

## Notes on Venezuelan freshwater red algae - I

by

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With 1 figure and 9 plates

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**Abstract:** Since earlier collections and studies on Venezuelan freshwater red algae are very few and uncritical, the present paper deals with our observations on 3 species, i.e. *Compsopogon coeruleus* (Balbis) Montagne (Compsopogonaceae, Compsopogonales, Bangiophyceae), *Rhodochorton sucrense* D'Lacoste et Ganesan sp. nov. (Acrochaetiaceae, Nemaliales, Florideophyceae) and *Bostrychia moritziana* (Sonder) J. Agardh (Rhodomelaceae, Ceramiales, Florideophyceae) collected from different part of eastern Venezuela. *C. coeruleus* constitutes a new addition to the Venezuelan algal flora, while *R. sucrense* is described as a new species. Female plants of *B. moritziana* are recorded for the first time. Vegetative and reproductive features of the 3 species are described and illustrated.

**Resumen:** Dado que anteriores colecciones y estudio sobre algas rojas dulciacuiculas en Venezuela son escasos e inexactos, el presente trabajo aporta nuestras observaciones sobre 3 especies, i.e., *Compsopogon coeruleus* (Balbis) Montagne (Compsopogonaceae, Compsopogonales, Bangiophyceae), *Rhodochorton sucrense* D'Lacoste et Ganesan sp. nov. (Acrochaetiaceae, Nemaliales, Florideophyceae) y *Bostrychia moritziana* (Sonder) J. Agardh (Rhodomelaceae, Ceramiales, Florideophyceae) colectadas en diferentes sitios del oriente de Venezuela. *C. coeruleus* constituye una nueva adición a la flora venezolana, mientras *R. sucrense* se describe como una nueva especie. Plantas femeninas de *B. moritziana* son registradas por primera vez. Se describen e ilustran los caracteres vegetativos y reproductivos de las 3 especies.

## Introduction

Although the vast majority of red algae are essentially marine in distribution, about 42 genera constituting 3% of the total known genera (Dawes 1981) are reported to occur in exclusively freshwater estuarine or subaerial conditions. A comprehensive recent bibliography relating to taxonomy, morphology and development, life-histories, cytology and ultrastructure, physiology, biochemistry and ecology of freshwater red algae are given by Ott & Sommerfeld (1982). Publications relating to the Venezuelan freshwater red algae up to 1970 are extremely scanty and uncritical

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and are merely restricted to species listing without adequate descriptions and illustrations. The cosmopolitan *Thorea ramosissima* (Thoreaceae, Nemaliales) was reported from Caracas (Gollmer in De Toni 1895). Steyermark (1957) gave a list of 6 species of *Batrachospermum* (Batrachospermaceae, Nemaliales) as occurring in Venezuela. Specimens of these 6 species formed a casual part of the extensive collections of some of the botanical explorations of higher plants. The algal specimens were sent to phycologists in U.S.A. and Europe for identification. The 6 species of *Batrachospermum* listed by Steyermark (loc. cit.) were identified by the late H. Skuja. In her *Botrychia-Caloglossa* study, Post (1963) reported *Bostrychia moritziana* from the Orinoco and Arature rivers in areas located about 40-50 km from the coast. This was based on the collections from the Gulf of Paria by F. Gessner. Besides, an unidentified *Batrachospermum* sp. from San Fernando de Atabapo, Amazonas Federal Territory, and *T. ramosissima* from Bolivar State, at the border of the tributary of River Maranjano at an altitude of 1756-1800 m, are also currently preserved in the Venezuelan National Herbarium, Caracas. Both species were collected from southern Venezuela and identified by F. Drouet.

With the object of contributing to detailed taxonomic and ecological studies on the Venezuelan freshwater red algae, we have been making since 1969 a series of collections of these algae from the different freshwater streams and rivers in eastern Venezuela.

A new species of *Rhodochorton*, *R. venezuelense* was described earlier (D'Lacoste & Ganesan 1972). We are reporting here our observations on 3 additional species, i.e. *Compsopogon coeruleus* (Compsopogonales, Bangiophyceae), *Rhodochorton sucrensis* sp. nov. (Acrochaetiaceae, Florideophyceae), and *Bostrychia moritziana* (Rhodomelaceae, Florideophyceae). Ott & Sommerfeld (1982) pointed out that most freshwater reds are from warm or semiwarm geographical latitudes and that a large number of additional taxa will be found and described as these areas are more thoroughly investigated. At the suggestion of Prof. John A. West, Dept. of Botany, University of California, Berkeley, California, a cooperative research proposal to investigate the Venezuelan freshwater reds from a taxonomic and ecological point of view is also planned.

#### Materials and methods

Details on the source of the materials, dates of collection and the conditions under which the 3 species were growing in their natural habitats are given following description of the respective species. The field collected material was fixed in 3% freshwater formalin and most of the microscopic observations were based on this material. However, living material of *C. coeruleus* and *R. sucrensis* were also brought to the laboratory and maintained in aquarium tanks with abundant water from the place of collection and aerated vigorously. Observation on living material was necessary to discern clearly the plastid morphology of *R. sucrensis* and the formation and liberation of monospores in *C. coeruleus*. Whole mounts, freehand and freezing microtome sections (25  $\mu$ m thick) were also prepared and the material stained in 1% aniline blue and mounted in 50% Karo syrup. Line drawings were made with the aid of a Camera Lucida. Voucher specimens of herbarium mounts are deposited in the Herbarium, Institute of Oceanography, Universidad de Oriente, Cumaná, Venezuela, and the Herbarium, University of California, Berkeley, California, U.S.A.

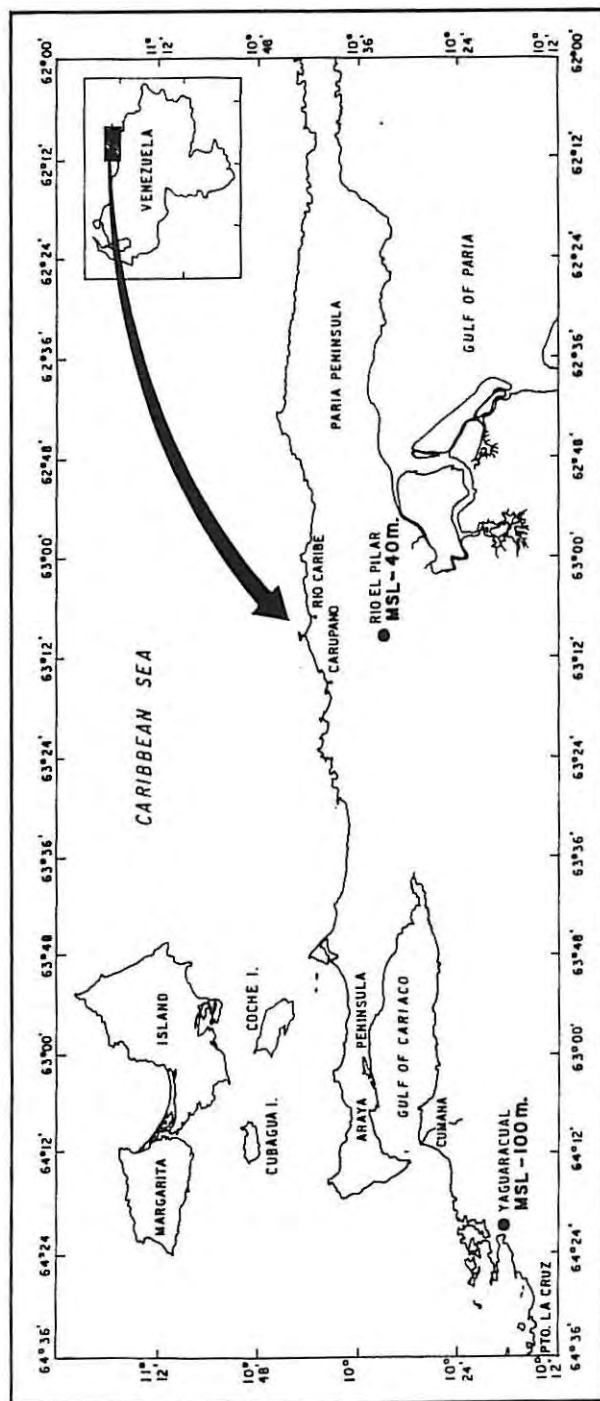
#### *Compsopogon coeruleus* (Balbis) Montagne

pl. I-III

Plants up to 24 cm long, olive green when alive, but turning dark green with a bluish tinge or black in herbarium specimens, abundantly and irregularly branched throughout; fixed to the substratum by a discoid base 200-600  $\mu$ m in diameter, giving rise to a prominent and dominant erect main axis; frequently the erect axis with numerous short, delicate branched proliferations arising from the basal disc and from the basal region of the erect axis; numerous elongate rhizoids issue from the basal part covering the central cells of the axis; thallus surface smooth, or wavy, apex of the main axis and the lateral branches uniseriate filaments 15-27  $\mu$ m broad and 5-12  $\mu$ m high; older portions of the main axis and lateral branches become multiseriate by cortication; each cell with numerous parietal, spherical, discoid, elongate, simple or lobed plastids; monosporangia produced abundantly in the cortical cells of both the main axis and the branches; occasionally cells of uniseriate filaments also produce monosporangia; monosporangia characteristically with dense contents and a hyaline terminal area; more or less in the form of a triangle but with an obtuse apex; monosporangia 13-19  $\mu$ m at the broadest part; spore liberation by dissolution of sporangial wall; liberated monospores naked, spherical 15-22  $\mu$ m broad with numerous small rounded plastids aggregated at its base; monospores grown in the laboratory developing into plants similar to those which produced them; neither sexual reproduction nor microaplanosporangia (sensu Thaxter 1900) observed in the Venezuelan material.

**HABITAT AND DISTRIBUTION:** In a small freshwater stream with swift currents in the village of Yaguaracual (map fig. 1), which is located between Cumaná and Puerto La Cruz in eastern Venezuela. The alga grows on a variety of objects like fallen palm trunks, small stones, waste plastic material and as an epiphyte on *Pithophora*. Periodic visits over 4 years revealed that the alga occurs from February till April and disappears during rest of the year. Dates of collection: 4.IV.1969; 13.IV.1971 & 5.II.1972.

**REMARKS:** *Compsopogon coeruleus*, despite being the most widespread of 6 species currently recognized in the genus (Krishnamurthy 1962), is not adequately described or illustrated from the tropical and subtropical part of the eastern United States and South America (see Taylor 1960). The Venezuelan material agreed in general very well with the descriptions given in the earlier literature (Krishnamurthy loc. cit.). Salient features of our observations which are at variance with some of the recent critical literature on *C. coeruleus*, are the following. Nichols (1964) interpreted the plastids in *C. coeruleus* as a single parietal lamina in young cells, segmenting progressively in mature cells. However, the discoidal segments remain united with each other by a cytoplasmic connection. Our observations on living and fixed material under high magnification showed that the mature cells had many independent plastids without any interconnecting strands. Also Nichols (loc. cit.), on the basis of culture studies, reported 5 different types of sporangial formation with a gradation in the size of the two types of spores, i.e. macroaplanospores and microaplanospores of Thaxter (1900) and Brühl & Biswas (1923). He also cited the presence of a single, parietal, laminate plastid in each monospore.



Map Figure 1: Eastern Venezuela showing Yaguaracual village and El Pilar river where collections were made.

In living and fixed material we observed no microplanospores and moreover the macroplanospores (monospores) differentiated in only one way. A vegetative cell either of the uniseriate filament or of the cortex divided to give rise to a monosporangium and no other division was observed in this cell and its contents was liberated as a single entity. All the spores were more or less of the same size without any gradation. The liberated monospores contained numerous small spherical plastids. Developmental stages in the formation of germlings from monospores in the Venezuelan material are very similar to those of *C. oishii* (Okamura 1915); *C. bengarii*, *C. hookeri*, *C. chalybaeus* and *C. corinaldii* (Krishnamurthy 1953, 1957) and *C. argentinensis* (Pujals 1967). However, Nichols (1964) had shown on the basis of culture studies that germination in *C. coeruleus* is bipolar and occasionally tripolar with variations in the erect and creeping portion (see Nichols 1964, p. 181, figs. 1-11). Additionally, he showed that the germlings always possessed a simple colorless rhizoidal prolongation or appendix. These features were not observed in the numerous germlings we examined. Variations in the mode of germination between the wild and laboratory grown individuals probably could be attributed to the nature of the substratum and the manipulation of the culture conditions, which are different for plants growing under natural conditions. Shyam & Sarma (1980), in a recent interesting study on an unidentified species of *Compsopogon* from India, have also shown considerable polymorphism in monospore germination, and early stages of development in this genus.

#### *Rhodochorton sucrense*\* D' Lacoste et Ganesan sp. nov.

pl. IV-V

Plantae heterotrichae, ad 2 mm altae. Portio basalis male definita aut irregularis, 5-14  $\mu$ m latis et 7-22  $\mu$ m longis. Filamenta erecta pleurumque in ramis alternis, saepe unilateralibus, raro oppositis. Cellulae filamentorum erectorum 5-17  $\mu$ m latae at 13-36  $\mu$ m longae. Pili nulli. Basis filamentorum erectorum habet quandoque raros rhizoides deorsum crescentes, saeptatos atque simplices, 5-6  $\mu$ m diametro. Monosporangia ovata-elliptical ad rotundata, inserta in extremis ramis atque ramusculis univel multicellularibus, saepe in fasciculis. Monosporangia 7-14  $\mu$ m lato et 9-20  $\mu$ m longa.

HABITAT: Super segmenta marsupiorum materiae plasticae atque epiphyticulis super *C. coeruleus* in rivulo permanente, sito in vico Yaguaracual, ad viam Cumaná-Puerto La Cruz, Estado Sucre, Venezuela.

HOLOTYPE: L.G.D. 14 (5.II.72) in "Ficoteca Venezolana", Instituti Oceanografici, Universitatis Orientalis, Cumaná, Venezuela depositus.

Plants very minute up to 2 mm high, in a living condition dark green in color; heterotrichous, basal system irregular with rectangular or oval cells arranged in 2 or more layers, cells of the basal layer 5-14  $\mu$ m broad and 7-22  $\mu$ m long; erect system with simple or usually alternately or occasionally unilaterally and oppositely branched filaments; cells of erect filaments 5-17  $\mu$ m broad and 15-33  $\mu$ m long; branching angles very close resulting in the branches appearing vertical or nearly parallel to the axial filament; basal part of some erect filaments giving out delicate, colorless, simple rhizoids, 5-6  $\mu$ m broad and 13-36  $\mu$ m long; hairs not observed; apical cells and their immediate derivatives with numerous, small plastids, discoid to

\*The specific name honours Field Marshal Antonio José de Sucre, a well known Venezuelan independence fighter from Cumaná, in the last century.



elongate, parietal and without pyrenoids; septal plugs ("pit connections") evident; reproduction in the field collected material solely by monospores; mature monosporangia ovoid, elliptical or round, small in size, 7-14  $\mu\text{m}$  broad and 9-20  $\mu\text{m}$  long; monosporangia borne terminally on uni- or multicellular laterals, rarely at the end of a long lateral in groups of 4.

HOLOTYPE: L.G.D. no. 14 (5.II.1972) deposited in the Herbarium, Institute of Oceanography, Universidad de Oriente, Cumaná, Venezuela. Isotype deposited in the Herbarium, University of California, Berkeley, U.S.A.

TYPE LOCALITY: Yaguaracual village (map fig. 1), which is located between Cumaná and Puerto La Cruz in eastern Venezuela. The alga grows epiphytically on submerged *Compsopogon coeruleus* and on plastic waste material in a small stream with swift water movements.

REMARKS: In comparison with marine representatives, there are only 4 species of *Acrochaetium* (Raikwar 1962; Patel 1970; Khan 1970; Kumano 1978), 5 species of *Audouinella* (Kyllin 1956) and 2 species of *Rhodochorton* (Swale & Belcher 1963; D'Lacoste & Ganesan 1972) reported from exclusively freshwater conditions. The above mentioned genera are distinguished in vegetative conditions from each other generally on plastid morphology (D'Lacoste & Ganesan loc. cit.). However, despite their simple, uniseriate, branched filamentous organization, and complex life-histories, criteria for separating the various genera in the acrochaetioid algae have been variously interpreted and emphasized and treated in many critical papers for more than 50 years (Drew 1928; Papenfuss 1945, 1947; Woelkerling 1971, 1983; Stegenga & Vroman 1977; Dixon & Irvine 1977; Garbary 1979; West & Hommersand 1981; Kraft 1981; Gargary, Hansen & Scagel 1982; Hansen & Garbary 1984). By the presence of numerous, small, discoid plastids in each cell, and by the absence of pyrenoids, we have assigned the Venezuelan plants tentatively to the genus *Rhodochorton* and not to *Audouinella* Bory. Besides, generic attributes of *Audouinella* are yet to be resolved precisely. For example, Garbary (1979) recognized only one genus *Audouinella* in the family, while Woelkerling (1971) includes under this genus only those species with sexual reproduction and *Colaenema* for those species in which sexual reproductive structures have not yet been observed. *Rhodochorton sucrensis* is sufficiently distinct from *R. investiens* and *R. venezuelense* in the following aspects to be described as a new species.

The exclusively freshwater habitat with no seawater influence or tidal intrusion, numerous small discoid plastids in each cell, formation of rhizoids at the base of erect filaments and reproduction solely by monospores, all indicate that *R. sucrensis* is very closely related to *R. venezuelense* (D'Lacoste & Ganesan 1972), although there are several differences. Cells of erect filaments of *R. venezuelense* are 17-36  $\mu\text{m}$  broad and 50-100  $\mu\text{m}$  long, whereas in *R. sucrensis* they are only 5-10  $\mu\text{m}$  broad and 13-36  $\mu\text{m}$  long. Basal rhizoids in *R. venezuelense* are 10-20  $\mu\text{m}$  broad, while in *R. sucrensis*, they are only 5-6  $\mu\text{m}$  broad. Monosporangia of *R. venezuelense* are 17-23  $\mu\text{m}$  broad and 30-40  $\mu\text{m}$  long, while *R. sucrensis* has very small monosporangia, 7-14  $\mu\text{m}$  broad and 9-20  $\mu\text{m}$  long. In *R. investiens* there is a single parietal, band-shaped plastid, which usually forms a loose, irregular spiral,

occupying only about half the space in the cell (Swale & Belcher 1963). In *R. sucrensis* there are numerous small, discoid plastids. Monospores of *R. investiens* are 16-18  $\mu\text{m}$  long and 7-9  $\mu\text{m}$  broad, while *R. sucrensis* these are 7-14  $\mu\text{m}$  broad and 9-20  $\mu\text{m}$  long. Sexual reproduction is also known in *R. investiens* (Swale & Belcher loc. cit.), while *R. sucrensis* reproduces solely by monospores.

It may also be pointed out here that some freshwater genera like *Batrachospermum*, *Lemanea* and *Sirodotia* sometimes pass an earlier or some part of its life cycle through a stage called *Chantransia* with an acrochaetioid morphology (Israelson 1942). In the stream where *R. sucrensis* was collected, *Compsopogon coeruleus* has been the only other red alga collected, so far. As shown in this paper, developmental stages of monospores of *C. coeruleus* do not have any resemblance to the young and adult plants of *R. sucrensis*.

#### *Buistrychia moritziana* (Sonder) J. Agaardh

pl. VI-IX

Plants up to 8 cm long, living specimens dark brown in colour, turning somewhat blackish in herbarium specimens, habit erect with a prominent discoid base; erect axis profusely distichously branched with secondary alternate pinnate branching up to 6th order, which constitute indeterminate branches, which in turn bear determinate branches up to 3 mm long; frequently haptera formed on indeterminate branches, which are formed by the transformation of an entire indeterminate branch or one of its segments; haptera made up of simple, closely packed rhizoidal cells; occasionally two haptera from different branches fuse; growing parts monosiphonous but becoming polysiphonous by pericentral formation a short distance from the apex; 4 pericentrals in young branches, increasing to 5-6 in the middle and up to 8 in the basal part of the erect axis; in surface view pericentrals elongate, but oval-circular in section; ecorticate throughout; determinate branches excepting at the base monosiphonous throughout with cells 16-29  $\mu\text{m}$  broad and 28-58  $\mu\text{m}$  long; tetrasporangial plants abundant, distinguished easily by the presence of many elongate, slightly swollen, pedicellate, polysiphonous and terminally pointed stichidia, which are the modified structures of some segments of the determinate branches; mature stichidia 15-200  $\mu\text{m}$  in its broadest part and up to 2 mm long; tetrasporangia generally appear arranged in 2 rows in surface view; in transverse sections each segment bears 7 tetrasporangia surrounding a central cell; each tetrasporangium borne on a basal cell and covered externally by a two celled branch; tetrasporangia 28-38  $\mu\text{m}$  broad and 40-63  $\mu\text{m}$  long; tetrahedrally divided; older stichidia showing rows of perforations on its surface leaving scars in the area of spore liberation; female plants rare, but are easily distinguished by their swollen, spherical to ovoid cystocarps; each branchlet of the determinate branch bearing 1-3 cystocarps; carpogonial branch 4-celled; trichogyne prominently projecting outside the fertile branch; mature cystocarp with a prominent basal fusion cell; carposporangia elongate, 38-65  $\mu\text{m}$  long and 13-27  $\mu\text{m}$  broad; mature cystocarps 500-720  $\mu\text{m}$  long and 540-680  $\mu\text{m}$  broad; spermatangial plants not found, although the presence of spermatium attached to the trichogyne indicated probable occurrence of separate male plants.

**HABITAT AND DISTRIBUTION:** Growing attached to stones forming dense masses at Rio El Pilar (map fig. 1), Sucre State, in eastern Venezuela. Collected on 12.III. 1972.

**REMARKS:** Of the 9 species of *Bostrychia*, i.e. *B. binderi*, *B. calliptera*, *B. moritziana*, *B. pilulifera*, *B. radicans*, *B. rivularis*, *B. tenella*, *B. scorpioides* and *B. montagnei* recorded by Taylor (1960) as occurring in the tropical and subtropical western Atlantic ocean, the first seven species are also recorded from Venezuela (Ganesan 1978; see also Taylor 1976). By having regularly distichous branching, ecorticate axes and especially by having fastigate completely monosiphonous (excepting at the base) determinate branchlets or ramelli, *B. moritziana* is distinguishable from other *Bostrychia* species.

Although *B. moritziana* is frequently reported from marine conditions, especially growing on mangrove roots, it is also recorded from freshwater situations (Taylor 1960; Post 1963). However, it appears that this species had not been adequately described and illustrated in the literature. Taylor (loc. cit.) reports only 3-4 sporangia in each segment of the stichidium, but in the present material up to 7 sporangia were observed. Cystocarpic plants are described here for the first time. The place where this alga was collected is situated about 10-12 km away from the mouth of the El Pilar river emptying into the Paria gulf, which indicates a probable migration from the sea to a freshwater environment without apparent changes in structural or reproductive aspects.

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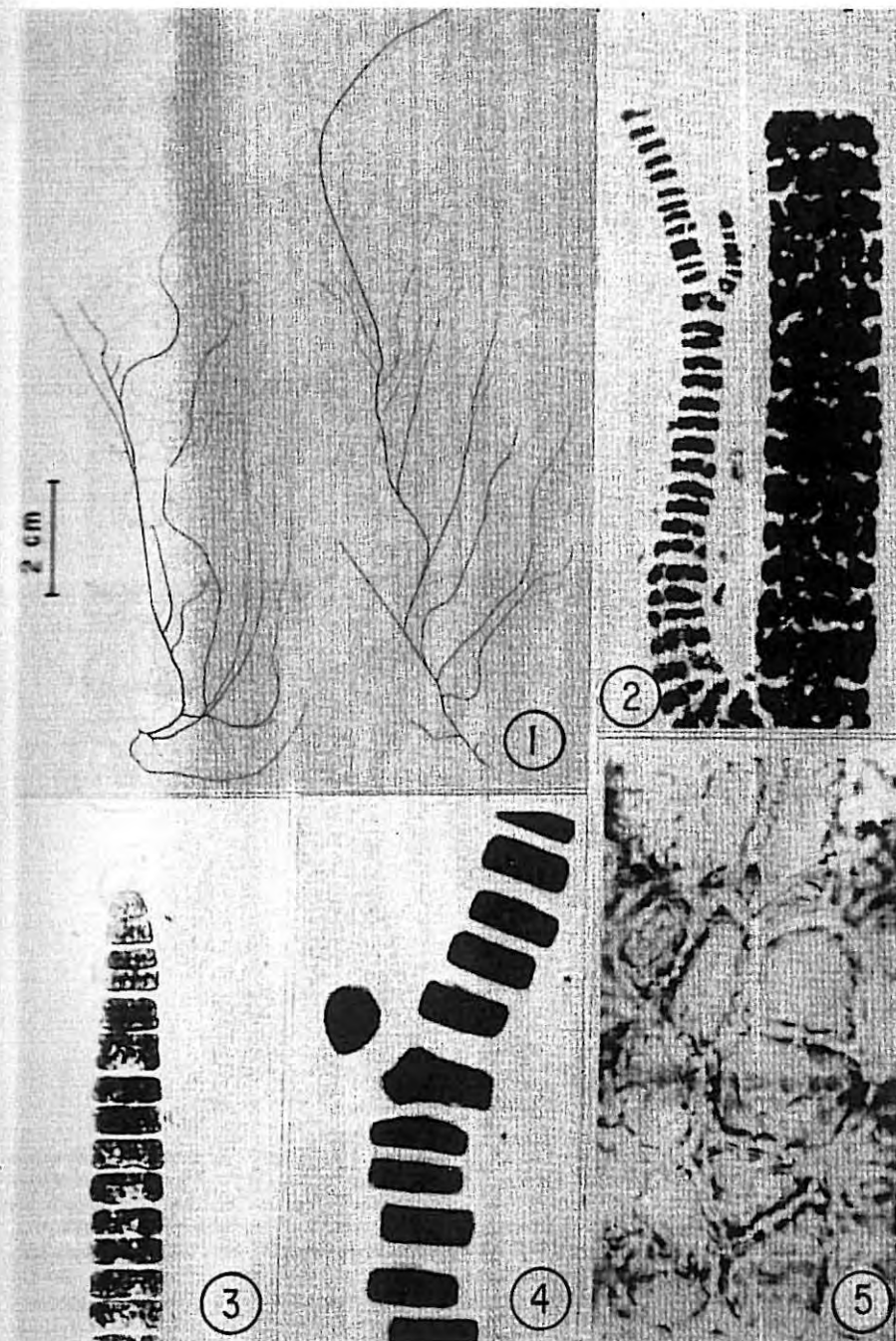


Plate I, Figs. 1-5: *Compsopogon coeruleus*. Fig. 1: Habit of 2 plants. Fig. 2: Part of multiserial axis with a lateral branch showing various stages in the formation of pericentral cells  $\times 159$ . Fig. 3: Apex of an uniseriate filaments enlarged to show rectangular cells  $\times 520$ . Fig. 4: Origin of a lateral branch  $\times 695$ . Fig. 5: Surface view of cortical cells to show variation in their form. Each cell has many elongate plastids  $\times 210$ .

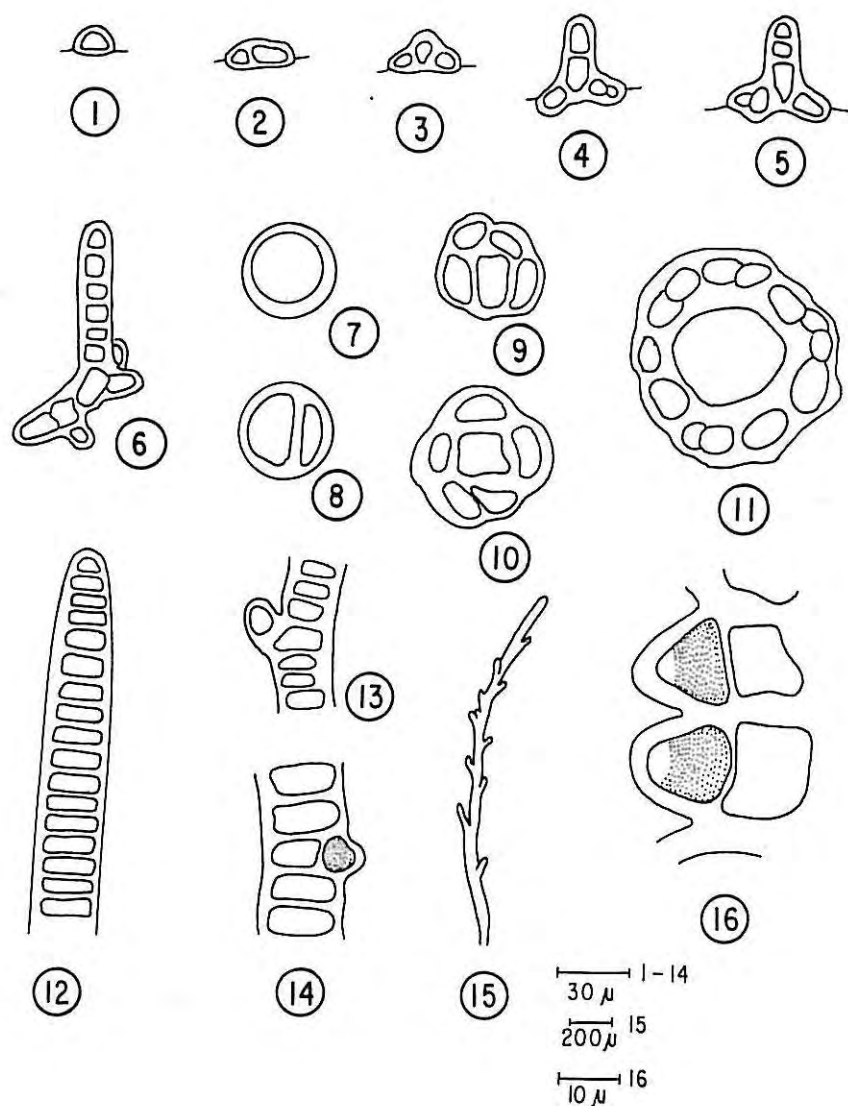


Plate II, Figs. 1-16: *Compsopogon coeruleus*. Figs. 1-6: Different stages in the germination of monospores and the formation of germings. Figs. 7-11: Successive transverse sections to show the formation of pericentral cells and the central cell. Fig. 12: Apex of a uniseriate filament. Fig. 13: First stage in the formation of a lateral branch. Fig. 14: Monosporangium differentiated in the uniseriate filament. Fig. 15: Branching pattern in the apical part. Fig. 16: Two monosporangia differentiated from cortical cells. Note each monosporangium borne on a basal supporting cell.

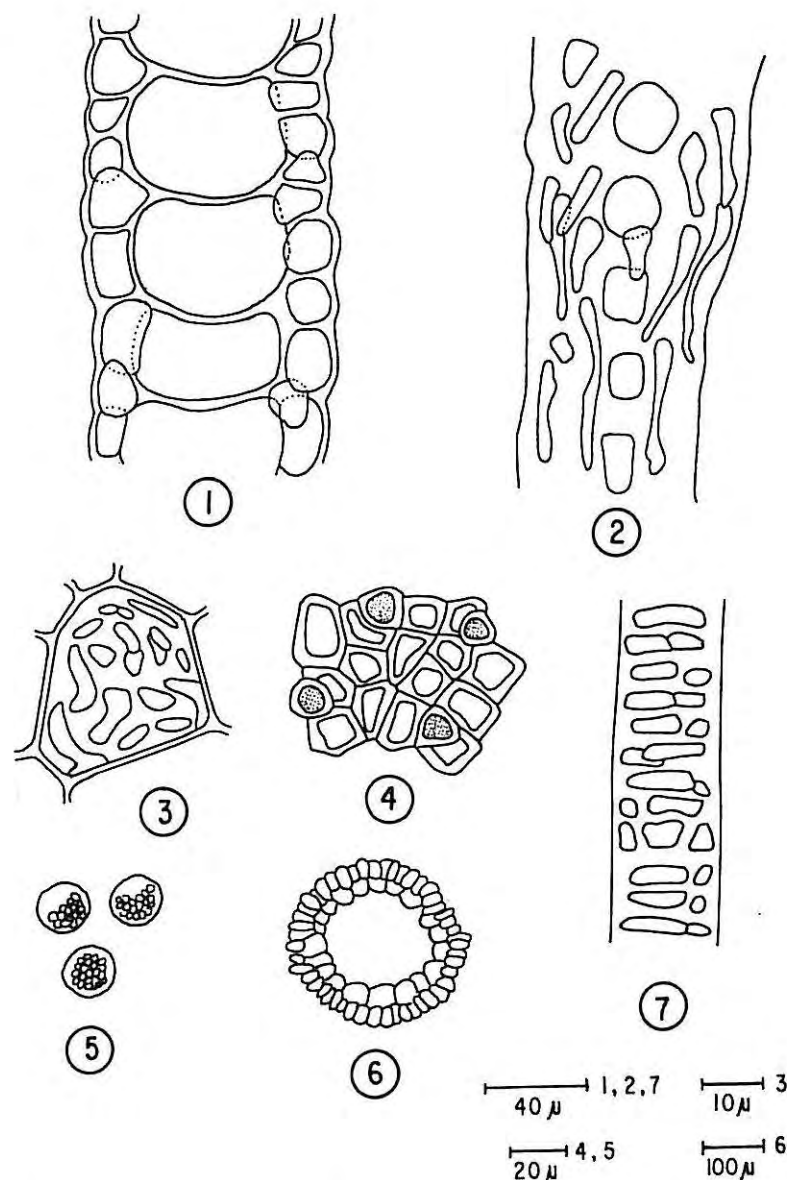


Plate III, Figs. 1-7: *Compsopogon coeruleus*. Fig. 1: Longitudinal section of a multiseriate filament. Fig. 2: Formation of rhizoids from the basal part of the erect axis. Fig. 3: A cortical cell with many elongate plastids. Fig. 4: Various monosporangia differentiated in the cortex of an old filament. Fig. 5: Liberated monospores with many plastids aggregated in the basal part and the hyaline zone. Fig. 6: Transverse section of an old filament to show cortication of pericentral cells. Fig. 7: Different stages in the formation of pericentral cells in a young filament as observed in surface view.

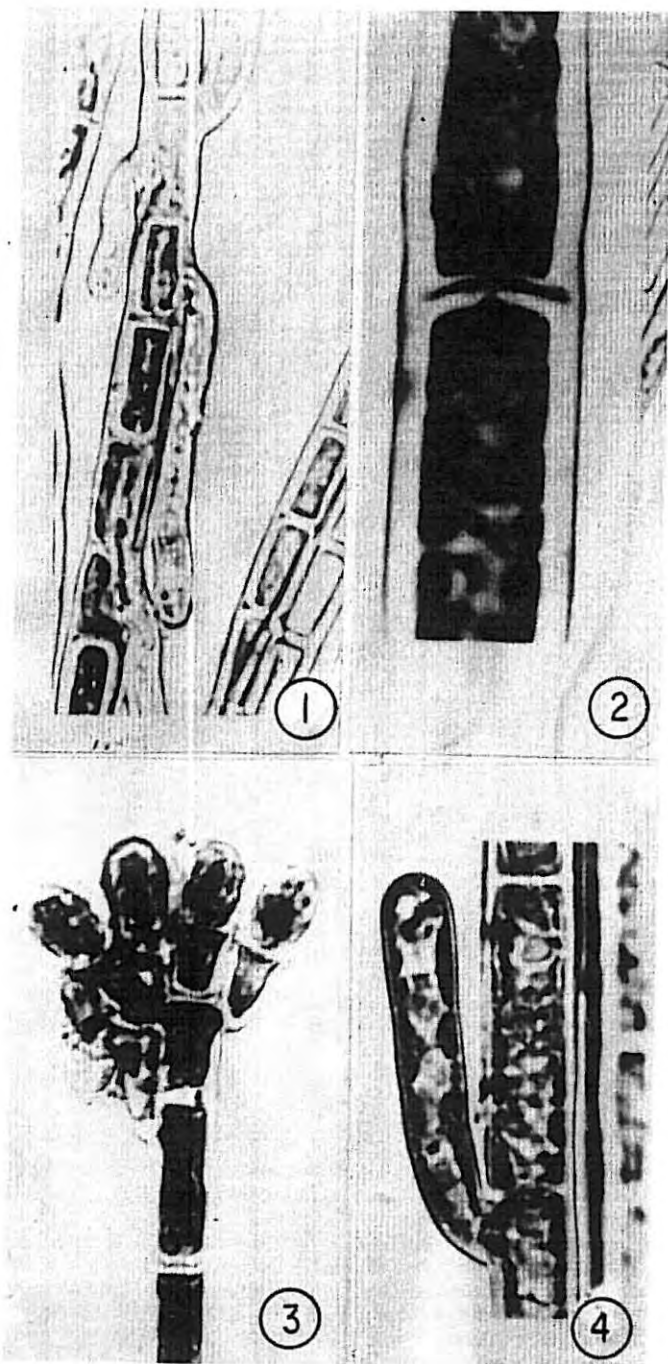


Plate IV, Figs. 1-4: *Rhodochorton sucrease* D'Acosta et Ganesan sp. nov. Fig. 1: Origin of rhizoids from the basal part of an erect filament  $\times 961$ . Fig. 2: Two cells with interconnecting "pit-connections"  $\times 2273$ . Fig. 3: A group of monosporangia borne in a terminal cluster  $\times 1000$ . Fig. 4: A monosporangium borne on a lateral filament  $\times 1000$ .

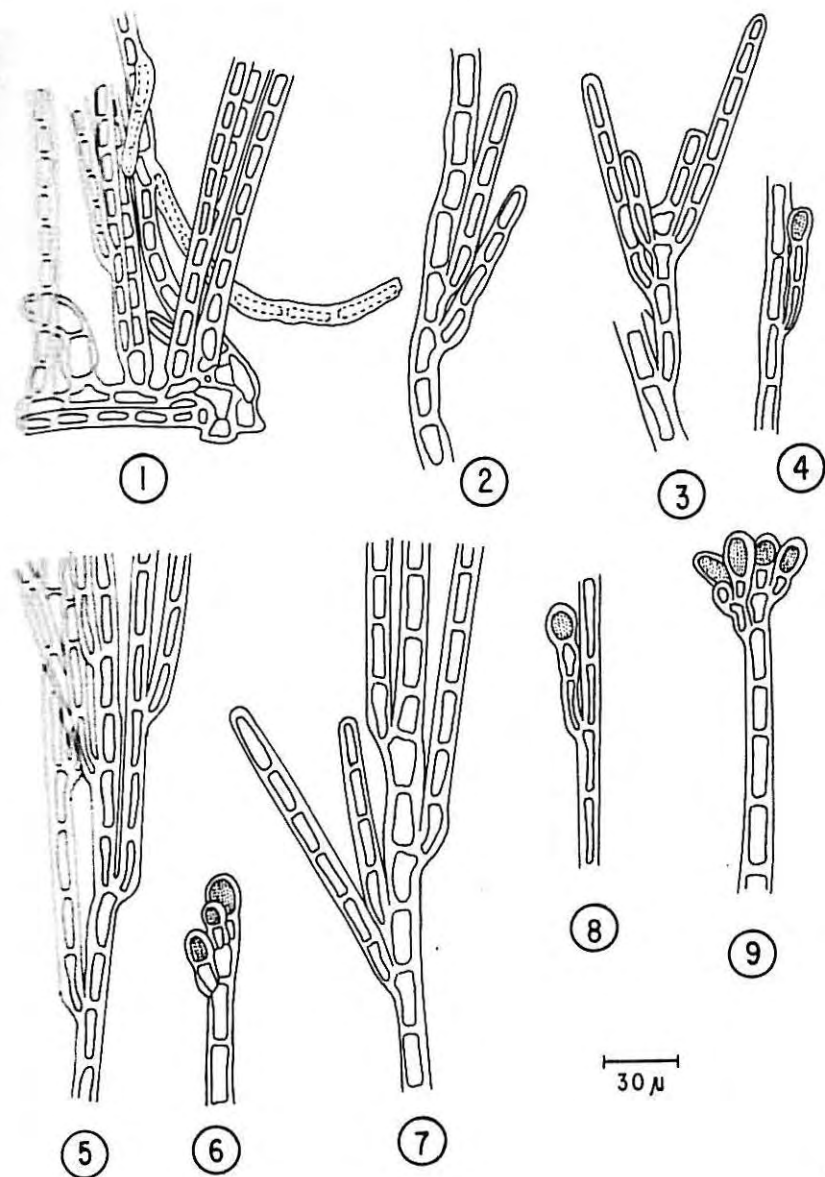


Plate V, Figs. 1-9: *Rhodochorton sucrease* D'Acosta et Ganesan sp. nov. Fig. 1: Basal part of a plant to show creeping and erect filaments and the origin of rhizoids from the erect filaments. Figs. 2, 3, 5 & 7: Erect filaments to show variations in branching pattern. Figs. 4, 8: Monosporangia borne on two-celled laterals. Figs. 3, 6: Monosporangia on single-celled laterals. Fig. 9: A terminal cluster of monosporangia.



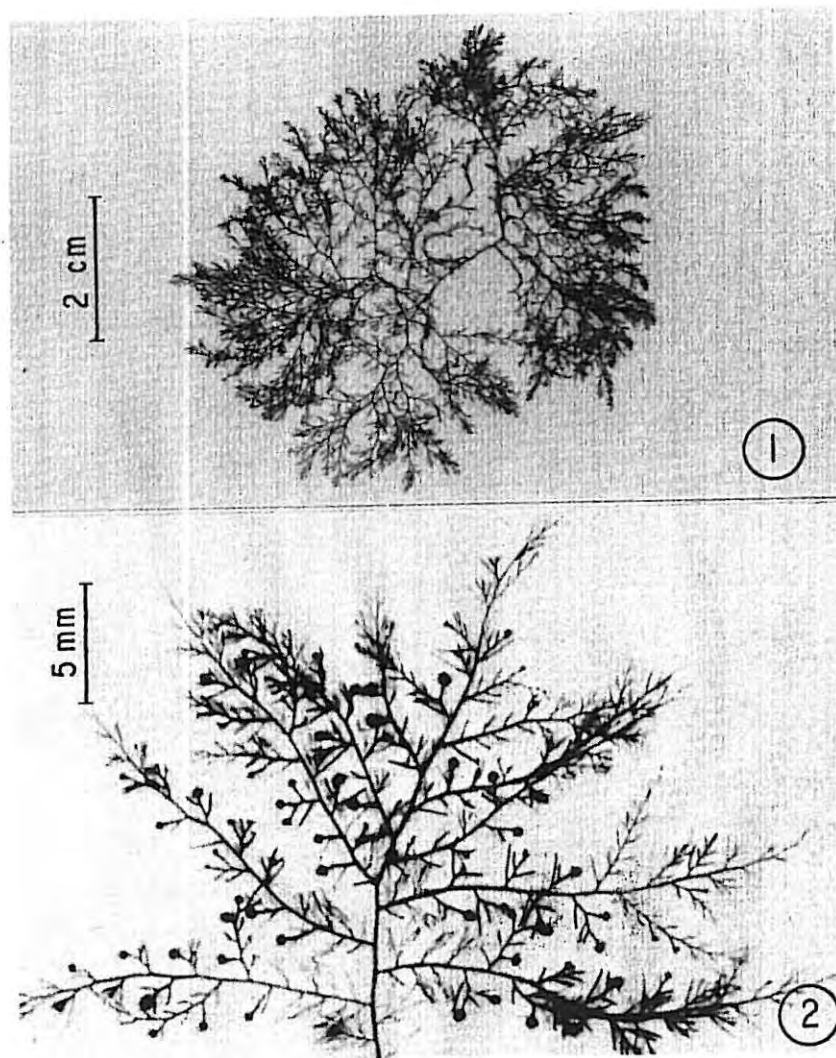


Plate VI, Figs. 1-2: *Bostrychia moritziana*. Fig. 1: Habit of a tetrasporic plant. Fig. 2: Habit of a cystocarpic plant.

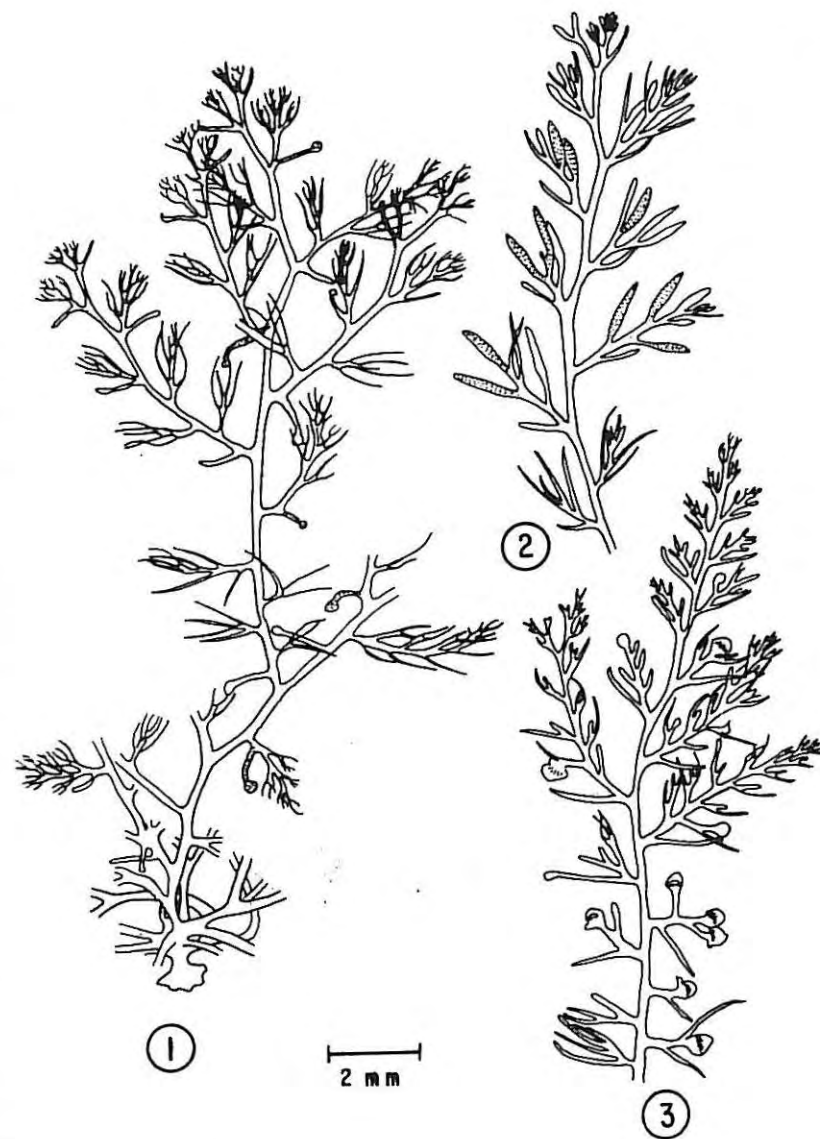


Plate VII, Figs. 1-3: *Bostrychia moritziana*. Fig. 1: Habit of a sterile plant to show the discoidal base, indeterminate and determinate branches and the haptera. Fig. 2: Part of a tetrasporic plant to show the tetrasporic stichidia. Fig. 3: Part of a cystocarpic plant to show the spherical cystocarps.

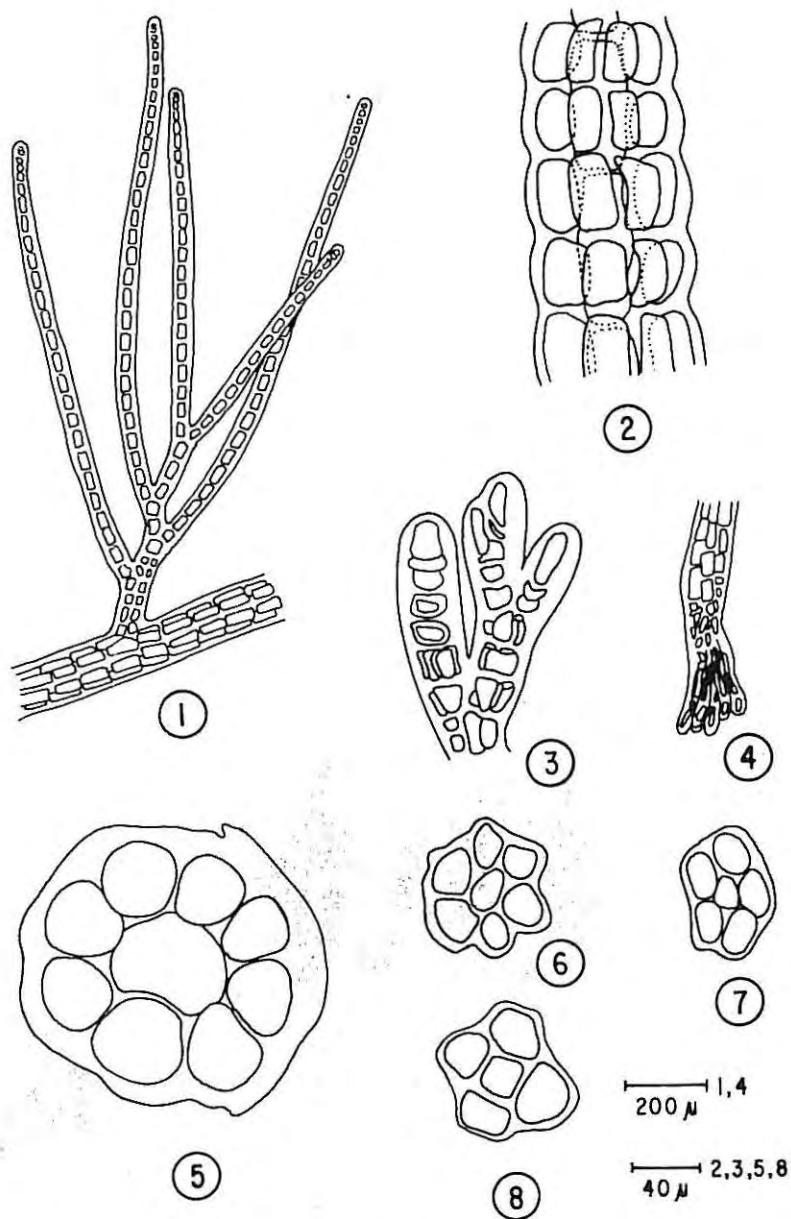


Plate VIII: Figs. 1-7: *Bostrychia moritziana*. Fig. 1: A determinate branch to show polysiphonous base and the terminal monosiphonous segments. Fig. 2: Part of an indeterminate branch to show the disposition of pericentrals. Fig. 3: Apex of young branches to show apical cells and the initiation of pericentrals. Fig. 4: A hapteron with simple multicellular rhizoids. Figs. 5-8: Transections to show varying number of pericentral cells and a central cell.

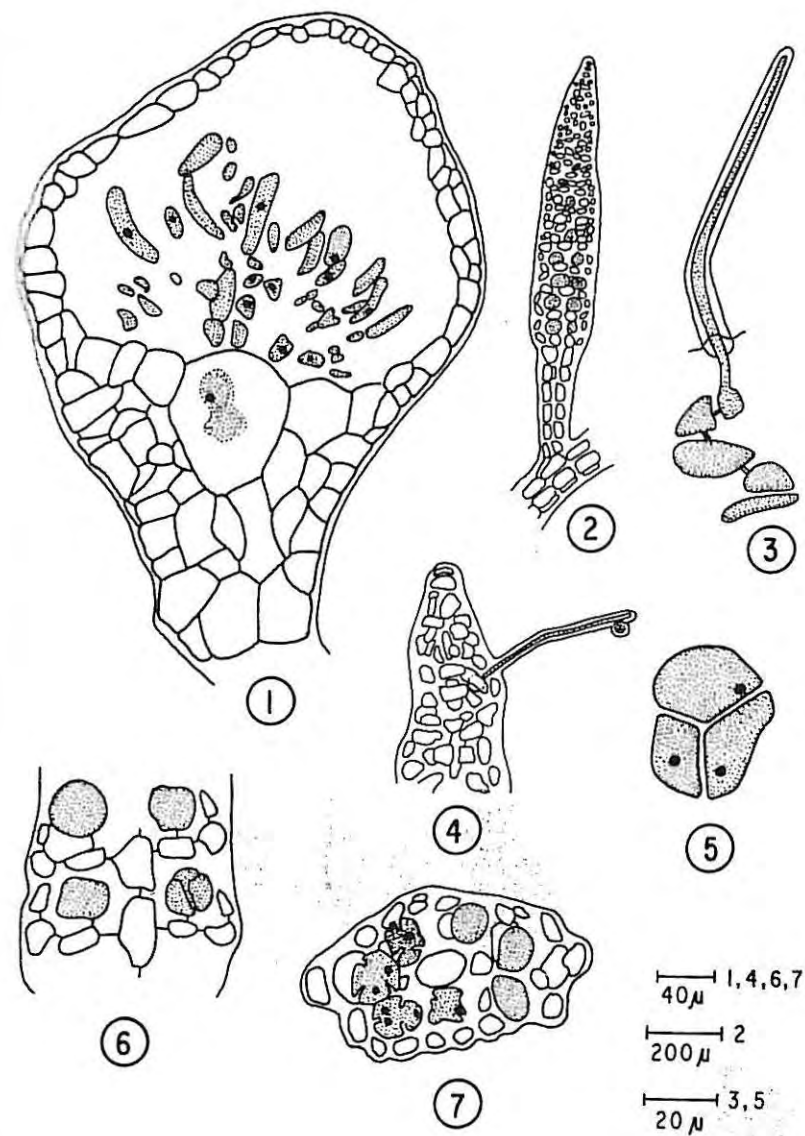


Plate IX: Figs. 1-7: *Bostrychia moritziana*. Fig. 1: Longisection of a cystocarp to show carposporangia and a large basal fusion cell. Fig. 2: A tetrasporic stichidium. Fig. 3: A carpogonial branch. Fig. 4: An antheridium attached to the trichogyne. Fig. 5: Mature tetraspores. Fig. 6: Part of a longisection of a stichidium to show 3 tetrasporangial mother cells, each borne on a basal cell and covered by a two-celled sterile branch. Fig. 7: Transection of a mature stichidium to show 7 tetrasporangia surrounding a central cell.