

STUDIES ON THE ANATOMY OF A CONTROVERSIAL BROWN ALGA, *CYTOSEIRA INDICA*

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Abstract: An investigation was carried out on the anatomy of different vegetative and reproductive parts of a Fucallean alga, *Cytoseira indica* (Thivy et Doshi) Mairh [= *Stokeyia indica* Thivy et Doshi]. Its nomenclature has been confirmed and its occurrence in the northern part of the Arabian Sea is assured. This is the first detailed study of the anatomy of its various thallus parts.

Keywords: Algae, Phaeophycota, *Cytoseira*, taxonomy, anatomy, reproduction.

Introduction

A new genus *Stokeyia* was established by Thivy and Doshi [1] with the type species *S. indica* under the family Cystoseiraceae (Fucales) on the basis of dioecious thalli, non-axillary receptacles, vesicles in the ultimate vegetative branches and rhizomatous hapteron which is stoloniferous. Only one year later Mairh [2] rejected this genus and placed it under *Cytoseira* as *C. indica* on the basis of his observations on the seasonal phenomena in its life-cycle, and furthermore described it taxonomically from Gujarat Coast of India [3]. Later on, its taxonomic description was presented from Karachi Coast of Pakistan and the binomial *Stokeyia indica* was re-established [4]. Soon after that, the populations of this species were investigated along 700 km (out of 1000 km) long coastline of Pakistan [5], where a very detailed study on its morphology, structure, development and reproduction was made, and it was proved to be *Cytoseira indica*. The controversy appeared to have been solved, but recently the nomenclature *S. indica* was recalled [6] by making a statement of "Non-occurrence of *Cytoseira* Kützinger of the Northern-Arabian Coast (Pakistan)". This controversial statement initiated the present study.

Materials and Methods

Specimens were collected from various coastal

parts of Karachi (Pakistan) during November 2006 to April 2009 and fixed in 4 % formaldehyde-sea water solution. Cross sections (C.S.) of the specimens were obtained free hand with razor blades, stained in 0.5 % methylene blue and mounted in glycerine. Glass slides were sealed with nail polish and examined under Nikon microscope (PFX, Japan). Photographs were taken by Nikon camera (F601, Japan). The voucher specimens are deposited in the Herbarium (FUU-SWH), Department of Botany, Federal Urdu University of Arts, Science and Technology, Karachi, Pakistan

Results

On general observation and microscopic examination of the collected specimens the following characters were found.

***Cytoseira indica* (Thivy et Doshi) Mairh 1968: 78 Basionym:** *Stokeyia indica* Thivy et Doshi 1966: 64.

References: [1: 64, 2: 78, 3: 779, 7: 13, 8: 514, 9: 52, 10: 296, 11: 301, 12: 178, 13: 86, 14: 41, 4: 33, 15: 648, 16: 227, 5: 593, 6: 303].

Morphological characters

Thalli 5-150 cm long, greenish to dark brown in colour, grow singly or in a group of rhizomatous branches (Fig. 1); thick, dark brown,

solid, cylindrical and horizontal. Rhizomes are present parallel to the substratum. On the upper side of rhizome 1-3 bunches of branches are present at specific intervals. Rhizome is attached to the substratum with the help of a small, compact, hard, disc-like holdfast, 1-3 mm long and 1-2 mm broad (Fig. 2). On the rhizome, 2-3 nodes are present, with internodal distance of 5-10 mm; from each node a group of 4-20 branches arise (Fig. 3). All such branches are not equal in size, some remain small in size and do not continue their growth, hence called dwarf fronds. They are small in size, dark brown in colour, cylindrical or terete (Fig. 4). Some branches become flat, appear leaf-like and are called leafy fronds, 2-15 mm long and 1-5 mm broad (Fig. 5). Other branches increase in size and form main stem or main frond.



Figs. 1-4. *Cystoseira indica*: 1. Habitat of the thallus, 2. Horizontal rhizome with erect branches and a small holdfast, 3. Branches emerging from rhizome, 4. Dwarf fronds arising from rhizome.

Upright stem or main frond

Usually many fronds arise from the tuft of the rhizome but 1-10 become dominant or larger than the others, forming the main stem in the cluster. The main stem or main fronds are cylindrical or terete throughout or compressed at the basal region. Usually the main stem and branches are equal in thickness but their apex or distal end becomes blunt to tapered tips. On the surface of the main stem and branches cryptostomata are present, usually prominent in young thalli. Branching spiral or alternate, branches terete or flat, are present on the main stem in acropetal succession; large branches towards proximal end and small branches towards distal end (Fig. 6), primary branches 5-80 cm long, secondary branches present also in acropetal succession, cylindrical to compressed. In some specimens, the primary branches on the main stem at lower side are so compressed that



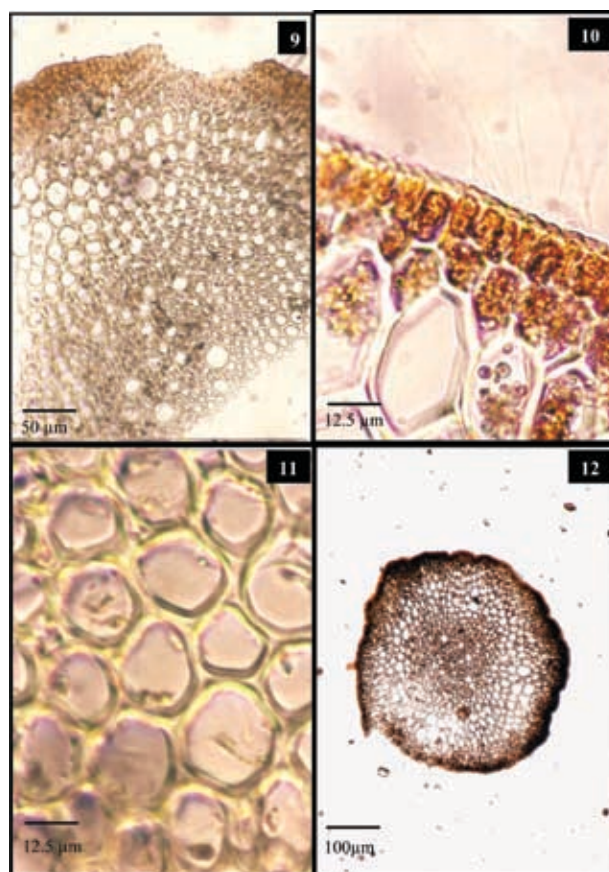
Figs. 5-8. *Cystoseira indica*: 5. Leafy fronds, 6. Branching pattern, 7. Vesicles, 8. Receptacles borne on vesicle.

these appear leaf-like. The primary branches are present on the main stem in acropetal succession, terete, spiral or alternate, 2-15 cm long and 2-3 mm broad, 0.5-5.0 cm apart and very close to the apex, smooth in surface, further branched, margin entire; secondary branches 1-6 cm long, present in acropetal succession, further branched, 1-2 mm broad, terete or flat.

Vesicles are present only in reproductive parts of the thallus, arise from axil of a receptacle; vesicles round to elliptical, yellowish brown or greenish brown in colour, smooth in surface, attached with the help of a very small stalk, 2-8 mm long and 1-4 mm broad, present singly or rarely in a chain of two (Fig. 7); each vesicle bearing one to two small projections at its distal end or on upper side. The projections may be branched or unbranched, the vesicles also occurring in acropetal succession, some being large at the distal end. Receptacles are borne terminally on all ultimate branches, being terete or varicose, unbranched to branched up to 4 times, with obtuse ends, dark brown, 2-20 mm long, 1 mm broad, 2-10 mm apart becoming very close near the apex (Fig. 8). In many thalli, receptacles bear a small red dot at the tip.

Growth: Apical growth is by a three-sided apical cell and vegetative growth is by hapteroid branches emerging near the holdfast.

Anatomical features: In the apical portion, the thallus width is 850 μm , the thallus consists of 3 parts in transverse section. A single peripheral layer encloses the cortex and the medulla (Fig. 9). The peripheral cells are small, slightly elongated, thin walled, with dense phaeoplasts, 25.0- 37.5 μm in length and 7.5- 15.0 μm in breadth (Fig. 10). The cortical region consists of 4-6 layers, the cells being large and thin walled with 2.5-5.0 μm thick cell wall. Intercellular spaces are present, poor in content, variable in size, rounded or polygonal in shape, 15-30 μm in length and 12.5-25.0 μm in breadth (Fig. 11). The medullary region consists of 6-7 layers with small cells, thick walled, cell-wall



Figs. 9-12. *Cystoseira indica*: **9.** Transverse section (T.S.) of apical portion of thallus, **10.** Peripheral cells in apical part, **11.** Cortical cells in apical portion, **12.** Transverse section (T.S.) of middle part.

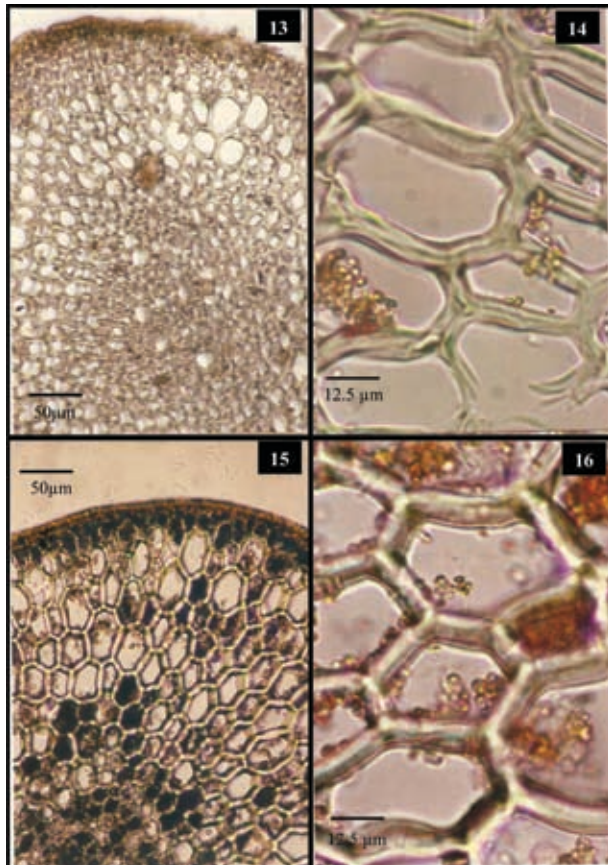
thickness 2.5 μm , poor in content. Intercellular spaces are absent, variable in size, rounded or polygonal in shape, 7.5-15.0 μm in breadth.

In the middle portion the thallus width is 1000 μm (Fig. 12); peripheral cells are small, slightly elongated, with dense phaeoplasts, dark coloured, thin walled, 10-20 μm in length and 5.0-12.5 μm in breadth (Fig. 13); cortical cells are large, thick walled, cell-wall thickness 5.0 – 7.5 μm , poor in content, polygonal or slightly rounded in shape, variable in size being 15-50 μm in length and 10.0-37.5 μm in breadth. Intercellular spaces are absent, (Fig. 14); medullary region consists of 5-6 layers with small cells, polygonal or rounded in shape, variable in size being 5.0-12.5 μm in length and 2.5-12.5 μm in breadth, thick walled, poor in content, cell-wall thickness being 2.5 μm .

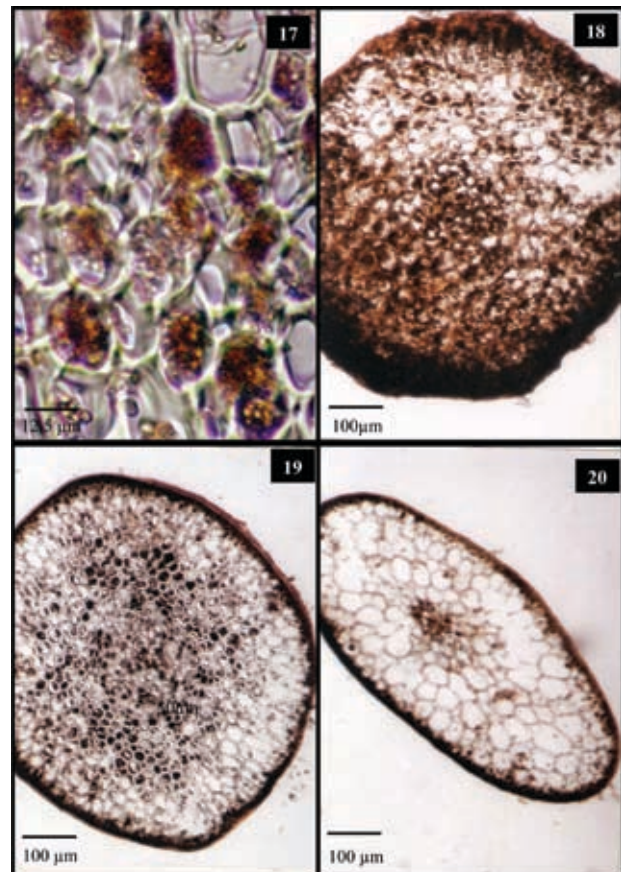
In the basal portion, the thallus width is 1125 μm ; peripheral cells are small, thin walled, slightly elongated, with dense phaeoplasts, 12.5-25.0 μm in length and 7.5-10.0 μm in breadth followed by cortex and medulla (Fig. 15); cortex consists of 4-5 layers, cells large, thick walled, cell-wall thickness being 5.0-7.5 μm with dense phaeoplasts, variable in size, hexagonal in shape, 30.0-87.5 μm in length and 15-45 μm in breadth (Fig. 16) and intercellular spaces are absent; medulla consists of 4-5 layers, cells small, thick walled, cell-wall thickness 5.0-7.5 μm , hexagonal in shape, with dense phaeoplasts, dark coloured, 10-25 μm in length and 7.5-10.0 μm in breadth (Fig. 17), intercellular spaces absent.

Dwarf fronds are dark brown in colour, almost round, cortical cells and medullary cells both contain dense phaeoplasts; cortical cells are large, thick-

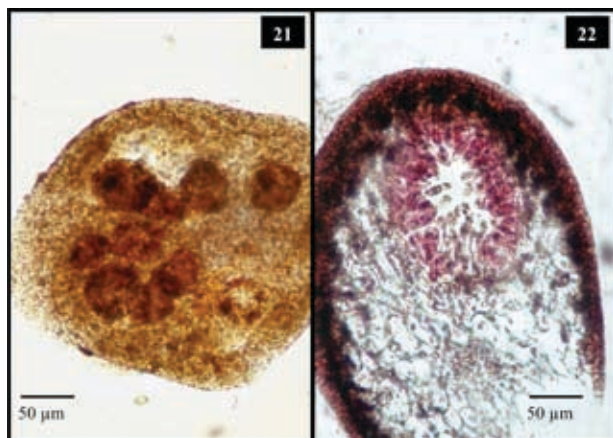
walled, 25-45 μm in length and 20.0-32.5 μm in breadth and intercellular spaces are absent, (Fig. 18); medullary cells small, thick-walled, without intercellular spaces, with dense phaeoplasts, 15.0-22.5 μm in length and 10.0-17.5 μm in breadth. Terete fronds are oval in shape; consist of cortex and medulla, medullary region large, cells small, thick-walled, with dense phaeoplasts, 7.5-25.0 μm in length and 10.0-22.5 μm in breadth; cortical cells are large, poor in content, thick-walled, isodiametric, without intercellular spaces, cells large, 17.5-45.0 μm in length and 15-30 μm in breadth (Fig. 19). Leafy fronds are almost elliptical, cortical region very large, consists of large thick-walled cells, 25-45 μm in length and 20.0-32.5 μm in breadth, poor in content and intercellular spaces being absent; medulla is very reduced, medullary cells are small, thick-walled, with dense phaeoplasts, 12.5-25.0



Figs. 13-16. *Cystoseira indica*: 13. T.S. of middle portion of the thallus, 14. Cortical cells in middle part, 15. T.S. of basal portion, 16. Cortical cells in basal part.



Figs. 17-20. *Cystoseira indica*: 17. Medullary cells in basal portion of the thallus, 18. T. S. of cylindrical dwarf frond, 19. C. S. of terete dwarf frond, 20, T.S. of leafy frond



Figs. 21-22. *Cystoseira indica*: **21.** T.S. of oogonial conceptacle, **22.** T.S. of antheridial conceptacle.

µm in length and 7.5-22.5 µm in breadth and intercellular spaces being absent (Fig. 20).

Reproductive structures: The thalli are monoecious. Branched receptacles arise from the axil of ultimate branches. In transverse section, each receptacle consists of 3-4 conceptacles. Oogonia and antheridia are present in the same receptacle but in different conceptacles. The oogonia are present in a conceptacle at the apex or tip of the receptacle. Each conceptacle has 2-8 oogonia. The oogonia are reddish brown in colour, round, sessile, uniovulate, 75.0-87.5 µm in length and 75.0-87.5 µm in breadth (Fig. 21). On the lower side of some receptacles, antheridia-bearing conceptacles are present. The antheridia are club-shaped, stalked, 37.5-50.0 µm in length and 12.5-20.0 µm in breadth (Fig. 22).

Habitat: Benthic in shallow sandy pools of mid-littoral region at Goth Haji Ali, Buleji (Leg. Alia Abbas 17-3-2006, 15- 3 & 18- 9- 2007, 29-11-2008, 24-1 & 7-3-2009); Manora (Leg. Alia Abbas 31-11-2006, 6-4- 2009, FUU-SWH. 12).

Type locality: Porbandar, Gujarat, India.

Local distribution: Karachi: Manora, Sandspit, Buleji, Paradise Point, Naugaza Mazar and Cape Monze; Balochistan: Gadani, Sonmiani, Miani Hor, Ras Malan, Ormara, Kappar, Sur Bunder, Gwadar, Pishukan, Ganz and Jiwani.

Geographical distribution: India, Pakistan and Qatar.

Discussion

It is observed that the thalli are attached to the substratum primarily by a disc-like holdfast (Fig. 2) and the rhizomes develop only afterwards. The formation of a rhizome is not unknown in the Cystoseiraceae, as it occurs in the genera *Acysts* Schiffner and *Bifurcaria* Stackhouse [1,5]. The disc-like holdfast is found at the proximal end of the stipe and the rhizome like branches are given-off from the stipe above the holdfast (Fig. 3). It is further observed that tips of the rhizomes also get expanded into holdfast-like structures when they come into contact with a substratum. Therefore, it is highly unjustified to consider these specimens under the genus *Stokeyia* [6] distinct from *Cystoseira*, as has already been argued previously [2,3,5].

Earlier workers [1,2] provided no information about the anatomy of *C. indica*, but later workers [3-5] gave a brief description of its anatomical features, indicating three concentric zones of cells: outer coloured zone of peripheral and hypodermal cells, intermediate zone of large cortical cells and central zone of narrow medullary cells [5]. The present study provides very detailed information about anatomical structures of the apical, middle and basal portions of the thallus separately, and reveals the differences present in these parts. It elaborates the details of various regions in all parts of the thalli. Furthermore, it also presents the anatomical details of different types of vegetative parts, such as dwarf, terete and leafy fronds, along with the variations observed in their anatomy. No such investigation has been made earlier [1-5], even a recent study [6] provides no information at all about the anatomy of *C. indica*. The present investigation is the first study of its kind.

Three species of the genus *Cystoseira* C. Agardh i.e. *C. indica*, *C. myrica* (S. Gmelin) C. Agardh and *C. trinodis* (Forsskål) C. Agardh have

been reported to occur on the coast of Gujarat, India [3]. Of these, *C. myrica* and *C. trinodis* were also reported from the Persian Gulf [17,18] and *C. indica* from Qatar [15]. Apart from that, *C. barbata* (Stackhouse) C. Agardh and *C. corniculata* (Turner) Zanardini have been reported from Sri Lanka [15] and *C. opuntioides* Bory de Saint-Vincent ex Montagne from the West coast of India [19]. Furthermore, six different species of *Cystoseira* have been reported to occur in various coastal areas around Arabian Sea [15]. In these circumstances, the statement made by Gul and Nizamuddin in a recent publication [6] about “non-occurrence of *Cystoseira* Kützinger of the northern-Arabian coast and recalling the present specimens as *Stokeyia indica* without any reasoning is beyond comprehension. This paper [6] brings no new information about the thalli of *Cystoseira indica*. A very peculiar thing that was observed in the present specimens is the occurrence of monoecious thalli. At the tip of certain receptacles which contain male conceptacles, a small red dot is present that includes 2-8 oogonia (Fig. 21). Whether these red dots, which constantly recur, are really female conceptacles is a matter of doubt, because in all the previous investigations this species was observed to be dioecious with separate male and female thalli [1-6]. Anyhow, the present specimens are suggested to be named as *Cystoseira indica* (family Cystoseiraceae, order Fucales, class Fucophyceae, phylum Phaeophycota; *vide* [20]). This is the only species of the genus *Cystoseira* which occurs along the entire coastline of Pakistan [5]. Reports on the occurrence of *C. barbata* from the coast of Karachi are unreliable [5,15]. On the basis of the present and the past observations [5], it may be concluded that all the studies made in the past on the binomial *Stokeyia indica* from the coast of Pakistan may be considered as *Cystoseira indica*.

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