

***Rhodolachne radicata*, a New Species of Red Alga (Rhodomelaceae, Ceramiales) from Fiji and Southern Parts of Japan**

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Abstract

A new species of the genus *Rhodolachne* Wynne is described based on the materials collected at the mangrove forests in Fiji and the southern parts of Japan. *Rhodolachne radicata* is distinctive in producing uniseriate rhizoids and in having tetrasporangia in pairs on the adjacent two pericentral cells in the fertile segment and each of the tetrasporangia is covered with three groups of two-celled corticating system. Detailed accounts on the vegetative structures and the tetrasporangial stichidia are given.

Introduction

The genus *Rhodolachne* was established by Wynne (1970) based on the specimens collected at Anse aux Pins, Mahé, Seychelles in the Indian Ocean. *Rhodolachne* is monotypic with the type species *Rhodolachne decussata* Wynne. Subsequent record of this species was made by Womersley & Bailey (1970) based on the specimens from the Solomon Islands. *Rhodolachne* provides distinctive features from other genera in the Rhodomelaceae, but its taxonomic relationship with other genera still remains obscure.

The genus has so far been recorded from the restricted parts of the world. It was therefore of interest when, as part of a survey of the marine algae of Fijian and the southern Japanese waters, one undescribed species of *Rhodolachne* was encountered which considerably expand both the geographical and morphological ranges of the genus. I have named the new species *Rhodolachne radicata* for its well developed attachment system.

This paper gives description of this species and the accounts on the vegetative structures and the tetrasporangial stichidia.

***Rhodolachne radicata* ITONO sp. nov.**

Thalli filamentosa e filamentis prostrati per rhizoidea multicellularia ad substratum affixis et e ramis erectis constans; rami erecti usque ad 6 mm alt., et 48-59 μm

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diam. ; rhizoidea e cellula pericentralis rami prostrati orientata ; axes prostrati et erecti uniaxiales, quattuor cellulas pericentrales omni in segmento quae transverse semel se dividunt, inferio cum cellula centrali connexa, haec cellulae ad axem thalli longum perpendiculariter visi ; tetrasporangia tetrahedraliter divisa, 36-43 μm diam., duo per segmentum, in seribus longitudinalibus in stichidiis ramis erectis terminalibus contenta ; plantae sexuales ignotae.

Thalli filamentous, with prostrate filaments attached by multicellular rhizoids to substratum and erect filament ; erect filaments up to 6 mm high and 48-59 μm in diameter ; rhizoids arising from pericentral cells of prostrate filaments ; prostrate and erect axes uniaxial, four pericentral cells in each segment and each divided into two, the lower in pit connection with central cell, these cells appeared to be longitudinally arranged on the axes ; tetrasporangia tetrahedrally divided, 36-43 μm in diameter, two per segment, in longitudinal rows in stichidia terminal to the erect axes ; sexual plants unknown.

Holotype : HI19841, tetrasporic, collected on 4-I-1982 by H. Itono, epiphytic on the prop roots of *Rhizophora* sp. at the estuary of the Rewa river, Viti Levu, Fiji.

Specimen is deposited in the Herbarium, Faculty of Science, Kagoshima University.

Observations on the specimens from the Ishigaki Island, southern part of Japan (HI19842, sterile, Miyara river and HI19843, sterile, Nagura river, both collected on 27-V-1984) represent that their vegetative structures are homologous to the Fijian materials suggesting to be conspecific with *Rhodolachne radicata* and thus this species is presently known from the type locality and from the Ishigaki Island, southern part of Japan.

Vegetative structures : The thalli are turf-like, with erect axes in groups of up to four from the prostrate axes attached by uniseriate rhizoids. The axes are uniaxial and the apical cell cuts off segmental cells from its posterior end (Figs. 1, 4, 7, 17). Division is not strictly transverse, but is slightly oblique, with the result that the high sides of the successive segments tend to generate spiral about the axis, but not in any very regular way. In general, four pericentral cells are produced in each segment (Fig. 3). Some segments, however, occasionally have one less or one more pericentral cell than usual four pericentral cells (Fig. 14). Initiation of the pericentral cells occurs within one to three segments below the apical cell (Figs. 1, 4, 5, 7, 17.). The first-formed pericentral cells are cut off on the high side, and therefore also tend to lie in a spiral around the axis. The second and third pericentral cells are adjacent to the first, and the fourth is opposite the first, their sequence is thus typical of the Rhodomelaceae. In the early stages each successive pericentral cell in a segment is smaller than the one produced before it, the fourth being the smallest. In later stages all four pericentral cells become almost equal size.

Each pericentral cell undergoes transverse division producing a filament two cells

long as is a diagnostic character of *Rhodolachne*, and the lower cell of which retains the pit connection with the axial cell. No subsequent division is usually observed, but infrequently upper cell of the two celled filament continues one or two divisions (Fig. 9, **d2, d3**).

Only the primary pit connection links the axial cell with each pericentral cell. Secondary pit connections are formed between the pericentral cells and the derivative cells of the pericentral cells in the segment below, commencing five to six segments below the apex.

At first the pericentral cells are attached to the middle of the axial cell, but during the growth, the upper part of the axial cell extends more than does the lower part, with the result that the point of attachments is ultimately situated in the lower one third of the axial cell. Upper cells of one segment tend to overlie the lower tip of the axial cell in the segment above. Cells of the central axis are narrow cylindrical, about 7 to 10 times as long as they broad.

The mature pericentral cells and their derivatives are arranged in four lines parallel to the long axis of the plant, but slightly shift (Fig.2) either to the right or to the left, showing the characteristic spiral arrangement of the decussate pairs of cells around the axial cells.

Plants are fundamentally erect, but as they grow the axes become secondarily prostrate with terminal erect or semi-prostrate axes. The prostrate axes are attached to the substratum by uniseriate rhizoids. The rhizoids are initiated by extension of the pericentral cells (Fig. 8, 10, **rhi**). Single rhizoidal initial is generated from each pericentral cell. Initiation of the rhizoids is seen at irregular intervals in the prostrate axes, and all pericentral cells of the prostrate axes as well as those of the basal segments of the erect axes are capable of producing rhizoids. Among the large amounts of materials used in this observations, as many as seven rhizoids are seen at the point of branching of the prostrate axes. The rhizoid initials are cut off from the pericentral cells while they are still small and grow toward the substratum by successive transverse divisions of the initial cells and by the enlargement of each segment. Rhizoids are usually unbranched or rarely branched few times and at first every segments of them devoid of pericentral cells (Fig. 7). Subsequently the proximal cell of a rhizoid begins to form pericentral cells (Fig. 11) and initiation of the pericentral cells may occur toward the mid part of a rhizoid (Fig. 12). In contrast to the regular formation of the

cells. Fig. 4. Apex of vegetative erect axis, showing exogenously produced lateral branch initial. Fig. 5. Endogenously produced branch of erect axis. Fig. 6. Part of vegetative axis, with exogenous branch laterally and adventitious branch terminally. Fig. 7. Part of prostrate axis with rhizoid and exogenously produced erect axis. Fig. 8. Lower part of erect axis, showing two initials of rhizoid on pericentral cells. (Scales: 50 μ m).

Abbreviations used in the figures. **a**: apical cell; **ap**: apex; **ax**: axial cell; **co1, co2**: first cover cell, second cover cell; **coi**: cover-cell initial; **d1, d2, d3**: first derivative cell of pericentral cell, second derivative cell of pericentral cell, etc.; **lb**: lateral branch; **lb1, lb2**: number of lateral branch; **lbi**: lateral-branch initial; **p**: pericentral cell; **rh**: rhizoid; **rhi**: rhizoid initial; **stk**: stalk cell; **ts**: tetrasporangium.

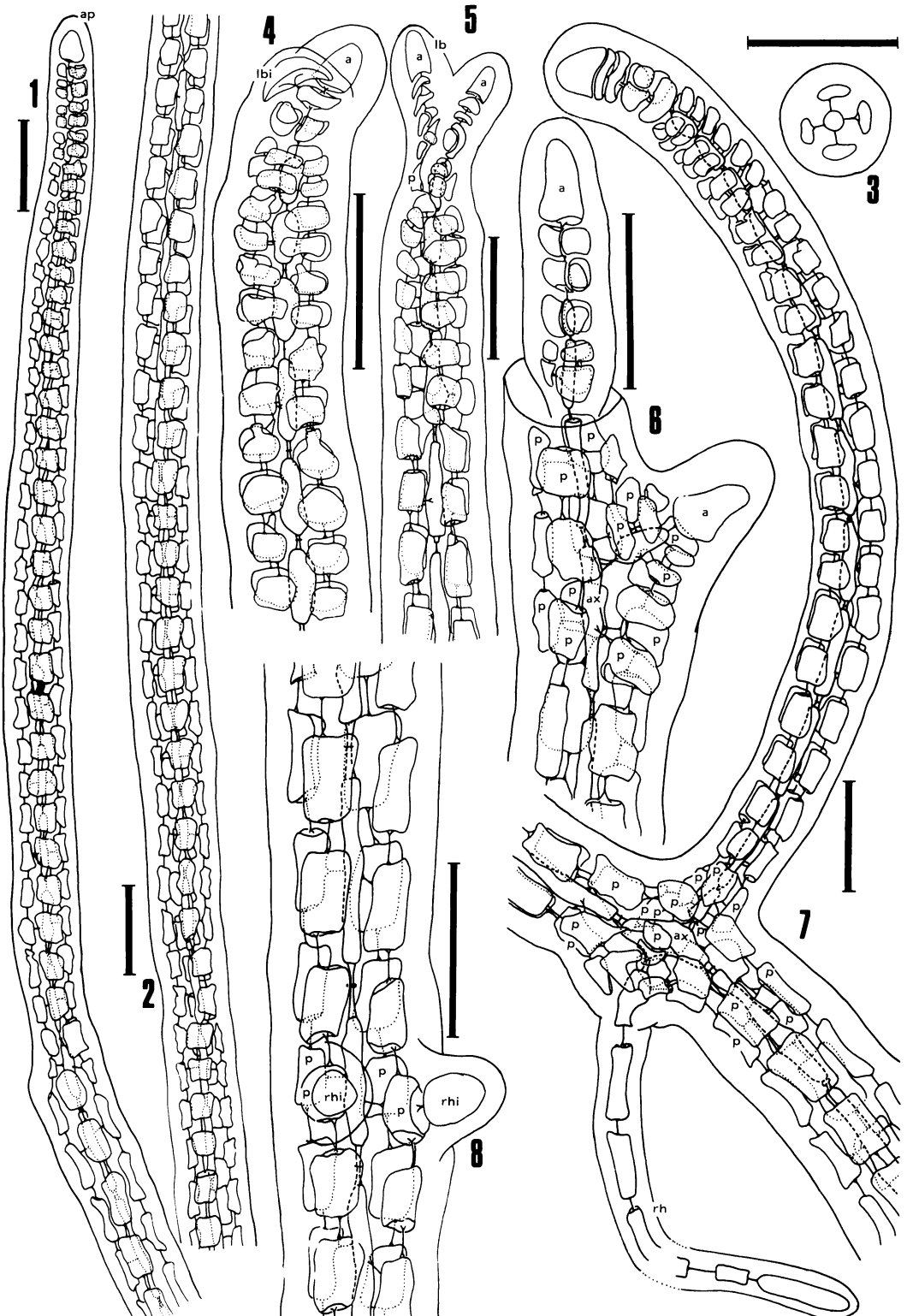


Fig. 1. Apex of vegetative erect axis. Fig. 2. Vegetative axis, with characteristic spiral arrangement of decussate pairs of cells around the axis. Fig. 3. Transverse section of axis, showing decussately arranged four pericentral

pericentral cells in prostrate and erect axes, the number of the pericentral cells in the rhizoids varies one to four per segment (Fig. 12). The pericentral cells thus formed usually remain undivided, but rarely they undergo transverse division cutting off small derivative cells toward the tips of the rhizoids, or they directly initiate the attachment rhizoids (Fig. 12). The tip of each rhizoid is mostly ending in blunt tip since no pericentral cell is formed in the terminal part of the rhizoid (Figs. 7, 11-12), but occasionally the prostrate axes are attached to the substrate by discoid haptere due to the progressive initiations of the pericentral cells from every segments of the rhizoid.

Erect branches arise in groups of up to four from lateral to dorsal surface of the principal exogenous branches of the prostrate system, and are simple or branched few times. Branches in the vegetative system are either exogenous or endogenous in origin. In the case of exogenous branching, which is produced only on the axes while they are still erect, the initials of the laterals are cut off from an axial segment near the apex before any pericentral cells have been produced (Fig. 4, **lbi**) and it is evident that the basal segments of these exogenously-derived branches have usual number of pericentral cells. In the erect axes, such exogenous branches remain small while they are still close to the apex of the main axes, and after the main axes grow well they commonly develop into lateral branches. The branching in the erect axes is thus not being dichotomous.

Although the endogenous branching is usually seen only when the erect axes arise from the surface of the prostrate system, in rare case erect branches initiate lateral branches endogenously, and these branches arise from the pericentral cells. The growth pattern is illustrated in Figure 5 (**1b**), in which one of four pericentral cells has initiated a branch. In the erect part of the thallus such endogenous branching discolor all cells either in lateral or in the main axes above the dichotomy, and all cells remain small in comparison with normally growing cells. These observations suggest that they either remain rudimentary or disintegrate.

As has already been pointed out, the lateral branches in the prostrate axes are endogenous in origin. Endogenous branches are easily identified because they originate from the pericentral cells. Usually one to three endogenous branches are produced at the point of the principal exogenous branching or only one branch is arising endogenously at irregular intervals from the dorsal surface of the prostrate axes (Fig. 9).

One of the most distinctive features of *Rhodolachne radicata* is shown in Figure 13, in which erect branch has been formed from a segment of rhizoid. As mentioned earlier in this paper, the rhizoids of the present species are divided into two types, and the initiation of erect branch may occur only on the rhizoids in which most segments devoid of pericentral cells. In such rhizoid some segment initiate up to four pericentral cells each and one segment of them provides erect branch. In Figure 13, it is difficult to distinguish whether the branch is exogenous or endogenous in origin, but the position of the pit connection between the basal axial cell of the erect branch and the rhizoidal cell suggests that the branch is endogenously formed, i. e., the basal segment of the erect branch is homologous to the pericentral cell of the rhizoidal cell.

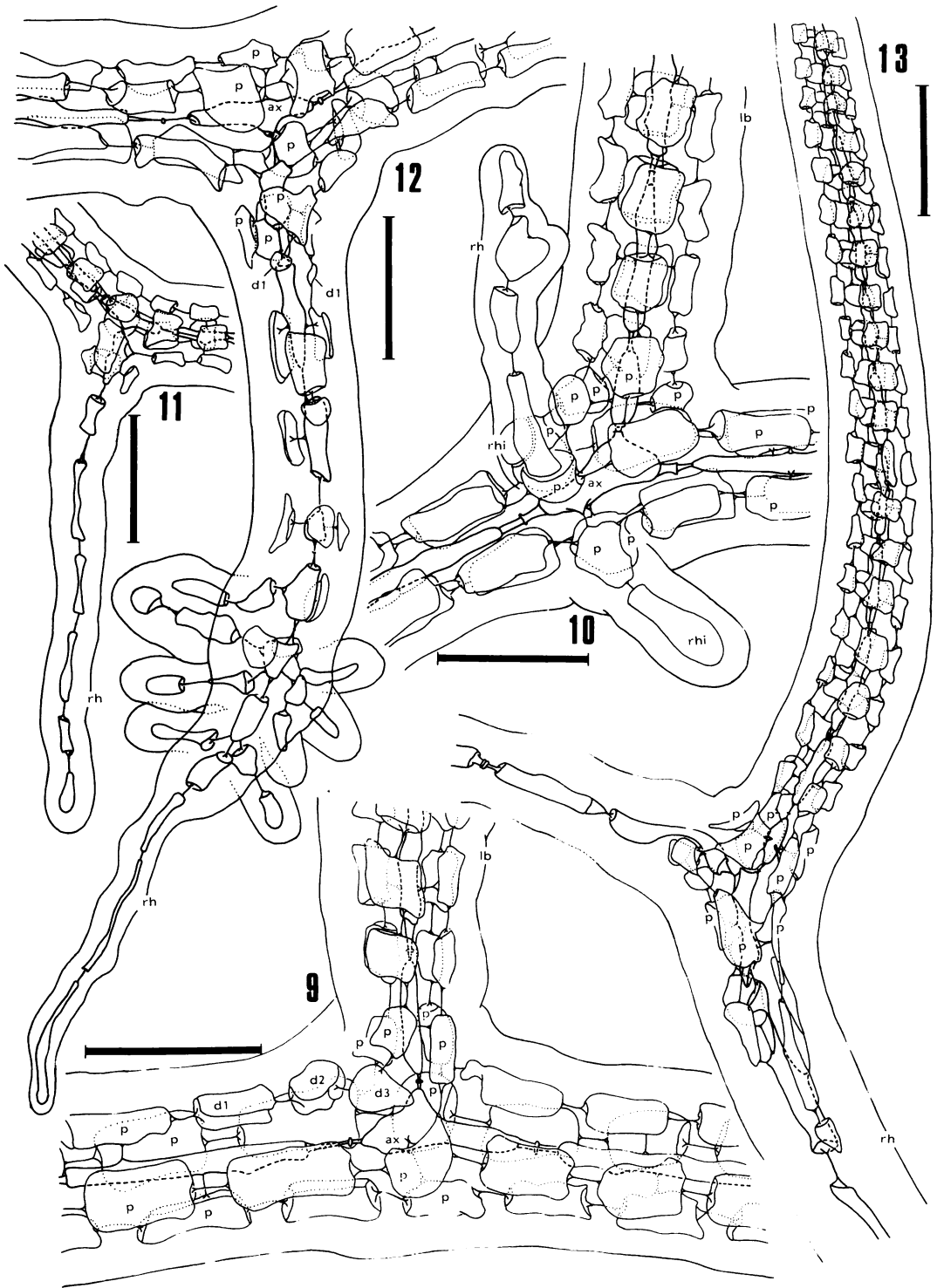


Fig. 9. Part of prostrate axis with endogenously produced erect axis. Fig. 10. Young rhizoid and two rhizoid initials on pericentral cells of principal exogenous branching in prostrate axis. Fig. 11-12. Parts of prostrate axis with rhizoid. Fig. 13. Erect axis produced endogenously from segment of rhizoid. (Scales: 50 μ m).

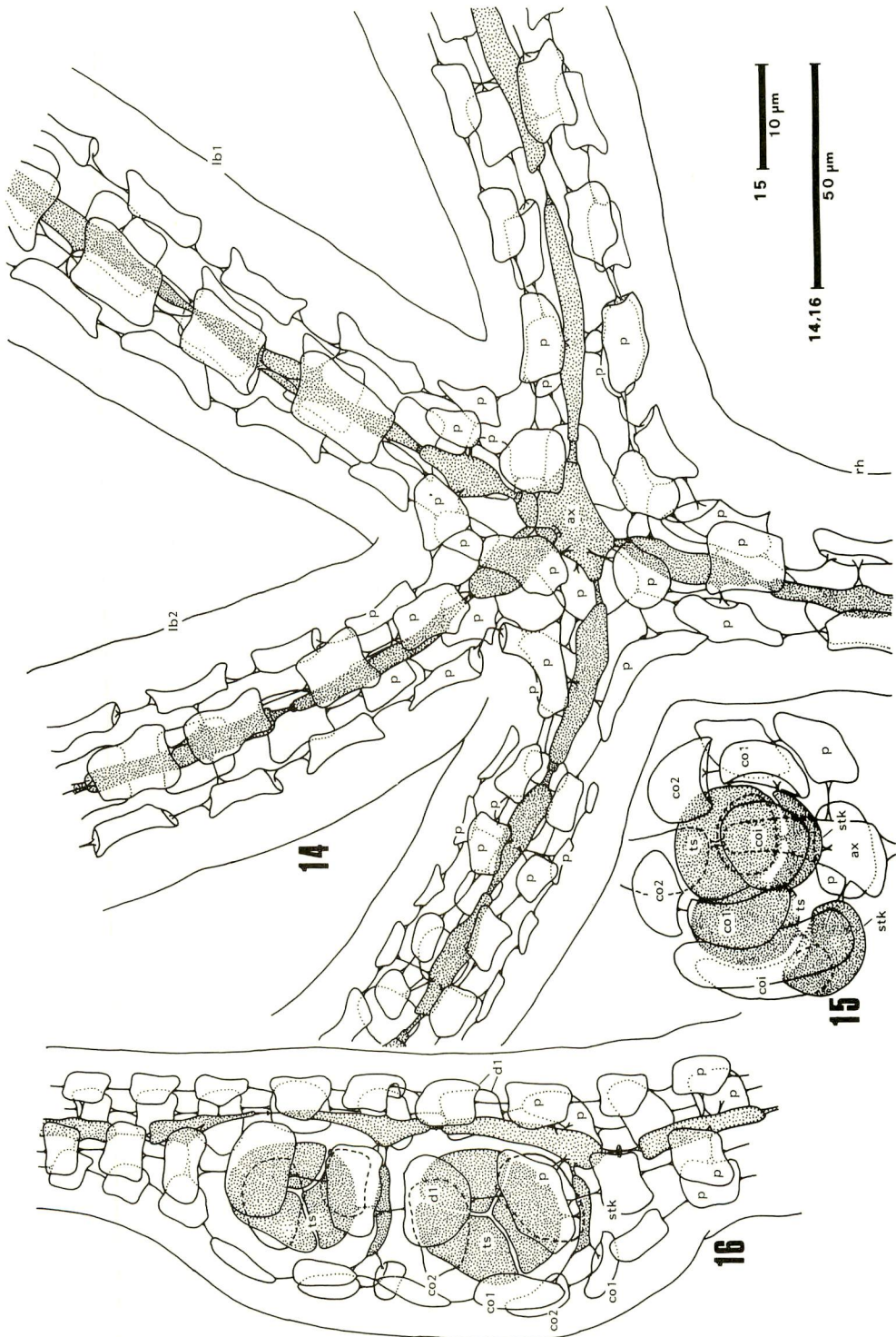


Fig. 14. Part of prostrate axis with rhizoid and erect axes. Fig. 15. Fertile segment, showing two young tetrasporangia and branching of cover cells. Fig. 16. Part of tetrasporangial stichidium with tetrahedrally divided tetrasporangium per segment.

Although the branching is either exogenous or endogenous in origin, no structural differentiation exists between prostrate and erect axes. Some erect axes arising from the prostrate axes curve slightly suggesting that the thalli have dorsiventral construction (Fig. 7), but all pericentral cells are essentially functionable to initiate either branches or rhizoids and there is no evidence to suggest both prostrate and erect axes as having dorsiventrality. Thus, they are considered to have radial construction.

The basal segments of the lateral branches are noticeably shorter than distal segments of the same branches, and have usually four pericentral cells. However, some of these segments provide a reduced number of pericentral cells (Fig. 14, **lb2**) and some initiate five pericentral cells (Fig. 14, **lb1**). Each pericentral cell on the basal segments of the branches normally divides into two cells (Figs. 6, 9) or sometimes remains undivided (Figs. 13, 14, **lb2**), or even these two types of the pericentral cells are formed on the same basal segment (Figs. 7, 10, 14, **lb1**).

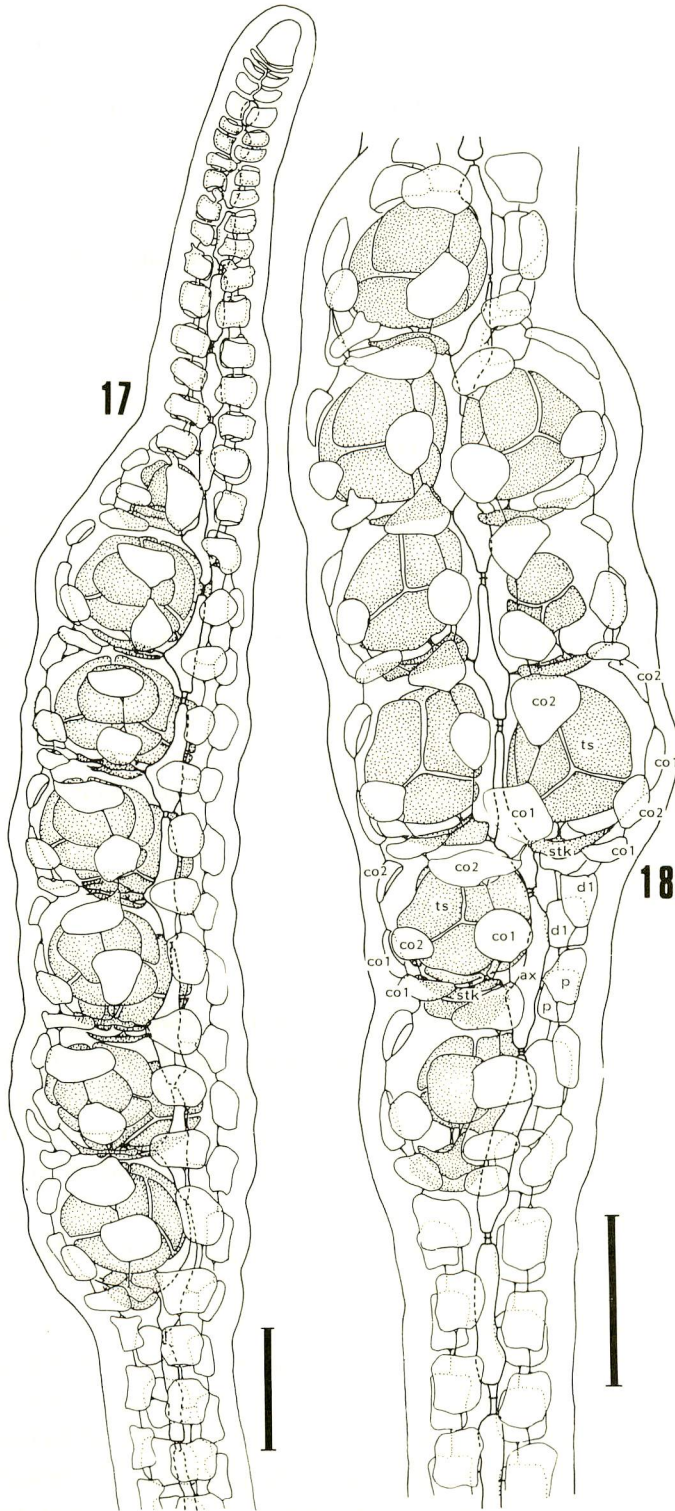
Figure 6 shows the young axis which is initiated adventitiously from the axial cell after the loss of the upper axis by some injury.

Tetrasporangia : Tetrasporangia occur in the terminal portions of erect or semi-prostrate axes. When fully developed the fertile branches are swollen, terete, and stichidia-like (Figs. 16-18). Stichidia are up to 96 μm broad and the production of tetrasporangia continues to some extent giving long stichidial regions. In general, the fertile branches provide four pericentral cells in each segment as in the case of the vegetative axes, and two tetrasporangia are produced in each segment (Figs. 17-18), or in rare case only one tetrasporangium is produced (Fig. 16). The sequence of pericentral cell formation is the same as that of the vegetative axis.

A fertile pericentral cell first cut off two cover-cell initials by oblique longitudinal divisions and then it divides transversely, producing a tetrasporangium on the upper side and a residual stalk cell (Fig. 15). The cover-cell initials first divide transversely to produce two-celled corticating system which grows up and about the developing tetrasporangium. A third cover-cell initial is cut off from the face of the stalk cell after the tetrasporangium is cut off (Fig. 15). A third cover-cell initial subsequently divides once by almost transverse division, and thus three groups of two-celled corticating system are developed from each stalk cell. In fully developed corticating system, the lower cell of each two-celled corticating system is connected by the secondary pit-connection with the upper cell of the corticating system produced in the segment below except those of the last formed corticating system in each segment (Figs. 17-18).

The fertile segments initiate four pericentral cells as described before, and only two adjacent pericentral cells become fertile but two pericentral cells remain sterile. Sterile pericentral cells in the fertile branch are undifferentiated and the division of these cells is the same as that of the vegetative axes. In the present observations, I can not elucidate the relation between the fertile pericentral cells and the sequence of pericentral cell formation in the fertile segment.

The pairs of tetrasporangia in successive segments develop in longitudinal row



Figs. 17-18. Tetrasporangial stichidia, showing arrangement of tetrasporangia and corticating filaments. (Scales: 50 μ m).

(Fig. 17), but occasionally the pairs of tetrasporangia are arranged at nearly right angles with the 1/4 divergence (Fig. 18).

Figure 16 includes anomalous example in which only one pericentral cell becomes fertile but other three remain sterile. In such part, fertile pericentral cell initiates corticating system and tetrasporangium normally, but other three pericentral cells in the segment divide once transversely as in the case of vegetative axes.

A tetrasporangium divides into four tetrahedrally arranged tetraspores, which are cut out simultaneously. Mature tetrasporangia are isodiametric and measure 36-43 μm in diameter.

Discussion

The genus *Rhodolachne* is morphologically distinct and is characterized by a combination of the following features based on the results obtained by Wynne (1970, 1970a) and Womersley & Bailey (1970).

- 1.) Transverse division of the pericentral cells into two, with the lower retaining pit connection with the axial cell.
- 2.) Spiral arrangement of the decussate pairs of the pericentral cells and their derivatives.
- 3.) Exogenous branching of erect branches and endogenous branching of prostrate branches.
- 4.) Radial symmetry of erect branch apices.
- 5.) Complete lack of trichoblasts.
- 6.) Presence of two tetrasporangia per segment in the stichidia-like branches.

Although detail of many features such as the procarp and its post-fertilization developments is still poorly known, the known features of *Rhodolachne* provide the significant characteristics among the genera in the Rhodomelaceae. In assessing the relationship of *Rhodolachne* with other genera in this family, Wynne (1970, 1970a) and Womersley & Bailey (1970) compared *Rhodolachne* with some genera in Rhodomelaceae, especially with those of Bostrychieae and Rhodomeleae, and Womersley & Bailey provisionally placed *Rhodolachne* under newly established tribe Rhodolachneae, suggesting the necessity of further study on the young female reproductive structures in this genus.

All characteristics of the genus *Rhodolachne* described above are essentially found in the materials of *Rhodolachne radicata*, a second species of the genus, and the placement of the present new species under this genus is thus feasible, although there are differences in a number of important features between *Rhodolachne radicata* and the type of the genus *Rhodolachne decussata*. The significant differences between these two species are the position of the tetrasporangia in a fertile segment, number of cover cells that surround a tetrasporangium and the structure of the attachment rhizoids. The tetrasporangia in *Rhodolachne radicata* are borne in pairs on the adjacent two

pericentral cells in a fertile segment, whereas in *Rhodolachne decussata* they are borne on the lateral pericentral cells. In the type description of the genus (Wynne, 1970) it is not clear that which pericentral cells in the fertile segment may initiate tetrasporangia, but according to Womersley & Bailey (1970) their descriptions and illustrations of the tetrasporangial stichidia in *Rhodolachne decussata* suggest that tetrasporangia are associated with particular pericentral cells in a fertile segment. These may be either the first and fourth or the second and third pericentral cells in each segment. It is generally accepted that the tetrasporangia tend to be produced on particular pericentral cell in most of the genera and species of the Rhodomelaceae. Therefore, if the restriction of tetrasporangia either to the first and fourth or to the second and third pericentral cells is regarded as generic criterion of *Rhodolachne*, the generic placement of the present species under this genus becomes unwarranted. In the present paper, however, I am of the opinion that such difference in position of the tetrasporangia in a fertile segment should be used as characteristic in distinguishing species. The stalk cell and tetrasporangium in each fertile segment are covered outwardly by six cover cells in *Rhodolachne radicata*, whereas in *Rhodolachne decussata* they are five.

Prostrate habit, with upright axes growing from prostrate system, is consistently adopted in *Rhodolachne decussata*, and the prostrate branches are attached by unicellular rhizoids formed by extensions of pericentral cells. In *Rhodolachne radicata* only secondary prostrate axes are formed from the modification of the lower axes of the well grown erect axes, and the prostrate branches are attached by uniseriate rhizoids that are cut off from the pericentral cells. Some segments of the uniseriate rhizoids produce up to four pericentral cells and erect branches are occasionally initiated endogenously from the segment of the rhizoidal portion. Such development of the erect branches, which is not described in *Rhodolachne decussata*, suggests that rhizoids in *Rhodolachne radicata* are the homologous structures to those of the branches and *Rhodolachne radicata* is morphologically distinct in its attachment rhizoids.

Unfortunately several features is still unknown especially those of the spermatangial and procarpial structures including their subsequent postfertilization development. However, the known features enable the present species to place under the genus *Rhodolachne* among the large numbers of genera in the Rhodomelaceae, but distinguish it from type species of the genus.

In the type description (Wynne, 1970) and in the subsequent observations by Womersley & Bailey (1970) they recorded that *Rhodolachne decussata* was found as growing on the encrusting coralline algae. *Rhodolachne radicata* was, however, found as epiphytic on the prop root of *Rhizophora* either in Fiji or in the southern parts of Japan, and in these localities this species constitutes a common mangrove inhabitant along with *Bostrychia moritziana*, *Bostrychia radicans* and *Bostrychia kelanensis*. Such difference in habitat in these two species may be used as another means of distinguishing *Rhodolachne radicata* from *Rhodolachne decussata*.

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