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THE STRUCTURE AND REPRODUCTION OF A NEW TAXON *DERMONEMA ABBOTTIAE* (NEMALIALES-RHODOPHYTA) FROM THE COAST OF PAKISTAN

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Dermonema abbottiae Afaq Hussain, Nizamuddin *et* Shameel sp. nov. is described from the coast of Pakistan. Its habit, vegetative features, anatomical structures, carpogonial branch ontogeny and diffuse cystocarps are discussed in detail. This species is characterized by angular sub-dichotomously branched axes, curved tips, parietal laminate rhodoplasts and 2-4-celled carpogonial branches.

Key words: Taxonomy, Anatomy, Reproduction, Carposporophyte ontogeny, *Dermonema*.

Introduction

The coast of Karachi is rich in marine algal vegetation. Algae belonging to the order Nemaliales have been studied very poorly from the coast of Karachi [1,2] and other coastal areas of the country [3,4]. *Dermonema* Harvey *ex* Heydrich grows on high tide level during South West Monsoon season in Sri Lanka [5] and India [6-8]. Although, it was not reported previously from the coast of Pakistan, but its occurrence was highly probable.

A survey was conducted during 1984-87 primarily to assess the biomass production of commercially important seaweeds of the country, during which some new algae were also collected. One of the new species discovered belongs to the genus *Dermonema*. It is named *D. abbottiae* in honour of Prof. Dr. (Mrs.)Isabella A. Abbott, University of Hawaii, Honolulu, who has made many significant contributions to our knowledge of the order Nemaliales. It belongs to the family Liagoraceae, which is poorly known from Pakistani waters [9]. However, there is a need of a detailed investigation of this family from the coastal areas of Pakistan.

Materials and Methods

Algae were collected from the rocky ledges near Naugaza Mazar, about 2 km east of the Light House of Cape Monze, at Paradise Point and Buleji, near Abdur Rehman Goth during June and Oct. of 1986–1987 and also from Gadani during Nov. 1987. Materials were either fixed in 4% formalin-seawater solution or mounted on herbarium sheets. These are kept in the Herbaria of PCSIR, Karachi (CLH) and of Botany Department, University of Karachi (KUH). Materials were squashed in 1% aniline blue in 5% HCl. Permanent slides were prepared in equal volumes of glycerine, acetic acid and distilled water. Drawings were made with the help of Camera Lucida.

Observations

Vegetative structures. Thalli are dark red, mucilaginous and cartilaginous; caespitose with 3-5 (-9) individuals (Figs 29,30); erect up to 8 cm high. Holdfast conico-discoid, 2-5 mm across. Main axes tereto-compressed, angular (Fig. 4), cylindrical near the base up to 4 mm across, sub-dichotomous, proliferations on the axes. First furcation at a distance of 4-6 mm from the holdfast. Branchings congested in the apical regions (Fig. 29). Main branches terete, 600-800 µm across; terminal ones curved, cylindrico-terete, gradually tapering upwards, 250-380 µm broad at the distal end, 450-650 µm broad at the proximal end, up to 1 mm broad at the furcation of the terminal ends (Figs. 1,2,29).

Anatomical structures. Thallus is multiaxial with a large medulla, consisting of dense anastomosing (*i.e.* running in different directions crossing each other) thick-walled filaments, composed of three zones (Fig. 5). The central core consists of main filaments, running in the direction of axis, apart from each other (*i.e.* remaining at distances from one another and not adpressed), 10-12 (-16) µm in diameter, giving branches and sub-branches di-or sub-dichotomously, 5-12 µm in diameter with obtuse and swollen (slightly enlarged) tips, running along the axis, but those of peripheral filaments run outwardly forming an interwoven mass of threads constituting the second zone. These filaments become densely packed and more thickly interwoven in the third zone. The cells of the filaments become short and broad near periphery and then these filaments are divided di- or tri-chotomously to form cortical region of the thallus. These branches produce one or two thin rhizoids running in different directions except the periphery (Fig. 6).

The cortical region is 100-200 µm wide, consisting of radial filaments free from each other or slightly anastomosing proximally, terminating in 3 (-6) -celled assimilatory branches. The assimilatory branches are 37-75 µm long, di- or trichotomous in corymbose manner, terminating in club-shaped cells forming the surface of the thallus, 8-32 µm long, 7-15 µm broad, round and slightly apart in surface view; 2-5 assimilatory branches develop from the top of the supporting cell. Terminal cell of an assimilatory branch contains a large

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rhodoplast, which is parietal laminate, occupying almost the entire peripheral space and bearing a single pyrenoid (Figs 3, 35). Cells just below the surface cells are 8-9 µm long, 4-12 µm broad, giving rise to one or rarely two long aseptate, hyaline hairs 2-4 µm broad, projecting out of the surface (Fig. 13). All except the terminal cell of the assimilatory branches give rise to new branches terminally, the cells are elongated, cylindrical or slightly enlarged terminally but always smaller than the cells of the parent branch. The lowermost cell of the assimilatory branch remains almost of the same size as other cells.

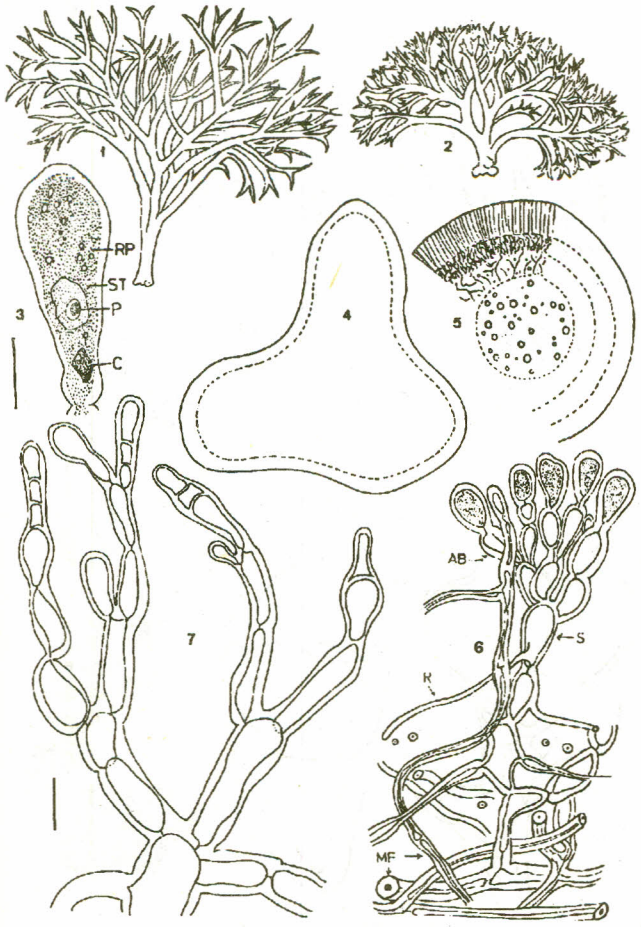
Sometimes medullary filaments terminate directly in a vegetative assimilatory branch having more narrow, slender cells (Fig. 6). Special arrested branches bear long cylindrical to ellipsoidal cells below, obovate cells in the middle, and small cylindrical cells above (Fig. 7). Obovate cells become active cutting off an initial cell terminally, which further develops into a few celled branch. Rhizoids 3-9 µm in dia. arise from the supporting cells and the cells below them but not from the assimilatory branches (Figs 6,12), having few or no rhodoplasts. The initials of the rhizoids are conical projections from the cell except the apical portion. Plants are dioecious.

Spermatangia. Spermatangial branches 1-3 -celled, borne on all cells of the assimilatory branches and also on the supporting cells except the terminal obovate cells (Figs 8,11). Spermatangial branch cells are long, slender as well as sparingly branched when borne on the supporting cells (Figs 9,10), but these are small and densely branched when borne on assimilatory branches (Fig. 8). Each supporting cell usually bears 3-5 assimilatory branches (Fig. 8), but the number may be reduced or totally absent when spermatangial branches develop (Figs 9,10). Spermatangial branches grow on upper portion of the assimilatory cells (Figs 8,11). The mother cells form up to 4 spermatangia each with one spermatium (Fig. 11). Assimilatory branches appear brush like due to thick growth of male branches and spermatangia (Fig. 8). Sometimes a second spermatangium develops in the discharged spermatangium. Spermatangia measure 4.5-6.6 x 3.0 µm. Spermatia are round (-oblong), 5.5-6.5 µm in dia. including the thick mucilaginous sheath (Fig. 14). Up to two spermatia were observed attached to the trichogyne almost near the tip (Fig. 19).

Carpogonia. Carpogonial branches are 2-4 -celled of accessory origin, lateral, curved, borne generally on the (3rd-) fourth (-5th) cell of the assimilatory branches (Figs 18,19). Carpogonia 20-40 µm long (without trichogyne), hypogynous cells 7-10 µm long and up to 10 µm broad. The trichogyne 25-80 µm long, bearing spindle-like thickening in the middle (3-4 µm thick, Fig. 19). Attachment of the carpogenial branch is almost adpressed along the length of the supporting cell. Carpogonial initial is cut off as a protuberance from the supporting cell and is divided by a longitudinal curved wall (Fig. 15) and is further followed by successive transverse divisions forming carpogonial branch (Figs 16,18,19). Direct development of carpogonial branch also occurs on supporting cell of assimilatory filaments instead of an assimilatory branch (Figs 17,20). Rarely a sterile branch develops on an assimilatory branch instead of a carpogonial branch (Fig. 12). The 2-celled carpogonia also occur occasionally (Fig. 33).

Development of gonimoblast. Immediately after fertilization the trichogyne disintegrates and the carpogonial cells increase in size (Figs 21-23), the lower ones almost doubling their original size. The fertilized carpogonium produces a protuberance first in one direction (Fig. 21), followed by cutting off cells leading to the formation of diffuse gonimoblast filaments (Figs 22-25, 36-38), which ramify in between the assimilatory branches and the cortical cells. These filaments are thin, irregularly branched, distally profuse (Fig. 25); and their cells are of variable length, 2-4 µm broad (broader at the branching). From the apices of these erect branches develop obovate, elongate carposporangia mesuring 26 x 10 µm, which are in clusters (Figs 26, 27, 38,39). The entire contents of the carposporangium accumulate in the apical region, which rounds off to produce a carpospore. Each carposporangium produces a single carpospore. Liberation of carpospores and regeneration within old carposporangial walls were not observed, but discharged carposporangia have often been observed (Figs 27,39). Fusion of fertilized carpogonium either with supporting cell or any other cell of the carpogonial branch was not observed. There is a little or no widening of the cytoplasmic connections between the above mentioned cells. Involucral filaments were not found in this species.

Diagnosis. Dermonema abbottiae Afaq Hussain, Nizamuddin *et* Shameel *sp. nov*: Thallus caespitose, tough, erect up to 8 cm high, much branched. Holdfast discoid, up to 4 mm across. Branch apices curved and tapering. Axes tereto-compressed or nearly flat or angular, up to 4 mm in dia. Structurally multiaxial with dense interwoven filaments. Surface cells obovate or clavate, 8-32 x 7-15 µm, containing a large laminate parietal rhodoplast with one pyrenoid. Rhizoids from the lowermost cells of the assimilatory branch and hairs from the subterminal cells, projecting out of the thallus surface. Plants dioecious. Spermatangial branches 1-3 -celled on the assimilatory cells as well as on the supporting cell, except terminal cells. Spermatangia oblong -elongate, 4.5-6.6 x 3.0 µm; spermatia round (-oblong), 5.5-6.5 µm in dia., covered with thick mucilaginous sheath. Carpogonial branch 2-4 -celled, 20-40 µm long without trichotyne, adpressed along the length of the supporting cell. Carpogonial cell 7-10 x 10 µm;



Figs.1-7. *Dermonema abbottiae* Afaq Husain, Nizamuddin *et.* Shameel *sp. nov.;*

1. Habit of the mature thallus; 2. Habit of a young plant; 3. Terminal cell of an assimilatory filament showing rhodoplast with a pyrenoid; 4. Cross section passing through the main axis (an outline); 5. Cross section through the stipe (diagrammatic) showing concentric zones of tissues;6. Longitudinal section through the thallus showing the fomation of assimilatory branch system from medullary filaments, one medulary filament directly terminating in a slender assimilatory filament; 7. Arrested branch in female plant, cell formation from the top of obovate cells.

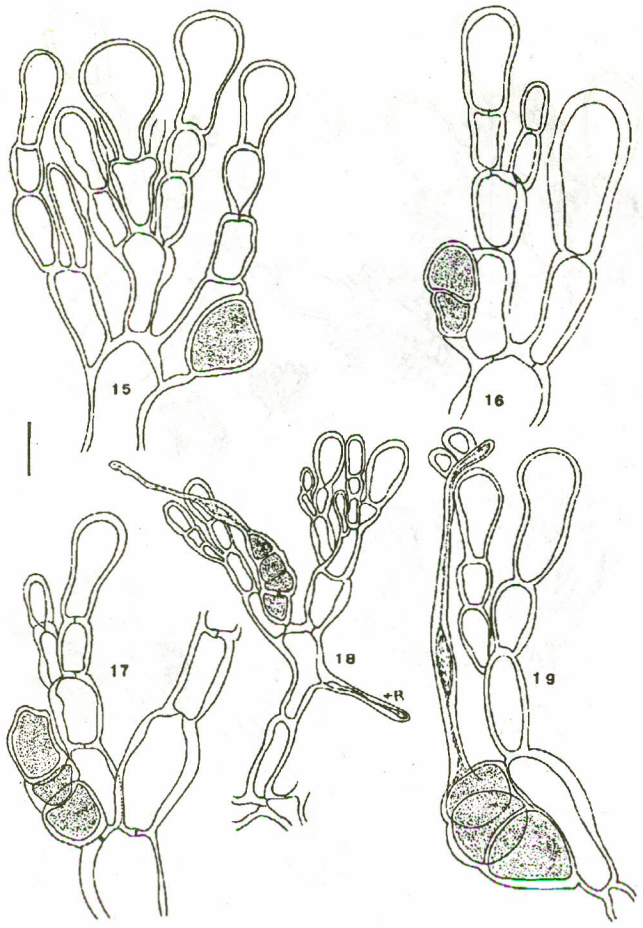
(AB = assimilatory branch, C = crystal, MF = medullary filament, P = pyrenoid, R = rhizoid, RP = rhodoplasts, S = supporting cell of assimilatory branches, ST = starch sheath; scale = figs. 1,2 = 1 cm, fig. 3 = 7 µm, figs. 6,7 = 20 µm).

Figs. 8-14, *D. abbottiae*.

8. Assimilatory branches bearing spermatangial branches; 9. Spermatangial branches on supporting cell alongwith assimilatory branches; 10. Spermatangial branches only on supporting cell; 11. Assimilatory cell bearing spermatangial branches with spermatangia and discharged spermatangia; 12. Assimilatory branch system with rhizoids, a sterile branch arising in place of carpogonial branch; 13. Hairs from sub-terminal cells of assimilatory branches; 14. Liberated spermatia with mucilaginous coat (a = one hair enlarged, DSP = discharged spermatangium, R = rhizoid, SB = sterile branch, SP = spermatangium; scale = figs. 8,9,14 = 10 µm; 10 = 25 µm 11 = 8 µm 12, 13 = 20 µm.

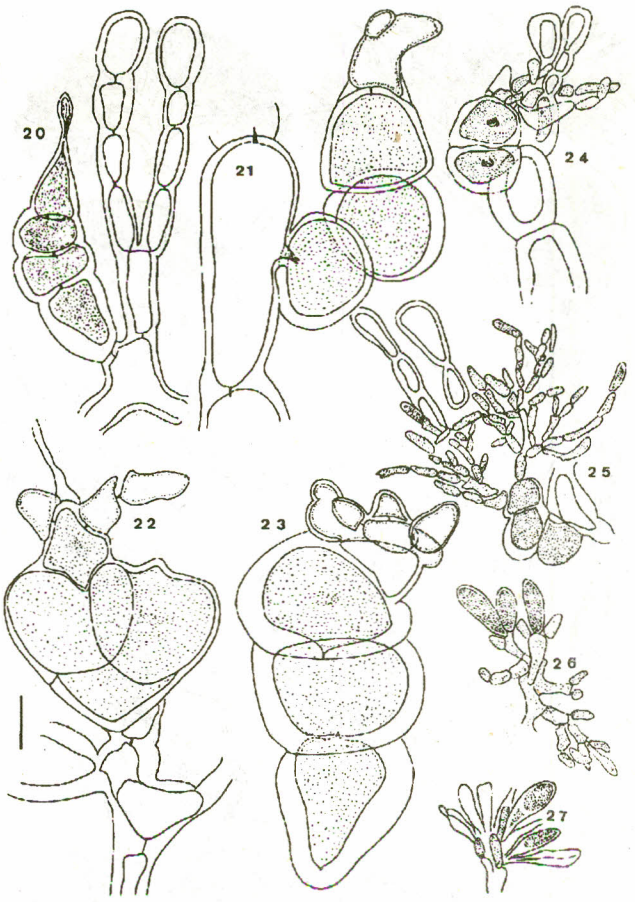
trichogyne elongate, 25-80 µm long. Carpogonial initial cut off from the supporting cell by a longitudinal curved wall followed by transverse walls leading to the formation of 2-4 -celled carpogonial branch. Fertilized carpogonium cuts off protuberance followed by further divisions and re-divisions forming much branched diffuse gonimoblast filaments (diffuse cystocarp), the terminal cell of each branch producing carposporangia each with a carpospore.

Diagnose. Thallus caespitosus, tenax, erectus, ad 8 cm altus ramosissimus. Discus ad 4 mm dia. Rami gradatim angustati apice curvati. Axes ad 4 m dia., tereto-compressae seu angulares seu complanatae. Stratum multiaxiale, filamentis dense intertextis. Cellulae periphericae 8-32 x 7-15 µm, obovatae sive clavatae, cum rhodoplastis parietalibus lumen omnio occupantibus cumque pyrenoide unicae. Rhizoidea cellulis ramorum assimilantium infimis insidentia nec non trichomata cellularum subterminalium superficiem thalli superantia. Species dioecies dioecia. Rami cellularum non solum assimilantium sed etium sustinentium spermatangii (terminalii exclusi) 1-3 -cellulati. Spermatangia 4.5-6.6 x 3.0 µm, oblongo-elongata. Spermatia rotundata vel oblongata, veginae mucosae crassae tecta, 5.5-6.5 µm dia. (vaginae inclusae). Rami carpogonii 2-4 -cellulati, 20-40 µm longi (trichogyne exclusae), cellulae sustinente longitudinaliter adpressi. Cellula carpogonialis 7-10 x 10 µm; trichogyne elongata 25-80 µm longa. Cystocarpium diffusum emultis



Figs. 15-19. *D. abbottiae*.

15. Carpogonial initial on basal cell of an assimilatory branch; 16. Two-celled carpogonial branch on basal cell of assimilatory branch; 17. Three-celled carpogonial branch on supporting cell of assimilatory branch; 18. A cortical filament system bearing 4-celled carpogonial branch; 19. Three-celled carpogonial branch with two spermatia attached near the tip of the trichogyne (R = rhizoid; scale = figs. 15-17, 19 = 10 μm fig 18 = 20 μm).



Figs. 20-27. *D. abbottiae*.

20. Four-celled corpogonial branch in place of assimilatory branch; 21. Formation of protuberances from fertilized carpogonium without division. 22. Formation of gonimoblast initials by fertilized carpogonium, 23. Formation of more gonimoblast initial; 24. Formation of gonimoblast filaments; 25. Mature diffuse cystocarp; 26. Gonimoblast filaments showing terminal carposporangia; 27. Gonimoblast filaments bearing carposporangia and discharged carposporangia (scale = figs. 20-23 = 10 μm , figs. 24-27 = 20 μm).

ramis filamentosia constans quorum cellulae terminales producent carposporangia omnia carposporam gerentia.

Holotype. Naugaza Mazar, 2 km east of light House of Cape Monze, west of Karachi , Pakistan (Leg. S. Afaq Hussain 23-7-1986), NO. R-1237 PCSIR.

Isotypes. Naugaza Mazar (Leg S. Afaq Husain 23-7-1986) Nos. R-1238-1244 PCSIR.

Specimens examined. Buleji (Leg. S. Afaq Husain 7-10-1986, 14-6-1987, Leg. M. Shameel 27-8-1987; S. Afaq Husain 26-9-1987, 8-10-1987) Naugaza Mazar (Leg. S. Afaq Husain 23-7-1986, 14-6-1987, 14-7-1987); Gadani (Leg. M. Shameel 18-11-1987).

Habitat and phenology. Mostly grows on intertidal rocks, exposed to rough sea, forming a long belt of 1 m breadth separating the upper and mid- littoral zones during August and September, both male and female plants occur side by side. In July the belt begins to develop and in October it breaks up. The thalli are also found individually in June and November at the edges of the rocks, sometimes forming the fringes.

Discussion

Dermonema frappiere (Mont. *et* Milard.) Borg. is a species widespread in the Indian Ocean [5-8]. *D. abbottiae* sp. nov. resembles *D. frappieri* in: 1. habit, 2 thickly interwoven filaments, 3. sub-terminal hairs, 4. diffuse cystocarps and 5. absence of involucral filaments, but it differs from the latter in: 1. colour, 2. height, 3. branching, 4. shape of axes, 5. absence of terminal hairs, 6. shape and position of plastids (rhodoplasts) and 7. number of cells in carpogonial branches (Table 1). The thalli of *D. frappieri* are yellowish to dark purple with cylindrical, firm and dichotomous axes. Its branches may be terete or sub-compressed only near the base but with straight tips [5,7,10, 11]. In *D. abbottiae* the axis is tereto-compressed or angular, lower branches are terete, the upper

Fig. 28.

Fig. 29.

Fig. 30.

Fig. 31.

Fig. 32.

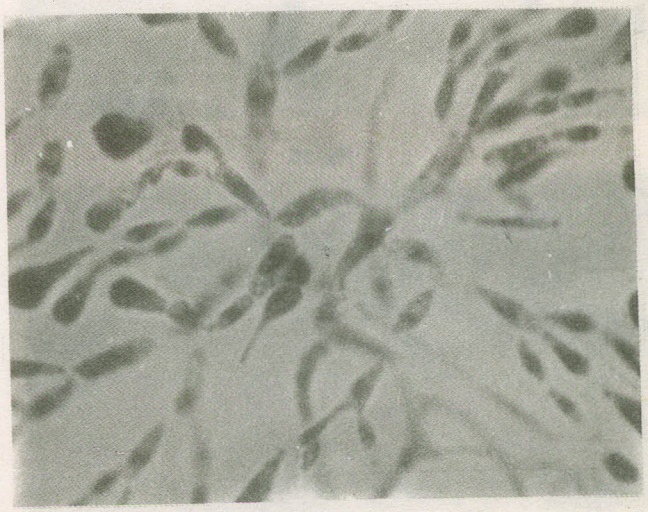


Fig. 33.

Figs. 28-33. *D. abbottiae.*

28. A sterile plant (x 2); 29. Female plant (x 2); 30. Male plant (x 2); 31. Male reproductive bodies (x 350): (a) Four-celled assimilatory branch bearing spermatangial branches on all except terminal cells. (b) Supporting cell bearing 4 assimilatory branches, the basal cell of which also bears spermatangial branches. (c) One cell of assimilatory branch bearing 5 spermatangial branches all around (polar view). (d) A cortical branch directly terminating in spermatangial branches; 32. Vegetative branch system with 1-or 2-celled stage of carpogonial branches and rhizoid (x 900); 33. Show-2-celled carpogonial branch (x 900).

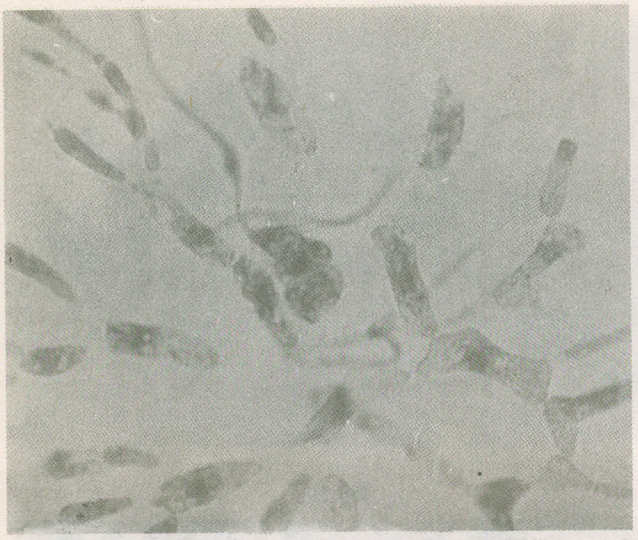


Fig. 34.

Fig. 35.

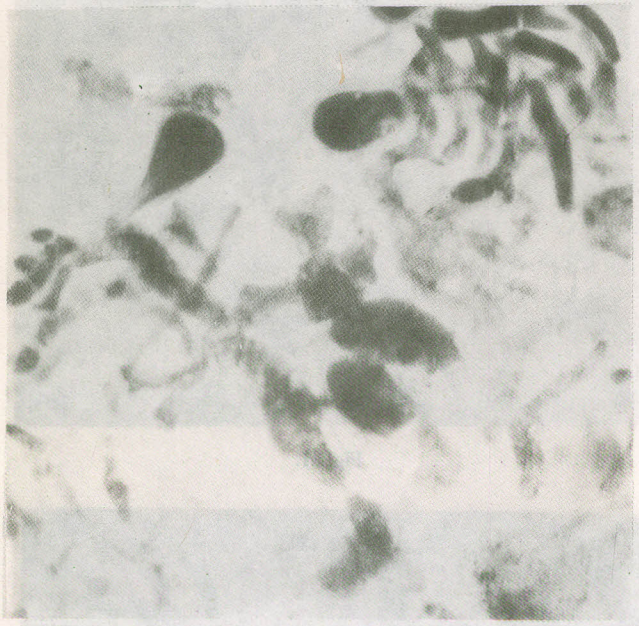


Fig. 36.

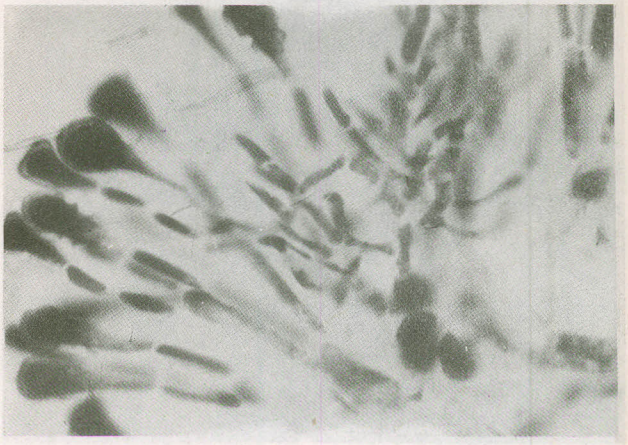


Fig. 37.

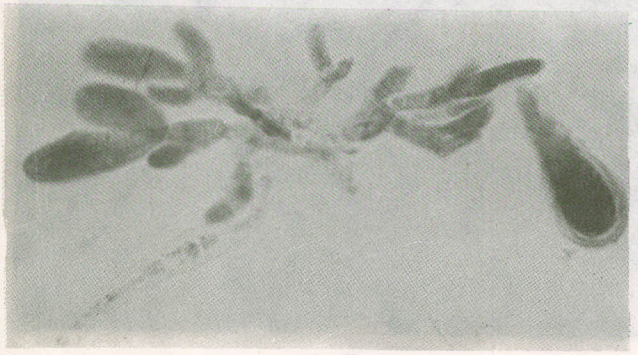


Fig. 38.

Fig. 39.

Figs. 34-39. *D. abbottiae.*

34. Three-celled carpogonial branh with thickening of the trichogyne at the middle (x 900); 35. Terminal cells of an assimilatory branch showing parietal laminate rhodoplast with one pyrenoid (x 200); 36. Gonimoblast initials and gonimoblasts (x 900); 37. Diffuse gonimoblasts (x 900); 38. Young and mature carposporangia (x 900); 39. Cluster of discharged and mature carposporangia (x 900).

TABLE 1. COMPARATIVE FEATURES OF DIFFERENT SPECIES OF *DERMONEMA*.

Features	*D. abbottiae*	*D. frappieri* [= *D. gracile*]	*D. dichotomum*	*D. pulvinatum*
Thallus height (maximum)	8 cm	6 cm	5 cm	3 cm
Colour of thallus	Dark red	Yellowish dark purple	Brownish purple	Dark olivaceous brown
Axes	Tereto-compressed or angular	Cylindrical	Cylindrical	Cylindrical
Branching	Sub-dichotomous	Dichotomous	Dichotomous	Dichotomous
Distal branches	Curved at apex	Straight	Straight	Straight
Plastids (rhodoplasts)	Parietal, laminate	Axial, band shaped or stellate	Axial	Axial
Terminal hairs	Absent	Present	Present	Present
Carpogonial branches	2-4 -celled, 2- celled rare	3-4-celled 4-celled rare	3-celled	3-celled
Spermatangial branches	Profusely branched, even on cell below the 3rd one	Growing on 2nd and 3rd cell of assimilatory branches	Growing on second and third cell	Sparingly branched, on second and third cell
Fusion of cells of carpogonial branch	No broadening of cytoplasmic connection and no fusion of cells	Broadening of cytoplasmic connection and fusion of cells	Broadening cytoplasmic connection and fusion of cells	Broadening of cyto-plasmicconnection and fusion of cells

ones cylindrico-terete, gradually tapering upwards and become curved near the tips.

In the new species the plastid (rhodoplast) is large,parietal and laminate, with a single pyrenoid. Svedelius [12] reported band shaped and axial rhodoplasts in *D. gracile* (Mont.)Schmitz, which has been brought to the synonymy of *D. frappieri* [13]; whereas Desikachary [7] reported axial stellate rhodoplasts in *D. frappieri*. The carpogonial branches are 3-celled in *D.frappieri* [5,7,12] but 2-4 -celled in *D. abbottiae* (Table 1). The lowermost cells of the assimilatory filaments are enlarged and spherical in *D. frappieri* [7], but they are almost of the same size as other cells of an assimilatory branch in *D. abbottiae*. However, such an observation has not been made in the specimens of *D. frappieri* from Taiwan [14].

In *D. abbottiae* rhizoid like filaments arise from supporting cels and the cells below them, but never from the cells of the assimilatory branches, while in *D. frappieri* they emerge from assimilatory branches [7]. In *D. frappieri* there are septate and short terminal hairs and a thick mucilaginous covering around terminal cells of the assimilatory branches [7],but such structures are absent in *D. abbottiae*. In this species spermatangial branches are borne on all the cells (except terminal ones) of the assimilatory branches (also if long) including supporting cells, but in *D. frappieri* they are produced only on the second and rarely on the third cell of the branch and never on the supporting cell [7]. Terminal cells die and are replaced in *D. frappieri*, but those of *D. abbottiae* appear to be persistent, as such a process was not observed in this species.

D. dichotomum Heydrich is the type of species of the genus [15] and *D. pulvinatum* (Grunow *in* Holmes) Fan is widely distributed in the pacific Ocean [10,11,14-16]. *D. abbottiae* differs from above species in height and colour of plants (Table 1). The plants of *D. pulvinatum* are cylindrical, densely irregularly dichotomously branched at short intervals, the branches are cylindrical or sub-compressed, straight, having obtuse spices [10,14,15,17]; while those of *D. abbottaie* are tereto-compressed and angular, sub-dichotomously branched, the branches are terete or cylindrico-terete, only congested in the apical region, with curved and tapering ends. The first furcation takes place at a distance of 4-6 mm from the holdfast.

D. abbottiae further differes from the above mentioned species in having sub-terminal hairs, in profusely branched spermatangia and in 2-4 -celled carpogonial branches. The 4-celled corpogonial branches are as frequent as 3-celled ones. Although, there is a rare occurrence of 4-celled carpogonial branches in *D. pulvinatum* [15] but 3-celled carpogonial branches are of usual occurrence. There are no sub-terminal hairs and spermatangia are sparingly branched in *D. pulvinatum*. The carpogonial brnches are usually 4, rarely 3-celled in *Cylindraxis* Kraft [18] and 4 or 5-celled in *Patenocarpus* Yoshizaki [19], the new genera of Nemaliales.

No other order of red algae has seen such dramatic changes made in its concept and classification as Nemaliales since the classical publication of Harald Kylin's treatise on red

algae [20]. Abbott [17] separated the family Dermonemataceae from Helminathocladiaceae, which was repudiated by Garbary *et al.* [21] and later was agreed upon by Abbott herself [22]. Recently published cladistic analysis of the assemblage of Liagoraceae by Kraft [18] brings us to the conclusion that this group of seaweeds cannot be divided into families or tribes along pre-existing lines. Presently, *Dermonema* may be safely placed under Liagoraceae. The phyco-chemical investigations of *D. abbottiae* are under way, they might throw some light on its taxonomic position and phylogeny.

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