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Studies on freshwater red algae of Malaysia VI. Morphology of *Batrachospermum gibberosum* (KUMANO), comb. nov.

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Tuomeya gibberosa differs from *T. americana* in the presence of the secondary branchlets and the absence of the gonimoblast placenta, the latter of which is characteristic of the genus *Tuomeya*. In the structure of thallus and the process of the fertilization, *T. gibberosa* is similar to the genus *Batrachospermum*. *T. gibberosa* is thus transferred to the genus *Batrachospermum* as *B. gibberosum* (KUMANO) comb. nov., basionym *Tuomeya gibberosa* KUMANO.

Key Index Words: Batrachospermum gibberosum; *freshwater Rhodophyta*; *Malaysia*; *process of fertilization*; *structure of thallus*; *taxonomy*; Tuomeya.

KÜTZING (1857) described *Baileya americana* based on the specimens collected by BAILEY. On the other hand, HARVEY (1858) described the same plant under the binomial *Tuomeya fluviatilis* based on the specimens collected by TUOMEY and BAILEY from North America. According to PAPENFUSS (1958), the generic name *Baileya* KÜTZING (1857) is invalidated by *Baileya* HARVEY (1849), although KÜTZING's specific name *americana* has priority over *fluviatilis*, this plant therefore should be known as *Tuomeya americana* (KÜTZING) PAPENFUSS. KÜTZING (1857) and HARVEY (1858) did not illustrate the reproductive organs of *T. americana*. However, the carpogonium-bearing branches illustrated by SETCHELL (1890), SKUJA (1944) and WEBSTER (1958) are strongly curved and appear to be similar to those found in the taxa of the section *Contorta* of the genus *Batrachospermum*. WEBSTER (1958) showed that *T. americana* formed the gonimoblast placenta, which has not been reported in the taxa of the genus *Batrachospermum*. *T. gibberosa* KUMANO (1978) has also a twisted carpogonium-bearing branch and produces a quite compact gonimoblast as found in the genus *Batrachospermum*. ENTWISLE and KRAFT (1984) pointed out that *T. gibberosa* appears to resemble the taxa of the section *Contorta* of the genus *Batrachospermum* and suggested that the reproductive features of this species should be re-examined. The present study provides the details on the vegetative and reproductive features of *T. gibberosa*.

Specimens examined in the present study

A holotype specimen and the duplicates collected by KUMANO from the type locality, Sungai Maron Kanan, Negeri Sembilan, Malaysia on April 26 and September 12, 1971, were examined. Other specimens examined were collected by M. RATNASABAPATHY of University of Malaya, from Sungai Air Terjin, Pulau Langkawi, Malaysia on November 11, 1979. All specimens examined are deposited in the Herbarium of Faculty of Science, Kobe University, Japan. Materials for the cytological study were fixed with an acetoalcohol (1 : 3) solution and WITTMANN's aceto - iron - haematoxylin - chloral hydrate method (WITTMANN 1965) was used for staining.

Observations

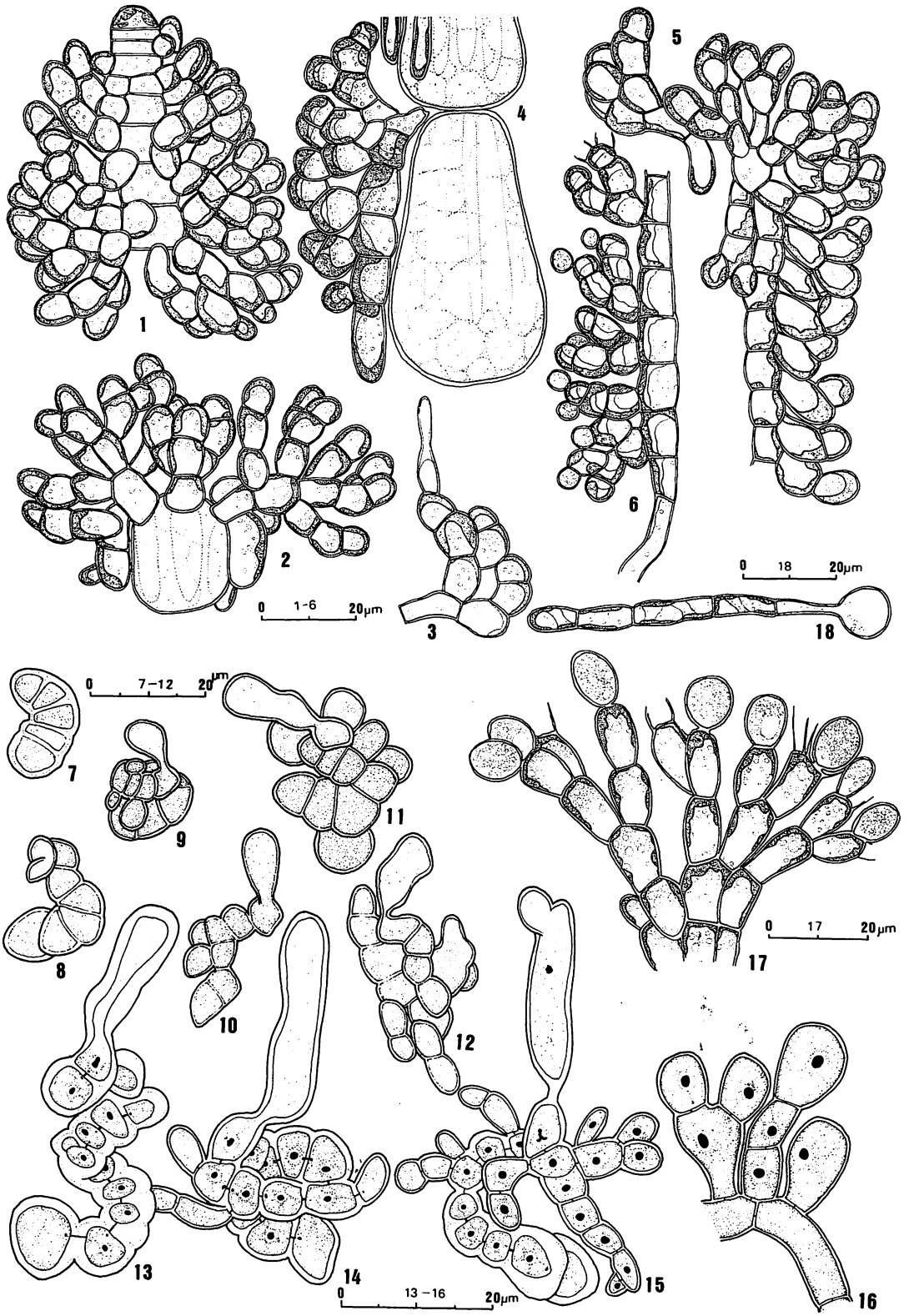
Vegetative Features: The apical cells of the thallus cuts off discoid segments, which are divided by longitudinal walls to produce several initials of primary branchlets, which are called the basal cells of the primary branchlets (Fig. 1). Primary branchlets are dichotomously, sometimes trichotomously branched and consist of 3-5 cell-strories (Figs. 1-2). Proximal cells of fascicles are barrel-shaped, distal cells are ovoidal and the outermost cells smallest, ovoidal and sometimes dome-shaped. A large parietal chromatophore is contained in each cell of the fascicle (Figs. 1-6). Hair cells rarely occur at the tip of primary branchlets and are varying in length (Fig. 3). From the basal cell of the primary branchlet, cortical filaments grow downwards around the axial cell, extend over along the next axial cell and tightly attached to it and with each other (Fig. 4). The pseudoparenchymatous feature of the cortical filaments is thus formed. The secondary branchlets are sparsely, somtimes dichotomously branched, consisting of 2-3 cell-stories and cover all the internodes.

Reproductive Features: Spermatangia are 4-6 μm in diameter, globose and therminal both on primary and secondary branchlets (Figs. 6, 21). In the process of the development of a carpogonium-bearing branch, it becomes twisted and coiled as the number of composing cells increases (Figs. 7-12, 20). The degree of twistings is two or three times. The walls of cells of the carpogonium-bearing branch are very thick and pit-connections are clearly recognizable between these cells (Figs. 13-15). The terminal portion of the young carpogonium swells out (Fig. 8) to form a rounded trichogyne initial (Fig. 9) and becomes a cylindrical or club-shaped trichogyne with a stalk (Figs. 10-15). The trichogyne is somewhat asymmetrical and slightly bent at the basal portion. The cytoplasm of an unfertilized carpogonium contains a female nucleus in the basal portion of the carpogonium, but no nucleus is seen in the trichogyne (Figs. 13-14). After attaching to the trichogyne, the nucleus of the spermatium divides into two nuclei, one of which fuses with the female nucleus, but another remains in the trichogyne (Fig. 15). After the male nucleus reaches the female, the wall of the basal portion of the trichogyne becomes thicker, and eventually separate the trichogyne from the carpogonium by the thick walled connection. Gonimoblast filaments grow out into radially branched, more or less compactly agglomerated one (Figs. 15, 17). This manner of the development of the carposporophyte is the same as those found in the taxa of the genus *Batrachospermum.* Bracts are frequent but very short, so that the gonimoblast is naked and forms a wart-like or semiglobular protuberance at the central axis (Fig. 22). Carposporangia are terminal on the compactly agglomerated gonimoblast filaments (Fig. 23).

Discussion

HARVEY (1858) mentioned that thallus in the genus *Tuomeya* possessed the solid axis as in the genus *Batrachospermum,* shut up within the tube as in the genus *Lemanea,* and coated externally with the filaments as

Figs. 1-18. *Batrachospermum gibberosum* (KUMANO) KUMANO, comb. nov. 1. An apical portion of thallus showing an apical cell, axial cells and primary branchlets; 2. A very young portion of thallus showing an axial cell, three primary branchlets and two cortical filaments; 3. A hair cell terminal on a primary branchlet; 4. A young portion of thallus showing axial cells, a primary branchlet, a cortical filament with secondary branchlets (after KUMANO 1978); 5. Primary branchlets, cortical filaments with secondary branchlets at developed stage; 6. Spermatangia terminal on secondary branchlets (after KUMANO 1978); 7-12. Carpogonium-bearing branches at the early stages in development; 13-14. Spirally twisted carpogonium-bearing branches with mature carpogonia showing female nucleus; 15. Fertilized carpogonium and gonimoblast filaments; 16-17. Carposporangia terminal on gonimoblast filaments; 18. A young germling of a carpospore.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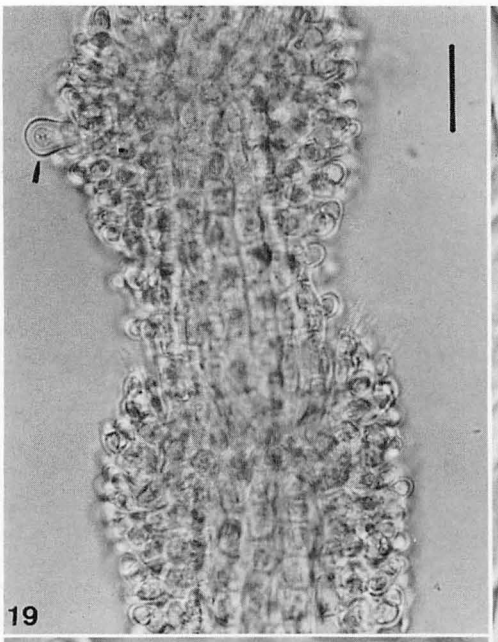
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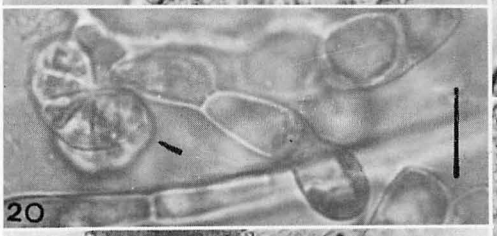
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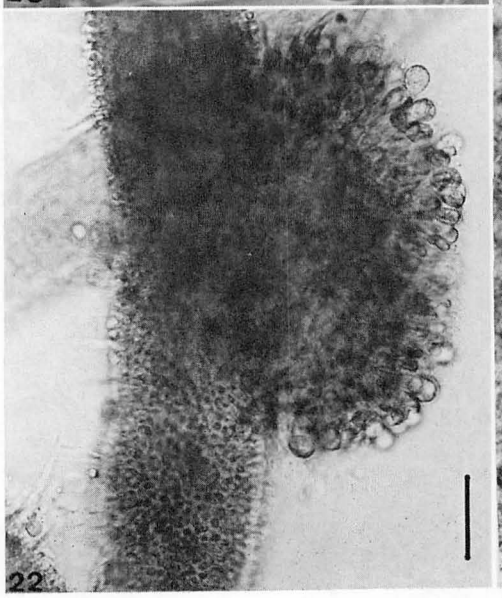
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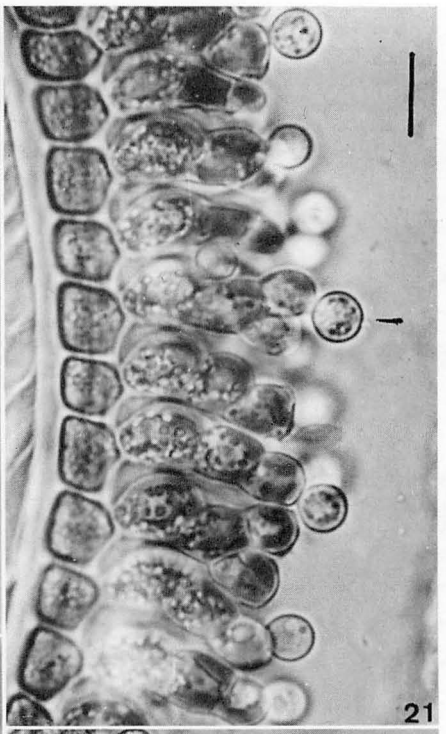
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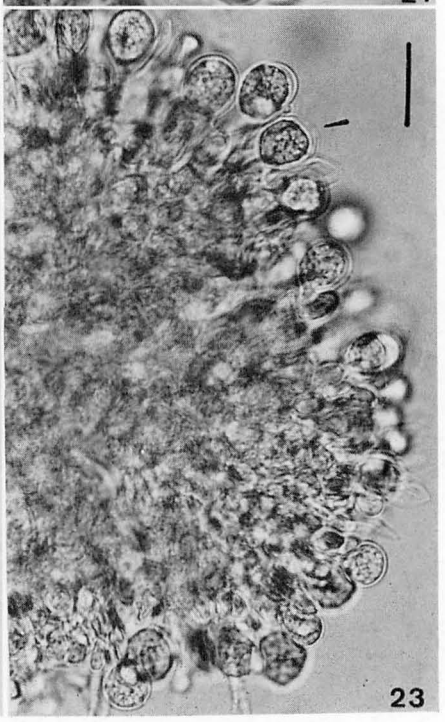
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in the genus *Thorea*. SETCHELL (1890) stated that the solid axis of the genus *Tuomeya* certainly more closely resembles that of certain species of the genus *Lemanea*, but, in the earlier stage, is almost like that of the genus *Batrachospermum*. SKUJA (1944) mentioned that the genus *Tuomeya* differed from the genus *Nothocladus* in having the differentiated and compact outer cortex, the swollen proximal cells of fascicle, no secondary branchlets, an internodal cavity between the axis and outer cortex.

The proximal cells of the fascicles in *Tuomeya americana*, the type species of the genus, are quite swollen and the distal cells are united to form a compact outer cortex. In *T. americana*, there are no secondary branchlets, so that the internodal cavity is present between the central axis and the outer cortex. The proximal cells of the fascicles in *T. gibberosa* are also quite swollen and consolidated to form a pseudoparenchymatous cortex (Figs. 1-6). In *T. gibberosa*, there is no internodal cavity due to the presence of secondary branchlets (Figs. 4-5). According to MORI (1975) and ENTWISLE and KRAFT (1984), the presence or absence of the secondary branchlets is important at the species level in the genus *Batrachospermum*. Moreover, ENTWISLE and KRAFT (1984) emphasized that reproductive features must be a better criterion for separating the genera of the family Batrachospermaceae than vegetative features.

Confusing carposporangia with spermatangia, SETCHELL (1890) misinterpreted that the genus *Tuomeya* was closly related to the genus *Lemanea* in the specialized spermatangial branchlets and their position at the nodes. Spermatangia of *T. americana* illustrated by SKUJA (1944) and WEBSTER (1958) are terminal on the primary branchlets, and are same as those found in *T. gibberosa* (KUMANO 1978 and present study, Fig. 6), and the taxa of the genus *Batrachospermum*.

SETCHELL (1890) observed that the carpogonium-bearing branch of *T. americana* becomes spirally twisted as it increases in length. The carpogonium-bearin branch of *T. americana* illustrated by SKUJA (1944) and WEBSTER (1958) and also that of *T. gibberosa* (KUMANO 1978 and present study, Figs. 7-15) are strongly curved. In having the spirally coiled carpogonium-bearing branch, the two species of the genus *Tuomeya* resemble the section *Contorta* of the genus *Batrachospermum* and the genus *Nothocladus*. The trichogyne nucleus of *T. gibberosa* is not recognized (Figs. 13-14). On the other hand, the trichogyne nucleus of *T. americana* is present, but just prior to the fertilization it is not apparent and may be in a state of degeneration (WEBSTER 1958). DAVIS (1896) reported the presence of a trichogyne nucleus in two species of the genus *Batrachospermum*, however, SCHMIDLE (1899), OSTERHOUT (1900), KYLIN (1917) and KUMANO and RATNASABAPATHY (1982) were unable to find out such a nucleus.

As shown in Figs. 15-17, it is observed that the fertilized carpogonium in *T. gibberosa* enlarges and cuts off the initials of gonimoblast filaments, which grow out into radially branched ones. This manner of the development of the gonimoblasts is the same as in the genus *Batrachospermum*. According to WEBSTER (1958), the gonimoblast placenta in *T. americana* is formed by the fusion of the primary gonimoblast cells with the gonimoblast initials at the distal end of the carpogonium-bearing branch and their nutritive cells. As a general rule, the family Batrachospermaceae exhibits the primitive characteristics in the absence of

Figs. 19-23. *Batrachospermum gibberosum* (KUMANO) KUMANO, comb. nov. 19. A part of young thallus showing cortical filaments, primary and secondary branchlets and a terminal portion of a trichogyne (arrow); 20. A primary branchlet and a coiled carpogonium-bearing branch at the early stage in development (arrow); 21. A cortical filament and spermatangia (arrow) terminal on secondary branchlets; 22. A wart-like or semiglobular gonimoblast; 23. Carposporangia terminal on compactly agglomerated gonimoblast filaments. (Scale bars: 10 μm for Figs. 20 and 21; 20 μm for Figs. 19 and 20; 40 μm for Fig. 22).

any fusion of a carpogonium with hypogynous cells after fertilization and in the formation of the gonimoblast filaments produced directly from the undivided carpogonium. The exceptions observed are such as the formation of gonimoblasts from the divided carpogonium in *Batrachospermum beraense* (KUMANO and RATNASABAPATHY 1982) and the formation of the protoplasmic connections between the carpogonium and the hypogynous cells in *B. hypogynum* (KUMANO and RATNASABAPATHY 1982).

As discussed above, *T. gibberosa* differs from *T. americana* in the absence of the gonimoblast placenta, which is characteristic of the genus *Tuomeya* and has not been reported in any taxa of the genus *Batrachospermum*. This result shows that *T. gibberosa* should be transferred to the genus *Batrachospermum* as *B. gibberosum* (KUMANO) comb. nov., basionym *Tuomeya gibberosa* KUMANO 1978, p. 105, fig. 7. *B. gibberosum* appears to assign to the section *Contorta*, which have a curved to spirally coiled carpogonium-bearing branch. Among the section *Contorta*, *B. gibberosum* is one of the most differentiated species, because the thick-walled cells of the carpogonium-bearing branch are differentiated to a high degree from the vegetative cells of fascicle.

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熊野 茂：マレーシア産淡水産紅藻 VI. *Batrachospermum gibberosum* (KUMANO) KUMANO, comb. nov. の形態について

Tuomeya gibberosa KUMANO は *Tuomeya* 属のタイプ種の *Tuomeya americana* (KÜTZING) PAPENFUSS とは2次輪生枝の存在および造胞糸プラセンタの欠除の2点で異なる。1次造胞糸が融合し生じる造胞糸プラセンタはカワモヅク属の種からは報告されていない。藻体構造と造胞体発達の過程からみると，*Tuomeya gibberosa* はカワモヅク属の種に類似し，カワモヅク属に所属させる方が適当と考える。この観点から新しい組合せ *Batrachospermum gibberosum* (KUMANO) KUMANO を提案した。

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