first account of a few species from this coast. After a synoptical study by Anand (1940) on marine Chlorophyta of Karachi, Prof. M. Nizamuddin was the first person to make a systematic taxonomic investigation of different species of green seaweeds. The first detailed studies were conducted out on two genera: *Polyphysa* (= *Acetabularia*) and *Udotea* (= *Decaisnella*; Nizamuddin, 1963a,b). A year later he gave detailed descriptions of ten species of *Caulerpa* occurring along this coast, including three new species (Nizamuddin, 1964); later on he added the description of two more species (Nizamuddin, 1967). He also provided the taxonomy of the marine *Vaucheria* (Nizamuddin, 1968) and siphonaceous green algae (Nizamuddin, 1969).

Other phycologists also made valuable contributions to the taxonomy of green algae of the Karachi coast. Shameel (1978a) added one more species to the list of *Caulerpa*, presented an ecological account of all the 13 known species, and investigated the order Dichotomosiphonales (Shameel, 1975) and the family Chaetophoraceae (Shameel, 1978b) of Karachi coast. Other significant studies made were by Nizamuddin and Begum (1973), Saifullah and Nizamuddin (1977), Zahid *et al.* (1983), and Amjad and Shameel (1993a). A few studies were conducted on the occurrence of algae, including green seaweeds, from the adjacent coast of Lasbela (Shameel, 1987; Shameel and Afaq-Husain, 1987; Shameel *et al.*, 1989). Recently, a checklist of marine planktonic and benthic algae of Pakistan was published by Shameel and Tanaka (1992) that includes 27 genera and 90 species of green algae. A taxometric study was also carried

out on three related species of *Caulerpa* (Shameel and Shaukat, 1992). From the foregoing literature survey it is apparent that most of these studies are ecological surveys and that very little work was done on the taxonomy of Bryopsidophyceae from the coast of Karachi. The present study, therefore, was undertaken to investigate the predominant coenocytic green algae occurring along the coast of Karachi for a better understanding of their morphology as well as their cellular and reproductive structures.

MATERIALS AND METHODS

Collections were made during 1989-1991 from four different areas along the coast of Karachi. Materials were obtained in attached form from the rocky platforms and pools near PNS Himalaya at the pseudo-island of Manora as well as in drift form from the sandy beaches near PNS Qasim (Fig. 1). The third point of collection was at the sandy beaches near the scattered, narrow, rocky ledges of Hawkes Bay, where large specimens were found in drift form. Most of the collections were from the wall-bounded, protected area (French Beach) near Goth Haji Ali at Buleji, where both attached as well as specimens were found. This area has several rocky ledges, a very large sandy platform and sandy bays, where large amounts of drift material from the sublittoral zone come in with the incoming tides, and accumulated. The next area of collection was Nathiagali (Pacha) near PNS Haider, which has both rocky ledges, pebbles and large boulders as well as sandy beaches. Here most of the collections were made from the pebbles and boulders where the specimens were found in attached form.

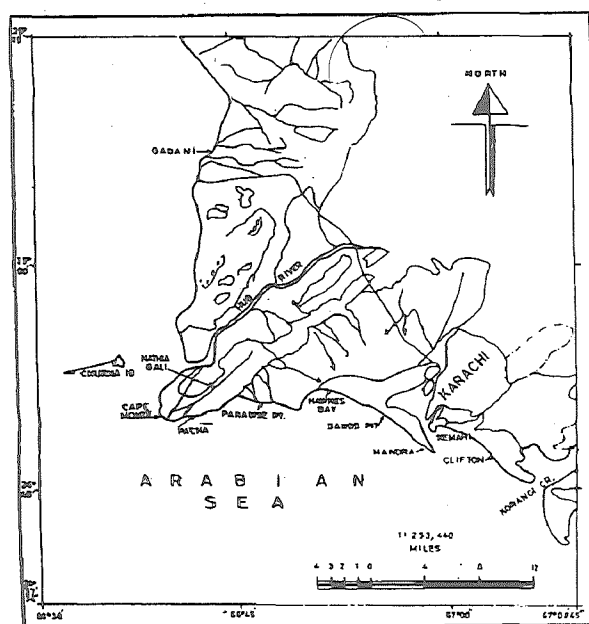


Fig. 1. Map showing collection sites on the coast of Pakistan.

Very few drift specimens were found in this area. All collections were made during low tide and between October and March, the most suitable tidal fluctuations are during this period of the year. The collected specimens were preserved in 4% formaline-seawater solution. A few were permanently preserved on herbarium sheets, and placed 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 twelve commonly occurring, coenocytic and siphonaceous green algae, belonging to the four orders of the class Bryopsidophyceae, were collected from the coastal areas of Karachi and investigated taxonomically. Their morphology as well as cellular and reproductive structures were studied.

Order Cladophorales West 1904

Family Cladophoraceae (Hassal 1845) Cohn 1880

Thallus filamentous; may be branched or unbranched, composed of coenocytic cells that are united end to end. Filaments usually attached by rhizoids or modified rhizoid like branches. Cells are multinucleate, chloroplasts are numerous, parietal, reticulate and densely packed, few to many pyrenoids are present. Cell wall thick, lamellate, composed of microfibrils of cellulose. Vegetative propagation by fragmentation and asexual reproduction with quadriflagellate zoospores formed in undifferentiated vegetative cells functioning as sporangia. Sexual reproduction isogamous by biflagellate gametes, formed in undifferentiated cells. Altogether three genera and 31 species belonging to this family occur on the coast of Karachi (Shameel and Tanaka, 1992). The following two species were studied taxonomically, and can be distinguished as follows:

Filaments simple, cells of the upper part barrel-shaped *Chaetomorpha antennina*
 Filaments branched, cells of the upper part rectangular *Cladophora uncinella*

1. *Chaetomorpha antennina* (Bory De Saint-Vincent 1804) Kützing 1849 (Figs. 2 a-c)

Basionym: *Conferva antennina* Bory de Saint-Vincent 1804.

Synonymy: *Conferva media* C. Agardh 1824, *Chaetomorpha media* (C. Agardh) Kützing 1849.

References: Setchell and Gardner, 1920: 203; Børgesen, 1940: 37, 1946a: 29; Nasr, 1947: 37; Taylor, 1966: 344; Nizamuddin and Gessner, 1970: 4; Shameel, 1987: 512; Shameel and Afaq-Husain, 1987: 293; Silva *et al.*, 1987: 95; Shameel *et al.*, 1989: 178; Shameel and Tanaka, 1992: 21.

Morphological characters: Plants tufted, 4-9 cm long with branched holdfast.

Filaments stout, thick, cylindrical, unbranched, emerging from a holdfast attached very

firmly to the rocks. Basal part curved, rhizoidal parts possess swollen areas from which new filaments arise. Small and new filaments growing out from swollen regions.

Cytological features: Basal cell 500-690 μm long, curved, narrow near the lower part, 150-250 μm broad, upper part 310-400 μm broad constricted. Cell wall strongly thickened and lamellate. In upper parts of the filaments cells barrel-shaped, but in other parts cells cylindrical. Cylindrical cells 1.2-1.4 mm long and 0.4-0.6 mm broad, apical cells pointed.

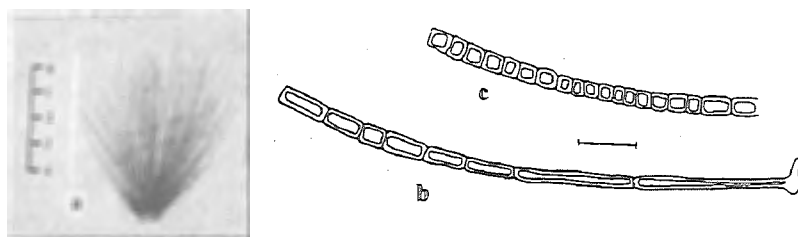


Fig. 2. *Chaetomorpha antennina* (Bory de Saint-Vincent) Kützing: a. habit of the thallus, b. basal portion with holdfast, c. upper part (scales: a=4cm, b-c=600 μm).

Ecological notes: Found epilithic on mid- and lower littoral rocks in direct contact with wave action facing the open sea.

Local distribution: Manora (*Leg.* Shameel 29-12-90, 28-1-91), Buleji (*Leg.* Aliya 26-12-89, 1-12-90).

Geographical distribution: Pakistan, Iran, India, Mauritius, Red Sea, the Philippines, Pacific coast of Australia, tropical coast of North America.

Remarks: The plants found in this study were very hard and brittle as compared to those described by Børgesen (1940) and Nizamuddin and Gessner (1970) from neighbouring coasts. Specimens were mostly found on rocky ledges, where wave action was very strong, and were so firmly attached to the substrata that detachment was extremely difficult. Because of their extraordinary thick cell wall many remained attached to the substrata following death for weeks in the form of thick, rough, and white threads.

2. *Cladophora uncinella* Harvey 1859

(Figs. 3 a, b)

References: Sakai, 1964: 60; Nizamuddin and Begum, 1973: 9; Shameel, 1987: 512; Shameel and Afaq-Husain, 1987: 293; Shameel and Tanaka, 1992: 23.

Morphological characters: Plant body filamentous, filaments much interwoven, bright green, sparingly to repeatedly branched. Main axis di- or polychotomous at long intervals, not much ramified, 75-130 μm thick and 8-10 times as long as broad; growth in length chiefly by the division of the apical cell. Branches di-, tri- or

polychotomous, mostly unilateral, rarely opposite or alternate, 50-100 μm thick and 3-8 times as long as broad. Ultimate branches acropetal, straight or slightly curved, 1-3 segmented, 25-55 μm thick and 3-6 times as long as broad.

Cytological features: Cell wall of the main axis lamillate, 20-30 μm thick, cell wall of the ultimate branches 8-15 μm thick. Cells of the branches and ramuli occasionally tapering at the apices. Apical cell obtuse or acute in shape, meristematic.

Ecological notes: Found epilithic in the upper littoral sandy bed forming cushion-like structures, making sandy pads beneath the thalli. Does not grow individually but occurs in large groups and forms clusters.

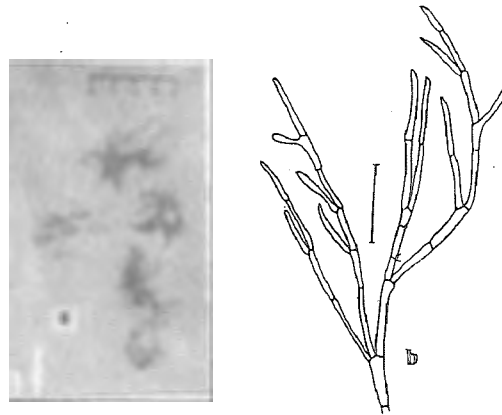


Fig. 3. *Cladophora uncinella* Harvey: a. habit of thallus, b. thallus structure (scales: a=4 cm, b=400 μm).

Local distribution: Manora (*Leg.* Shameel 29-12-90, 28-1-91), Buleji (*Leg.* Aliya 26-12-89, 1-12-90).

Geographical distribution: Japan: Ashima, Mihama; Pakistan: Karachi, Gadani.

Remarks: The polychotomous and much ramified filaments are entangled together and produce carpet-like structures on littoral rocks. They are attached to the rocks by small basal discs formed by the intertwining of the numerous branched rhizoids given off from the basal cell. Plants are soft, flaccid, and profusely branched ending in smaller or larger tufts of terminal ramuli. Tufts of the terminal fasciculate ramuli are thinner and longer in the lower region, while they are thicker and shorter in the upper part. Several plants grow closely together and form small cushions, collecting sand in between and, hence, producing compact masses of thick and rough filaments. They can withstand long emergence and prefer mild or no wave action. The plants found in this study agreed with those described by Nizamuddin and Begum (1973) from Pakistan as well those from Japan (Sakai, 1964).

Order Siphonocladales (Blackmen *et* Tansley 1902) Oltmanns 1904
Family Valoniaceae Nägeli 1847

Thallus globular, expanded and membranous, or filamentous and clavate, simple or branched, branching lateral or irregular on the main axis or in 2-3 planes into specialized structures. Cells multinucleate, develop by segregative division, expansion of new segments either exogenous or endogenous. Homoplastic chloroplasts peripheral, lobed or discoid, arranged in a reticulate manner; pyrenoids may or may not be present, thylakoids occupying most area of the chloroplast. Specialized reproductive organs lacking, reproduction iso- or anisogamous. Isomorphic alternation of generation, life history diplobiontic, sporophyte producing quadriflagellate zoospores and gametophyte biflagellate gametes. Many authors include Valoniaceae within Cladophorales. While this family may resemble Cladophoraceae, the morphological differences are enough to place it under Siphonocladales. This family is represented by two genera and three species from the coastal areas near Karachi (Shameel and Tanaka, 1992). The following species is predominant.

3. *Valoniopsis pachynema* (Martens 1868) Børgesen 1934
(Figs. 4 a-c)

Basionym: *Bryopsis pachynema* Martens 1868.

Synonymy: *Valonia confervoides* Harvey in J. Agardh 1886, *Valonia pachynema* (Martens) Boose 1913.

References: Børgesen, 1934: 10, 1936: 63, 1949: 5; Anand, 1940: 44; Durairatnam, 1961: 30; Taylor, 1966: 347; Nizamuddin, 1969: 240; Shameel, 1987: 512; Shameel and Afaq-Husain, 1987: 293; Silva *et al.*, 1987: 103; Shameel and Tanaka, 1992: 24.

Morphological characters: Thallus forming low dense tufts on exposed rocks, about 3 cm high. Filaments cylindrical, branched, more or less incurved, placed more or less vertically, many filaments growing out in various directions between the upward directed filaments forming cushions, attached by branched septate haptera. Branches given off in a basipetal manner, cut off from the main filament by septa, apparently opposite; haptera developed from base of the filament or at the end of any of the branches. Haptera irregularly ramified. Transverse walls often present, but rarely occur in filaments except before division. Several branches formed higher up in the thallus bend downwards, become rhizoid-like, and affix to a suitable substratum to it by means of haptera, the tuft is strengthened and kept together.

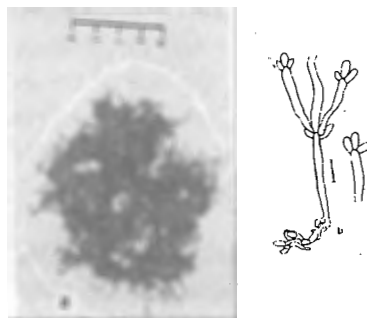


Fig.4. *Valoniopsis pachynema* (Martens) Børgesen: a. habit of thallus, b. lower portion with basal septate haptera, c. upper part with branches emerging due to segregative cell division (scales: a=4 cm, b-c=600 μ m).

Cytological features: In plasma below the wall a layer of densely packed rounded or polygonal chromatophores, generally with elongated corners forming a coherent net, containing 1 or 2 large pyrenoids; numerous fairly large nuclei scattered. During division of thallus, terminal end of branches become slightly thicker and cell contents accumulate forming a dense dark green mass assuming a spherical form, which separates by a transverse wall and grows in length. Immediately after wall formation two cup-like outgrowths develop below the transverse walls, become swollen with cell contents, separated by walls, and then grow.

Ecological notes: Forms tufts on exposed rocks in the lower and sublittoral zone being epilithic. Also occurs as drift material in the form of dark green, soft, flabby, and spongy balls, cast on sandy shores.

Local distribution: Manora (*Leg.* Shameel 29-12-90, 28-1-91), Buleji (*Leg.* Aliya 26-12-89, 1-12-90).

Geographical distribution: Indonesia, Formosa, Malayan Archipelago, the Philippines, northern and eastern Australia, New Caledonia, Hawaiian archipelago, Gulf of California, Baja California, West Indies, Mozambique, East Africa, Mauritius, Sri Lanka, Pakistan, India, Bermuda, Spain.

Remarks: Børgesen (1934) reported the occurrence of *Valoniopsis pachynema* from the coastal areas of Karachi. It was taxonomically described for the first time from the coast of Karachi by Nizamuddin (1969), and was also reported from the coastal areas of Lasbela (Shameel, 1987). The present investigation is a detailed study of this alga from the Karachi coast. The filaments are so compactly arranged that they produce cushions on the exposed rocks, which are hard, light green and do not imprison sand. When the rocks face rough seas and much wave action, they may be detached and are cast ashore as ball like structures by incoming tides. The balls are hollow inside and filled with water. The plants collected in this study generally resemble those described from Mauritius (Børgesen, 1949), Sri Lanka (Børgesen, 1936; Durairatnam, 1961), Karachi (Børgesen, 1934; Nizamuddin, 1969) and the Philippines (Taylor, 1966; Silva *et al.*, 1987).

Order Bryopsidales Feldmann 1956

Family Bryopsidaceae Bory 1829 *Orth. Mut.* De Toni 1888

Thallus heterotrichous, siphonous, coenocytic; basal parts prostrate, creeping or caespitose; erect parts, pinnately branched, structurally simple. Branches tubular, non-septate, branches and ramuli basally constricted, cylindrical to slightly tapering, homoplastic chloroplasts with pyrenoids; siphonein and siphonaxanthin being accessory pigments. Gametophyte monoecious or dioecious, producing anisogametes within ramuli cut off by basal septum, liberated through papillae or from lateral gametangia. Sprophyte produces stephanokont meiospores within the filament. This family has not been thoroughly investigated and only two genera and four species have been reported from the coast of Karachi (Shameel and Tanaka, 1992), but several others are suspected to occur. The following species grow commonly on ledges of rocks and rocky boulders.

4. *Bryopsis pennata* Lamouroux 1809
(Figs. 5 a-c)

References: Lamouroux, 1809: 132; Børgesen, 1936: 67; Anand, 1940: 38; Taylor, 1940: 553; Dawson, 1956: 34; Womersley, 1956: 364; Durairatnam, 1961: 25; Saifullah, 1973: 141; Silva *et al.*, 1987: 103; Shameel and Tanaka, 1992: 26; Aleem, 1993: 32.

Morphological characters: Fronds erect, dark green to olive green, fluorescent, 4-7 mm high, sparsely branched; ultimate branches with small, feather-like pinnules arranged in two rows on the axis. Main axis erect, cylindrical, tubular; only a few small globose and subglobose pinnules developing near base of the thallus, long basal part of the thallus remaining without pinnules; rhizoids developing at the base. At upper part of branches distichous, leaf-like, linear-lanceolate pinnules arranged in two vertical rows. Pinnules gradually narrowed towards the slightly constricted base, grading evenly from the longest at the base of the pinna to the initials at the apex.

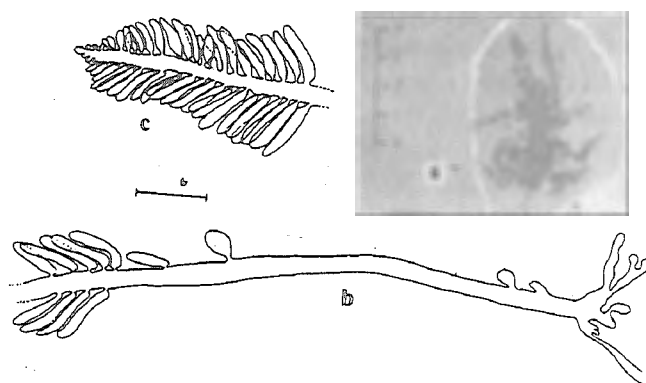


Fig. 5. *Bryopsis pennata* Lamouroux: a. habit of thallus, b. basal part with a few globose pinnules and developing rhizoids, c. pinna with distichous, linear-lanceolate pinnules (scales: a=4 cm, b-c=400 μ m).

Cytological features: Main axis, branches, pinnae, pinnules and rhizoids coenocytic, numerous disc shaped homoplastic chloroplasts, each with a single pyrenoid.

Reproductive structures: Pinnule developing a septum at the base, behaving as gametangium to produce biflagellate gametes.

Ecological notes: Found attached to rocks forming small, dense and fluorescent bushes in sandy bottom pools on mid- to lower littoral rocks, sometimes occurring as drift material; growing in association with *Caulerpa manorensis* Nizamuddin.

Local distribution: Manora (*Leg.* Aliya 11-11-89, 9-9-91), Sandspit (*Leg.* Aliya 16-10-89), Buleji (*Leg.* Shameel 20-9-90).

Geographical distribution: West Indies, Egypt, southern of Australia, Malayan Archipelago, Sri Lanka, and Karachi (Pakistan).

Remarks: Thalli grow in tufts in the form of small and soft bushes. From September to November they grow luxuriantly and dominate the littoral rocks,

wherever they occur. The plants collected in this study resemble those described from Sri Lanka (Børgesen, 1936; Durairatnam, 1961), southern Australia (Womersley, 1956), Alexandria, Egypt (Aleem, 1993). The thalli, under submerged conditions, exhibit beautiful colours due to fluorescence, which are lost on emergence. They prefer rocks exposed to sun light; some species (*e.g.*, *B. hypnoides* Lamour.) grow in sheltered places.

Order Codiiales Feldmann 1954

Family Codiaceae (Trévisan 1842) Zanardini 1843

Thalli aplanate, globose or erect, branched, coenocytic; composed of densely entangled, nonseptate filaments, forming medulla and a cortex of elongate utricles bearing lateral gametangia. Thallus variously shaped, in some genera encrusted with lime. Homoplastic chloroplasts without pyrenoids; cell walls made up of mannan (1,4-linked β -D-mannose); chloroplasts containing siphonoin and siphonaxanthin. No asexual reproduction; sexual reproduction anisogamous; gametes biflagellate, formed in gametangia of distinctive shape. This family has not been studied thoroughly from the coast of Karachi. Two genera and six species have been reported (Shameel and Tanaka, 1992), but a large number of species belonging to the genus *Codium* are suspected to grow at these coastal areas. The following three species were collected, and can may be taxonomically distinguished as follows:

1. Thallus throughout cylindrico-terete *C. iyengarii*
Thallus completely or partially flat 2
2. Frond throughout flat *C. flabellatum*
Frond basally cylindrico-terete, flattened above *C. decorticatum*

5. *Codium decorticatum* (Woodward 1797) Howe 1911
(Figs. 6 a, b)

Basionym: *Ulva decorticata* Woodward 1797.

Synonymy: *Fucus fungosus* Desfontaines 1798, *Myrisdorum dilatatum* Rafinesque 1810, *Fucus tomentosus* Hudson var. *elongatus* Turner 1811, *Codium elongatum* (Turner) C. Agardh 1822, *Agardhia areolata* Cabrera 1823, *Codium tomentosum* Stackhaus var. *elongatum* (Turner) Ardissonne 1886.

References: Setchell and Gardner, 1930: 130; Lucas, 1936: 56; Silva, 1960: 517; Nizamuddin, 1991: 62; Aleem, 1993: 36.

Morphological characters: Thallus spongy, green up to 60 cm high regularly or irregularly di- or trichotomously branched, one to several erect fronds arising from a crustose base. Branches wholly terete, flattened only at dichotomies, or flattened almost throughout, interdichotomies usually terete or slightly compressed, 6-25 mm broad, upper portion usually cylindrical, 3-7 mm in diameter, with age becoming compressed; basal portion cylindrico-terete, 5-7 (-10) mm in diameter, near the forkings becoming thick and broad to 4 cm; dichotomies generally close or at a distance of 3-4 cm from each other. Branching often congested at the base of plant, more open distally, dichotomies 8-40 cm, distant terminal segments up to 60 cm long.

Anatomical features: Thallus dissecting out into individual utricles; utricles

cylindrical or clavate, variable in shape and form, (1050-) 1200-1800 μm long, (240-) 300-600 (-750) μm broad, some utricles slightly constricted. Apices of utricles round or flat or truncate; utricular walls 1.5-2 μm thick, at apex very slightly thickened (4-8 μm). Hairs (or hair scars) variable in occurrence, when present usually abundant (1-2 per utricle). Medullary filaments 2-3 from each utricle, 40-60 μm across.

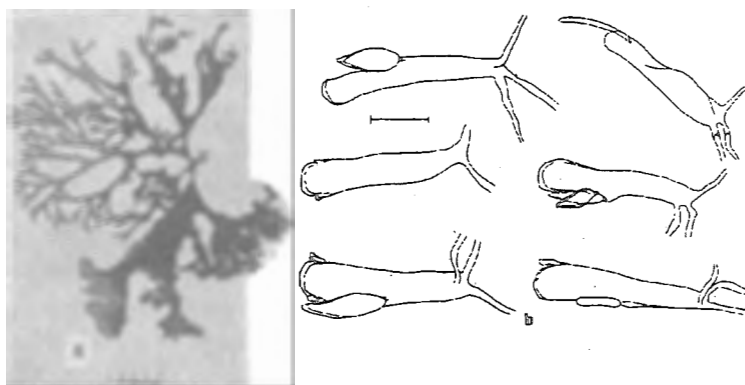


Fig. 6. *Codium decorticatum* (Woodward) Howe: a. habit of thallus, b. utricles from different parts of thallus (scales: a=4 cm, b=300 μm).

Reproductive structures: Gametangia lanceolate-ovoid, lateral pedicellate, oblong or fusiform at a distance of 400-450 μm below the utricular apices, 144-390 μm long, several (up to 7) per utricle, 58-200 μm broad.

Ecological notes: Found growing attached to rocks in shallow water, in lower littoral zone. Also occurs in drift form on the sandy beaches intermingled with *Codium flabellatum* and *C. iyengarii*.

Local distribution: Manora (*Leg.* Aliya 12-12-89, 28-1-91), Buleji (*Leg.* Aliya 26-12-89, Shameel 1-12-90), Nathiagali (*Leg.* Aliya 26-12-89, 24-1-90).

Geographical distribution: Bermuda, North Carolina, Florida, Cape Verde Island, Canaries, western coast of Africa, Gibraltar to southwestern Africa, Caribbean Sea, Salvador, Brazil to Puerto Madrym, Argentina, Azores, Mediterranean Sea, Adriatic Sea and Arabian Sea.

Remarks: In this study *C. decorticatum* was reported and taxonomically described for the first time from the coast of Pakistan. It resembled in general features those described from the western Atlantic (Silva, 1960), Libya (Nizamuddin, 1991), and Alexandria, Egypt (Aleem, 1993). It grows in lower and sublittoral zones, usually attached to small and large pebbles partly burried in sand in shallow water. When seen from above, appears to emerge from a sandy bottom in the form of small, spongy bushes. The algae growing along the coast of Karachi belong to the form *C. decorticatum* f. *monstrosum* (Montagne) Nizamuddin. The Karachi specimens of *C. d.* f. *monstrosum* differed slightly from those originally described from the coast of Libya (Nizamuddin, 1991) in having slightly large utricles and bearing up to seven gametangia per utricle; the Libyan plants possess 12 or more gametangia per utricle.

6. *Codium flabellatum* Nizamuddin Ined.

(Figs. 7 a, b)

Synonymy: *Codium latum* Suringer 1867, *Codium flabellatum* Silva et Nizamuddin *nom. nud.*

References: Anand, 1940: 43; Shameel, 1987: 513; Shameel and Afaq-Husain, 1987: 294; Shameel *et al.*, 1989: 178; Shameel and Tanaka, 1992: 26.

Morphological characters: Thallus flat, large, dichotomously branched, 10-25 cm high, 1-3 cm broad, anchored firmly to rocks by small basal disc. Lower portion of the thallus sometimes cylindrical, upper portion always flat, apices blunt.

Anatomical features: Utricles clavate, 180-270 μm broad, 700-800 μm long, cylindrical when young, bearing one or two long hairs just below their tips; usually two medullary filaments at the base of each utricle, 30-40 μm in diameter, sometimes three.



Fig. 7. *Codium flabellatum* Nizamuddin: a. habit of thallus, b. utricles from different parts of thallus (scales: a=4 cm, b=200 μm).

Reproductive structures: Gametangia present laterally on the utricles. Size varies from 350-400 μm in length and 150-175 μm in breadth. Contents of the gametangia usually divide into two by transverse division.

Ecological notes: Usually found attached to rocks in the midlittoral rocky ledges and attached to barnacle shells in the lower littoral region. Also found as drift material on sandy beaches.

Type locality: Karachi coast, Pakistan.

Local distribution: Manora (*Leg.* Aliya 12-12-89, 28-1-91), Buleji (*Leg.* Aliya 28-3-89; Shameel 6-12-89).

Geographical distribution: Karachi and Lasbela coasts of Pakistan.

Remarks: This species was initially incorrectly identified from the coast of Karachi as *C. latum* (Anand, 1940). Prof. M. Nizamuddin (*pers. commun.*) identified it about 25 years ago as *C. flabellatum* sp. nova and sent the taxonomic description for confirmation to Dr. P.C. Silva; the manuscript was neither received nor sent for publication. Consequently, this species has been mentioned as *C. flabellatum* Silva et Nizamuddin in several studies describing its occurrence in various locations in Pakistan under different ecological conditions (Shameel, 1987; Shameel and

Afaq-Husain, 1987; Shameel *et al.*, 1989; Shameel and Tanaka, 1992). Dr. Nizamuddin is currently reinvestigating *Codium* spp. from the coast of Karachi. Therefore, this species is noted here as *C. flabellatum* Nizamuddin *ined.* *Codium flabellatum* is described taxonomically for the first time in this study.

7. *Codium iyengarri* Børgesen 1947

(Figs. 8 a, b)

Synonymy: *Codium elongatum* (Turner 1811) C. Agardh 1822.

References: Anand, 1940: 41; Børgesen, 1946b: 4; Shameel, 1987: 513; Shameel and Afaq-Husain, 1987: 294; Shameel and Tanaka, 1992: 26.

Morphological characters: Plant dark green, cylindrical, fleshy, much elongated, 10-30 cm high, 3-5 mm in diameter, attached firmly to rocks by basal disc. Branches terete, regularly dichotomous with a distance of 1 cm between divisions, younger branches of the thallus cylindrical, older ones slightly expanded beneath furcations.

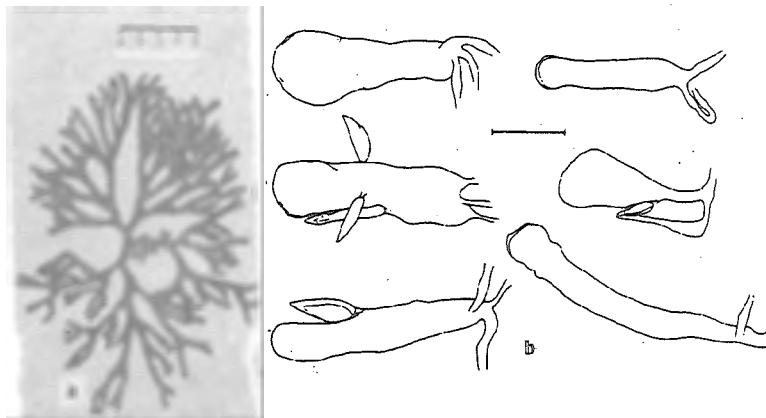


Fig. 8. *Codium iyengarri* Børgesen: a. habit of thallus, b. utricles from different parts of thallus (scale: a=4 cm, b=400 μ m).

Anatomical features: Utricles broadly clavate to pyriform in shape, the broadest ones barrel-shaped, 700-1100 μ m long and 150-180 μ m broad. Tips of slender vesicles vaulted, some nearly flat or even slightly depressed, broad vesicles less vaulted above. Apical wall always quite thin also in narrow vesicles, but in some rare slender vesicles up to 8 μ m in thickness. Hairs given out from upper sides of vesicles but not in great numbers, medullary filaments 2-3, 50-70 μ m in diameter.

Reproductive structures: One to four gametangia borne laterally on utricles, stalked, lanceolate, pointed at the apex, 350-400 μ m long, 100-150 μ m broad, opening by an apical pore.

Ecological notes: Epilithic on lower littoral rocks. Also found in abundance as drift material on the sandy beaches.

Local distribution: Manora (*Leg.* Aliya 12-12-89, 28-1-91), Buleji (*Leg.* Aliya 28-3-89, 9-12-89, 26-12-89, Shameel 1-2-90), Nathiagali (Aliya 14-11-89, 26-12-89, 24-1-90).

Geographical distribution: Indian Ocean: Karachi, Cape Monze, Lasbela.

Remarks: This species was initially described from the coast of Karachi as *C. elongatum* (Anand, 1940), but this is a Mediterranean species and does not occur in the Arabian Sea. It was subsequently correctly identified as *C. iyengarii* (Shameel, 1987). It is cylindrical, very long and the most common species of *Codium* occurring along the coast of Karachi. This is the first taxonomic description of *C. iyengarii* from the coast of Pakistan given in this study.

GENERAL REMARKS ON *CODIUM* SPECIES

Five species have been reported from the coast of Karachi (Shameel and Tanaka, 1992). The sixth one is added in this study as *C. decorticatum*. *Codium flabellatum* is a new species, though reported previously from the neighbouring coast of Lasbela (Shameel, 1987), and is taxonomically described for the first time. *Codium iyengarii* is a well known species, reported from the adjacent coast of Dwarka, Okha Port (Børgesen, 1946b). All the three species of *Codium* have been taxonomically described for the first time in this study from any area of Pakistan under their correct taxonomic names. *Codium decorticatum* is characterised by basally cylindrico-terete and above flattened thalli, while the thalli of *C. iyengarii* are cylindrical throughout and those of *C. flabellatum* entirely flattened. *Codium decorticatum* further differs from other two in possessing strongly cylindrico-compressed segments with thick, flat or swollen terminal ends. The utricles of *C. decorticatum* are variable in shape and form, may be clavate or cylindrical having smooth flat or round apices; they are largest in size of the three species.

Børgesen (1946b) refers to *C. indicum* Setchell as a manuscript name for a specimen from Karachi in Kew Herbarium, though Setchell never published this name. An examination of this specimen reveals that it is *C. flabellatum* (Nizamuddin, pers. comm.). Dixit (1940) tentatively described *C. indicum* Dixit from Malwan Harbour as a new species at the same time pointing out its close similarity to *C. decorticatum*. A detailed taxonomic examination of all these specimens from adjacent coasts of Pakistan and India is needed.

Order Caulerpales Feldmann 1954

Family Caulerpaceae Greville ex Kützing 1843 *Orth. Mut.* Cohn 1880

Thallus coenocytic, composed of branched filaments, calcified or uncalcified heterotrichous, cylindrical, siphonous, aseptate. Filaments either associated in tufts or interwoven or morphologically differentiated into basal stolon with rhizoids and erect, variously branched fronds; chloroplasts containing siphonein, siphonaxanthin, lutein and lutein-5,6-epoxide pigments; cell walls of microfibrillar xylan (1,3-linked β -D-xylose). Thallus monoecious or dioecious, life history diplontic with gametic meiosis; reproduction isogamous or usually anisogamous, no zoospore formation. Zoidangia with compound whorls, arising from the basal portion of a simple lateral fertile branch of limited growth, separated from the main axis by a distinct transverse wall and without trabeculae were recently observed (Prud'homme van Reine and Lokhorst, 1992) in the newly discovered taxon, *Caulerpella ambigua* (Okamura) Prud'homme van Reine et Lokhorst (= *Caulerpa ambigua* Okamura = *C. vickersiae*

Børgesen). This family is represented in the coastal areas of Karachi by 13 species belonging to the genus *Caulerpa* (Shameel and Tanaka, 1992). The following five species have been investigated, and are distinguished as follows:

- | | |
|--|----------------------|
| 1. Foliar branches cylindrical, ramuli radial | 2 |
| Foliar branches flat, ramuli distichous | 3 |
| 2. Pinnules terminally swollen, cylindric | <i>C. racemosa</i> |
| Pinnules terminally depressed, pestlate | <i>C. chemnitzia</i> |
| 3. Ramuli long, smooth, mucronate | <i>C. taxifolia</i> |
| Ramuli short, oblong or obovate | 4 |
| 4. Branchlets oblong, arcuate, terminally narrow | <i>C. faridii</i> |
| Branchlets obovate, short, terminally broad | <i>C. manorensis</i> |

8. *Caulerpa chemnitzia* (Esper 1802) Lamouroux 1809

(Figs. 9 a, b)

Basionym: *Fucus chemnitzia* Esper 1802.

Synonymy: *Caulerpa racemosa* var. *chemnitzia* Weber van Bosse 1898.

References: Yamada, 1944: 36; Durairatnam, 1961: 28; Nizamuddin, 1964: 206; Saifullah, 1973: 141; Shameel, 1978a: 279; Shameel and Tanaka, 1992: 27.

Morphological characters: Ramuli partly cylindrical at the base of vertical axis but gradually becoming broader and trumpet-shaped upwards, radially arranged on upper part, up to 5 mm long and 2 mm broad at apices. Horizontal axis cylindrical, up to 4 mm broad; rhizoids much branched. Assimilators up to 24 cm high, up to 1 mm broad, irregularly branched.

Ecological notes: Usually occurs in sublittoral pools in attached condition. Few specimens also found in drift form.

Local distribution: Manora (*Leg.* Aliya 11-11-89, 12-12-89), Buleji (*Leg.* Aliya 2-10-89, 9-12-89, 26-12-89; Shameel 1-12-90).

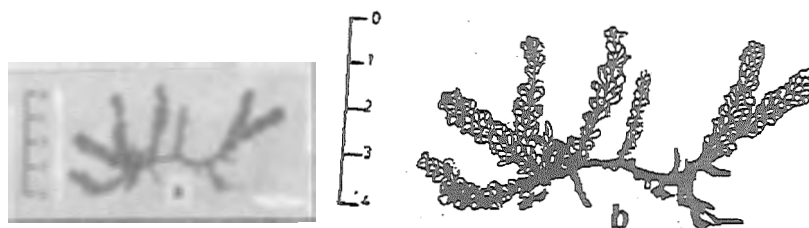


Fig.9. *Caulerpa chemnitzia* (Esper) Lamouroux: a. habit of thallus, b. diagrammatic thallus structure (scales: a-b=4 cm).

Geographical distribution: Red Sea, Indian Ocean, Sri Lanka, Pakistan, Japan, West Indies, Tahiti.

Remarks: The species was described for the first time from the coast of Karachi by Nizamuddin (1964) and its ecology under different habitat conditions was discussed by Shameel (1978a). Its morphology lies between *C. racemosa* and *C. peltata*, the only difference is in its ramuli, which instead of being swollen like *C. racemosa* are depressed. This species was placed in the synonymy of *C. racemosa* by Weber van Bosse (1898, p. 370). The specimens from Karachi exhibit remarkable differences from *C. racemosa*. In a variety of habitats, both species occur side by side, indicating that the differences are not ecological but genetic. It appears that *C. chemnitzia* is a distinct species. *Caulerpa chemnitzia*, *C. peltata* and *C. racemosa* were considered as conspecific by some phycologists, e.g., Silva *et al.* (1987), but a recent study revealed that they differ considerably in their haemagglutinin activities (Amjad and Shameel, 1993b), indicating that they are distinct species.

9. *Caulerpa faridii* Nizamuddin 1964

(Figs. 10 a, b)

References: Nizamuddin, 1964: 210; Shameel, 1978a: 27; Shameel and Tanaka, 1992: 27.

Morphological characters: Plants coenocytic, aseptate, differentiated into prostrate, horizontal axis and erect assimilators with ramuli cylindrical and incurved upwards. Rhizomes cylindrical up to 1 mm broad, with branched rhizoids. Assimilators flat up to 12 cm high and up to 2 mm broad. Ramuli arranged in opposite manner, pinnate and slightly incurved, stalked, up to 4 mm long and 1 mm broad.

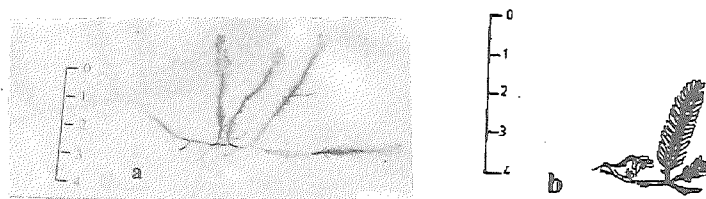


Fig. 10. *Caulerpa faridii* Nizamuddin: a. habit of thallus, b. diagrammatic thallus structure (scales: a=4 cm b=2 cm).

Ecological notes: Found attached on upper sublittoral rocks, very seldom occurs as drift material. Sometimes grows intermingled with *Caulerpa manorensis* and *C. sertularioides* and sometimes in pools with *Sargassum* spp. and *Stokeyia indica* Thivy *et* Doshi.

Type locality: Paradise Point, Karachi, Pakistan.

Local distribution: Manora (*Leg.* Aliya 11-11-89, 12-12-89), Buleji (*Leg.* Aliya 2-10-89, 9-12-89, 26-12-89; Shameel 1-12-90).

Geographical distribution: Karachi coast of Pakistan.

Remarks: This species appears to be endemic to Karachi and has not yet been reported elsewhere, even from neighbouring coastal areas. It was described as a new

species by Nizamuddin (1964) along with two more species *C. manorensis* and *C. qureshii*. It closely resembles both these species in bilateral symmetry of ramuli on assimilators, but differs from them in shape and arrangement. This species was named in honour of the late Prof. M.A.F. Faridi, who made significant contributions on the Charales and fresh-water algal flora of Pakistan. A study of the fatty acid compositions of *C. faridii*, *C. manorensis*, *C. qureshii* and *C. veravalensis* should remarkable differences in them and clearly indicated (Shameel and Khan, 1991) that they are distinct species.

10. *Caulerpa manorensis* Nizamuddin 1964

(Figs. 11 a, b)

References: Nizamuddin, 1964: 210; Nizamuddin and Gessner, 1970: 3; Shameel, 1978a: 279, 1987: 513; Shameel and Afaq-Husain, 1987: 294; Coppejans and Meinesz, 1988: 186; Coppejans, 1992: 395; Shameel and Tanaka, 1992: 27; Verheij and Prud'homme van Reine, 1993: 394.

Morphological characters: Prostrate, creeping rhizome cylindrical about 1 mm broad, branched rhizoids present, anchoring up to 4 cm long and 2 mm broad. Branching of ramuli varies from pinnate to opposite, sometimes attenuate. Ramuli obovate, up to 3 mm long and up to 1 mm broad near the apex, tapering towards the base, apex or tips rounded.

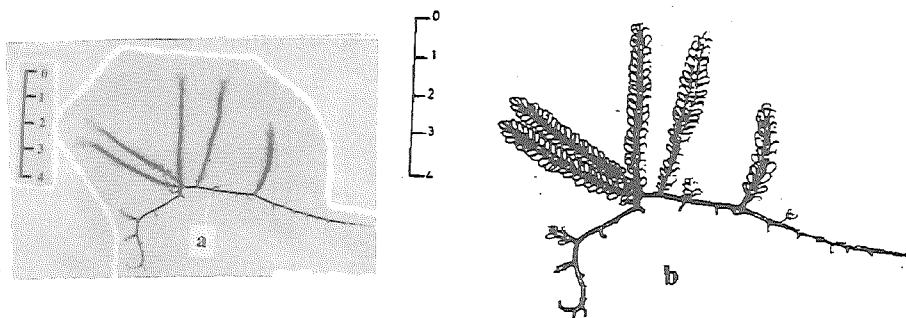


Fig.11. *Caulerpa manorensis* Nizamuddin: a. habit of thallus, b. diagrammatic thallus structure (scales: a-b=4cm).

Ecological notes: Found attached on lower littoral rocks in sandy pools. Usually occurs intermingled with *Caulerpa faridii* and *C. sertularioides*. Also found to grow along with *Bryopsis pennata*.

Type locality: Manora (PNS Qasim), Karachi, Pakistan.

Local distribution: Manora (Leg. Aliya 11-11-89), Buleji (Leg. Aliya 2-10-89, 9-12-89; Shameel 26-12-89).

Geographical distribution: Karachi, Lasbela, Persian Gulf, Papua New Guinea, Indonesia.

Remarks: This species was described for the first time from Karachi, Pakistan by Nizamuddin (1964). It was also found to occur on the neighbouring coast of Iran

(Nizamuddin and Gessner, 1970) and other areas of Pakistan (Shameel, 1978a, 1987). It was thought to be endemic to the northern areas of Arabian Sea including the Persian Gulf. Recently, this species was described from distant locations such as the coast of Madang Province, Papua New Guinea (Coppejans and Meinesz, 1988; Coppejans, 1992) and the Spermode Archipelago, Sulawesi, Indonesia (Verheij and Prud'homme van Reine, 1993). The specimens from Papua, New Guinea and Indonesia differ from the Karachi specimens in two characters: (1) a large number of assimilators remain connected with the same rhizome, therefore, one plant covers a big area, and (2) assimilators are naked, *i.e.*, without ramuli.

Coppejans and Meinesz (1988) recorded *C. manorensis* from Papua, New Guinea, discussed its similarities with *C. qureshii* and *C. veravalensis*, and considered the last two as conspecific. The dendrogram resulting from hierarchical agglomerative clustering showed three distinct groups at 85% similarity level, suggesting that these three species of *Caulerpa* are readily delineated with respect to morphological (phenetic) and ecological characters (Shameel and Shaukat, 1992). The results of numerical analysis also confirmed the finding that these species differed in a number of morphological and ecological features and are to be recognized as distinct species. These species further exhibited distinct differences in fatty acid compositions (Shameel and Khan, 1991; Shameel, 1993) as well as haemagglutinin activities (Amjad and Shameel, 1993b); hence, they are clearly delineated from one another.

11. *Caulerpa racemosa* (Forsskål 1775) J. Agardh 1872
(figs. 12 a,b)

Basionym: *Fucus racemosus* Forsskål 1775: 191.

Synonymy: *Fucus clavifer* Turner 1808, *Caulerpa clavifera* (Turner) C. Agardh 1817, *Caulerpa uvifera* C. Agardh 1817, *Chauvinia clavifera* (Turner) Bory de Saint-Vincent 1829.

References: Børgesen, 1932: 59, 1934: 26, 1935: 29, 1940: 32; Anand, 1940: 35; Nasr, 1947: 55; Dawson, 1956: 35; Nizamuddin, 1964: 206; Taylor, 1967: 49, 1969: 150; Taylor and Rhyne, 1970: 6; Islam, 1976: 19; Shameel, 1978a: 279, 1987: 513; Shameel and Afaq-Husain, 1987: 294; Silva *et al.*, 1987: 106; Coppejans and Meinesz, 1988: 191; Coppejans and Beeckman, 1989: 384; Nizamuddin, 1991: 15; Coppejans,

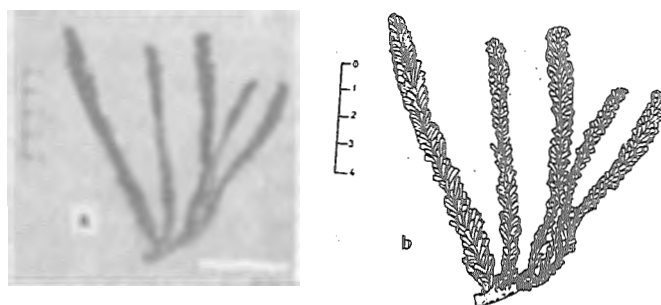


Fig. 12. *Caulerpa racemosa* (Forsskål) J. Agardh : a. habit of thallus, b. diagrammatic thallus structure (scales: a-b=4 cm).

1992: 397; Coppejans and Prud'homme van Reine, 1992: 693; Shameel and Tanaka, 1992: 28; Aleem, 1993: 34; Verheij and Prud'homme van Reine, 1993: 394.

Morphological characters: Prostrate or horizontal axis cylindrical, up to 3 mm broad; attached by many branched rhizoids; assimilators erect, cylindrical up to 19 cm high and 5 mm in diameter. Ramuli cylindrical, radially arranged, up to 6 mm long and round, with convex, concave or disc-shaped apices; apices mostly rounded, up to 2 mm in diameter. Some shorter assimilators are wholly covered by peltate ramuli.

Ecological notes: Usually found attached to upper littoral and midlittoral rocks, sometimes adhering to edges of pools.

Local distribution: Manora (*Leg.* Aliya 11-11-89), Buleji (*Leg.* Aliya 2-10-89, 9-12-89, 26-12-89; Shameel 1-12-90).

Geographical distribution: Pakistan, Iran, India, Sri Lanka, Red Sea, Australia, the Philippines, Japan, Tahiti, West Indies.

Remarks: This species is widely distributed in the warmer areas of the three large oceans of the world. The Karachi specimens are distinguishable in two forms: *C. r. f. laetevirens* (Montagne) Weber van Bosse and *C. r. f. occidentalis* (C. Agardh) Børgesen (Nizamuddin, 1964). Although *C. chemnitzia* (Esper) Lamouroux and *C. peltata* Lamouroux have been placed under the synonymy of *C. racemosa* (Weber van Bosse, 1898; Coppejans and Beeckman, 1989; Verheij and Prud'homme van Reine, 1993), but in Karachi they have been treated as autonomous species (Nizamudin, 1964; Shameel, 1978a). A thorough taxonomic investigation of all these species is definitely needed. In a recent investigation these three species were found to exhibit significant differences in haemagglutinin activities (Amjad and Shameel, 1993b), indicating that they are distinct species.

12. *Caulerpa taxifolia* (Vahl 1802) C. Agardh 1822

(Figs. 13 a, b)

Basionym: *Fucus taxifolius* Vahl 1802.

Synonymy: *Caulerpa crassifolia* J. Agardh 1872.

References: Børgesen, 1932: 58, 1934: 20; Anand, 1940: 36; Dawson, 1956: 35; Durairatnam, 1961: 27; Nizamuddin, 1964: 209; Taylor, 1967: 52, 1969: 150; Taylor and Rhyne, 1970: 7; Shameel 1978a: 279, 1987: 513; Shameel and Afaq-Husain, 1987: 294; Silva *et al.*, 1987: 111; Coppejans and Beeckman, 1990: 122; Coppejans, 1992: 406; Coppejans and Prud'homme van Reine, 1992: 706; Shameel and Tanaka, 1992: 28; Verheij and Prud'homme van Reine, 1993: 398.

Morphological characters: Stolons or rhizomes naked, creeping on rocks, attached by branched rhizoids. Plants up to 10 cm high; assimilators erect in one plane, lanceolate, linear, simple or branched, pinnate, stalked. Ramuli, sickle-shaped, opposite and distinctly constricted at base, ending in a short mucronate tip, 4-7 mm long and 1-1 1/2 mm broad. In some cases the entire assimilator bears ramuli in three rows.

Ecological notes: Found growing attached on lower and sublittoral rocks and rocky pools and sometimes in sandy bottom pools, in sand or mud. Sometimes seen growing along with *Stokeyia indica* Thivy *et* Doshi and *Sargassum* spp. in large pools.

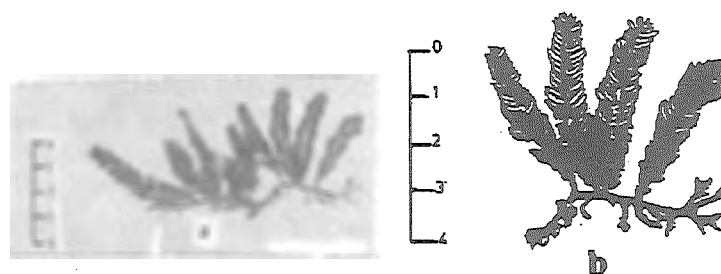


Fig.13. *Caulerpa taxifolia* (Vahl) C. Agardh: a. habit of thallus, b. diagrammatic thallus structure (scales: a-b=4 cm).

Local distribution: Manora (*Leg.* Aliya 11-11-89, 12-12-89), Buleji (*Leg.* Aliya 2-10-89, 9-12-89; Shameel 26-12-89).

Geographical distribution: Red Sea, Arabian Sea, Indian Ocean, Sri Lanka, Pakistan, Australia, Malaya, Archipelago, China Sea, Hong Kong, the Philippines, Polynesia, islands of the tropical Pacific, Japan, Guyana, West Indies, Bermuda, Florida, Canary Island, Friendly Island, Hawaiian Islands, Barbados, Flores, Gold coast of Africa.

Remarks: This is another species of *Caulerpa*, which has a world wide distribution in the warmer areas of the three big oceans. *Caulerpa veravalensis* Thivy et Chauhan has been placed in the synonymy of this species (Dixit, 1968; Krishnamurthy and Joshi, 1970), however, the specimens from Karachi revealed that they are two independent species differing remarkably from one another (Shameel, 1978a). Recently, phycochemical investigation on the fatty acid compositions of *C. taxifolia* and *C. veravalensis* indicated significant differences between them (Shameel, 1993), proving that they are distinct species.

GENERAL REMARKS ON CAULERPA SPECIES

The taxonomy of *Caulerpa*, that grows along the coast of Karachi is in a chaotic state. A total of 13 species have been recorded from this area (Shameel 1978a). They fall into two major groups: (1) radially branched species with cylindrical, closely packed ramuli, characteristically found in shallow and brighter habitats of the littoral zone; and (2) the bilateral, leaf- or frond-like species, showing flattened ramuli in two rows, typically growing in quiet waters below the littoral. The first group includes *C. chemnitzia* (Esper) Lamouroux, *C. lentillifera* J. Agardh, *C. peltata* Lamouroux and *C. racemosa* (Forsskål) J. Agardh. The second group contains *C. faridii* Nizamuddin, *C. manorensis* Nizamuddin, *C. qureshii* Nizamuddin, *C. taxifolia* (Vahl) C. Agardh and *C. veravalensis* Thivy et Chauhan. There are exceptions, however, the most notable being *C. sertularioides* (Gmelin) Howe, a shallow water, high-light plant that is bilateral but possesses cylindrical ramuli.

The two groups of *Caulerpa*, differentiated on the basis of radial or bilateral symmetry, possess several conspecific taxa. In the first group, *C. chemnitzia* and *C. peltata* are considered to be the forms of *C. racemosa* by several phycologists

(Coppejans and Beeckman, 1989; Coppejans, 1992; Verheij and Prud'homme van Reine, 1993). In the second group, *C. veravalensis* is thought to be synonymous with *C. taxifolia* by some (Dixit, 1968; Krishnamurthy and Joshi, 1970). Others regarded *C. qureshii* and *C. veravalensis* as conspecific and note their close similarities with *C. faridii* and *C. manorensis* (Coppejans and Meinesz, 1988). In the present study *Caulerpa chemnitzia*, *C. faridii*, *C. manorensis*, *C. racemosa*, and *C. taxifolia* are treated as separate and independent taxa. Recently, a taxometric investigation was carried out on some of these species that confirmed their separate entities (Shameel and Shaukat, 1992).

CONCLUDING REMARKS

All the investigated seaweeds are taxonomically known species. While large number of them were known from the coast of Pakistan (Shameel and Tanaka, 1992), some of them have not been taxonomically described. In this study *Codium decorticatum* was reported for the first time from this region and *Co. decorticatum* and *Co. flabellatum* taxonomically described for the first time from the coast of Pakistan. These and other species have been compared to those described from the neighbouring coasts of India (Børgesen, 1932, 1935, 1946b; Dixit, 1940, 1968), Sri Lanka (Børgesen, 1936; Durairatnam, 1961), Iran (Børgesen, 1934; Nizamuddin and Gessner, 1970), Saudi Arabia (Basson, 1979), Egypt (Nasr, 1947; Aleem, 1993) and remote sites of the Indian Ocean (Lucas, 1936; Børgesen, 1949; Womersley, 1956; Taylor, 1967; Islam, 1976; Coppejans and Beeckman, 1989, 1990; Verheij and Prud'homme van Reine, 1993) as well as neighbouring areas of Pacific Ocean (Taylor, 1966; Silva *et al.*, 1987; Coppejans and Meinesz, 1988; Coppejans, 1992), and the differences were noted. The differences observed were not very remarkable but minute. These differences are quite natural, as Karachi, being situated at the northern part of the Arabian Sea, has its peculiar geographical location and ecological conditions. However, the genetical conditions of the same species lead to a close resemblance.

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