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Observations on *Ditria zonaricola* (OKAMURA) comb. nov. based on *Herpopteros zonaricola* OKAMURA (Rhodophyta, Rhodomelaceae)

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A rhodomelaceous alga currently known as *Herpopteros zonaricola* OKAMURA is shown to have such distinctive characteristics as 1) divergence in formation of lateral initial is 1/5, 2) pericentral cells are constantly 5, 3) among the 5 rows of lateral initials, 2 ventral rows remain undivided, lateral 2 rows develop into branches of indeterminate growth, and the dorsal one usually rests undivided except for occasional formation of deciduous trichoblasts. These characteristics are those of *Ditria* HOLLENBERG, resulting in *D. zonaricola* (OKAMURA) T. YOSHIDA et M. YOSHIDA, comb. nov. Details of reproductive structures are also given.

OKAMURA (1909) described a species of red alga under the name of *Herpopteros zonaricola*, based on materials (Fig. 1) collected at Nemoto, Chiba Prefecture, central Japan. This species, growing exclusively on the frond of *Zonaria diesingiana*, was later reported from western Japan from central to south at: Izu Peninsula, Shizuoka Prefecture (SEGAWA 1935), Shirahama, Wakayama Prefecture (YAMAMOTO 1957), Hirado Island, Nagasaki Prefecture (MIGITA and KAMBARA 1961) and Fukuoka Prefecture (HIGAKI 1975). We collected fresh material from Nagashima, Mie Prefecture

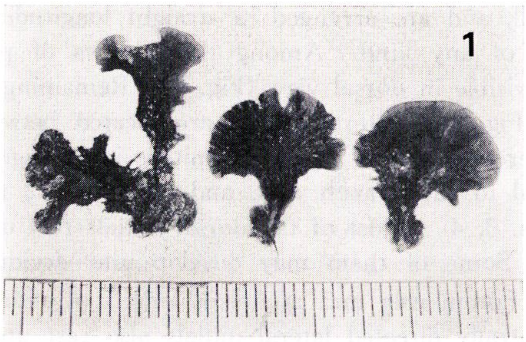

Fig. 1. Holotype of *Herpopteros zonaricola* OKAMURA, on *Zonaria diesingiana*, Nemoto, Chiba Prefecture (SAP).

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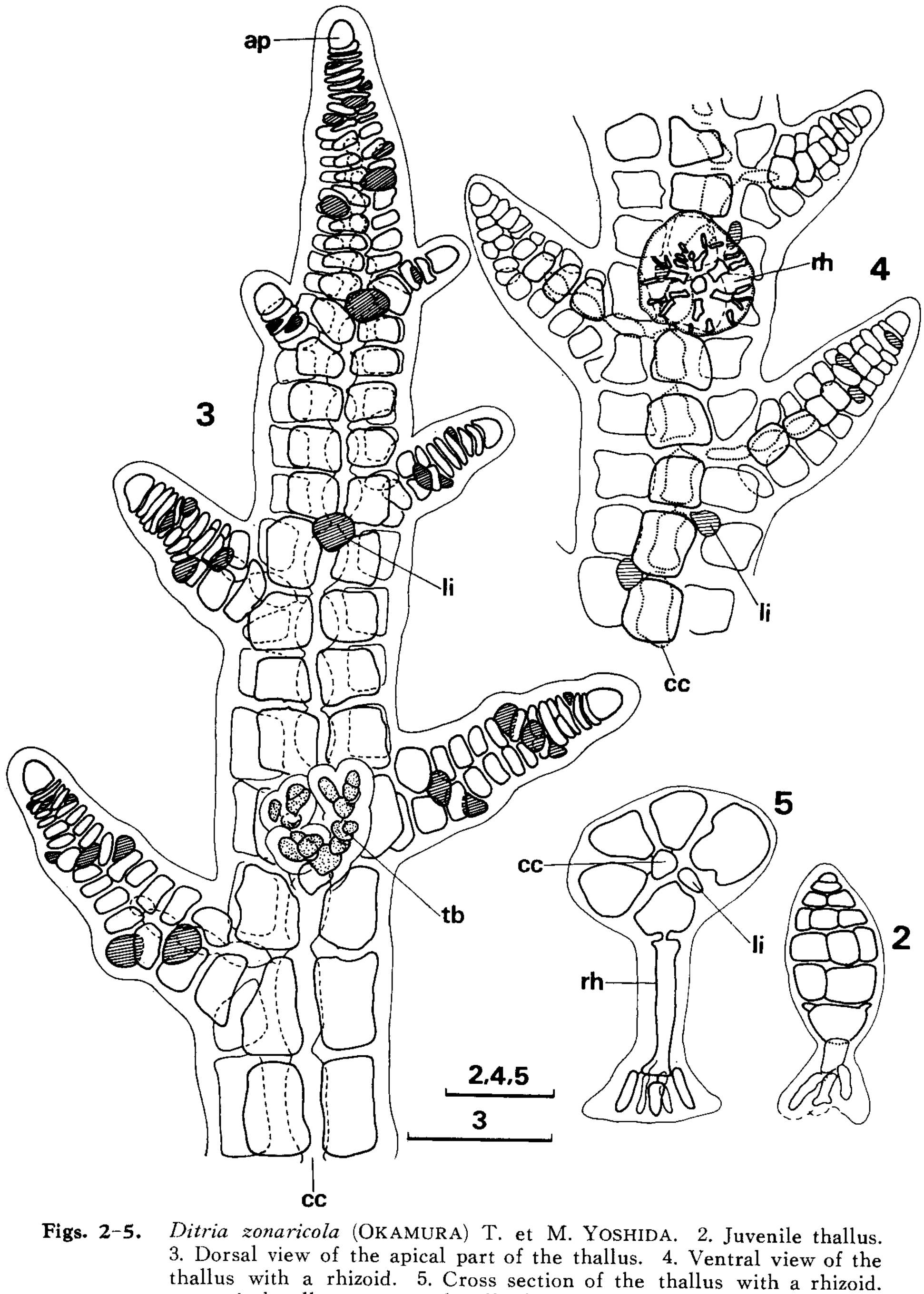
in May, 1979 (SAP 034908), and made observations on the vegetative morphology as well as reproductive structures. Although OKAMURA (1909) tentatively placed this species in the monotypic genus *Herpopteros* FALKENBERG 1897, known from southern Australia, we concluded that this species belongs to the genus *Ditria* described by HOLLENBERG (1967).

Observations

Juvenile thallus: A young germling (Fig. 2) was found adhering to the tetrasporic mother plant. It is erect, 7 segments in length, attached to the substratum by several rhizoidal cells issued from the lowermost segment. Except for apical and subapical cells, the upper segments already contained pericentral cells. Formation of prostrate part from this erect germling was not observed.

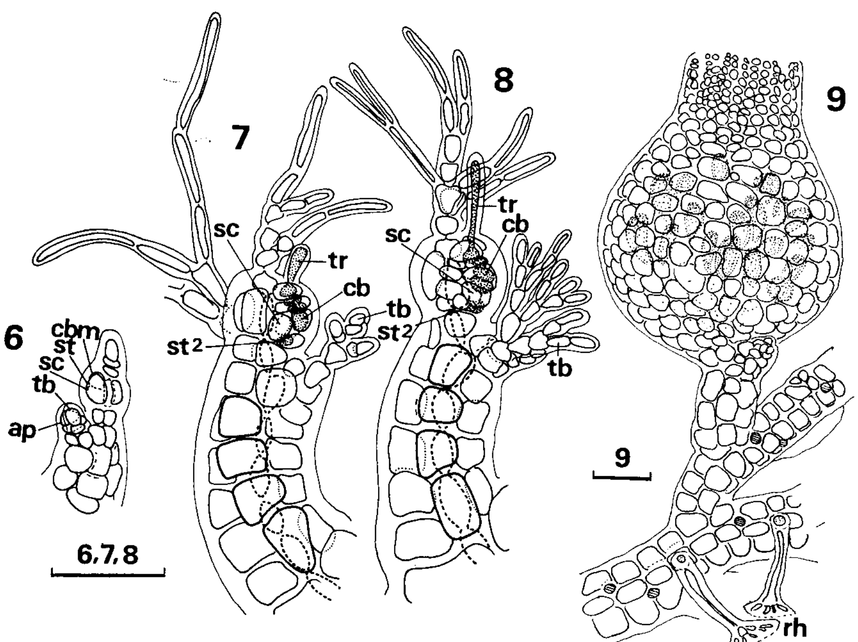
Vegetative structure of the thallus: The thallus is always prostrate forming a dense mat on the frond of *Zonaria diesingiana* growing in the lower intertidal or upper subtidal zones. The prostrate thallus is cylindrical or slightly compressed, measuring up to 140 μm in diameter and branches alternately and distichously. Growth of the thallus is initiated by the activity of an apical cell (Fig. 3, ap), which cuts off segmental cells (central axial cells) from its posterior end. Division is not strictly transverse, but is slightly oblique because of the early formation of a lateral initial (Fig. 3, li) from the higher side of segmental cell. The lateral initials are cut off in spiral sequence with a divergence of 1/5, that is, every 5th segment has a lateral initial in the same direction (Fig. 3). After the lateral initials are formed, 5 pericentral cells are cut off successively from a segmental cell in usual rhodomelacean mode. The pericentral cells are nearly the same in length as the central cell, and are arranged in straight longitudinal rows. There is no cortication of any kind. Among the 5 rows of pericentral cell, 2 rows are wholly visible in dorsal view (Fig. 3). Remaining 3 rows are seen in ventral view (Fig. 4). Lateral initials are located between the rows of pericentrals. Therefore, 1 row of lateral initials is arranged on dorsal side, 2 rows are lateral to the branch axis, and remaining 2 rows are seen in ventral view (Figs. 3, 4). Most of the dorsal initials rest undeveloped in an unicellular state. Some of them may develop into deciduous trichoblasts, which branch dichotomously and attains a length of more than 1000 μm. Two rows of ventrally directed lateral initials also rest undeveloped except in the fertile parts. They are usually smaller than the dorsal ones. The laterally formed initials develop into branches similar to the main branch. Right-side branches cut off lateral initials spirally in the same direction as



Figs. 2–5. *Ditria zonaricola* (OKAMURA) T. et M. YOSHIDA. 2. Juvenile thallus. 3. Dorsal view of the apical part of the thallus. 4. Ventral view of the thallus with a rhizoid. 5. Cross section of the thallus with a rhizoid. ap: apical cell; cc: central cell; li: lateral initial; rh: rhizoid; tb: trichoblast. Scale 50 μm.

the main branch. If the spiral on the main branch is dextrorse, the same spiral is seen on right-side branches. Branches issued on left side form lateral initials in reverse sinistrorse spiral (Fig. 3). All branches develop horizontally to form a mat of radiating growth. Rhizoids issue from the cells of ventral rows of pericentral cells at irregular intervals (Figs. 4, 5), the distal part of the rhizoid expanding to form an adhering disc (Figs. 4, 5, 9).

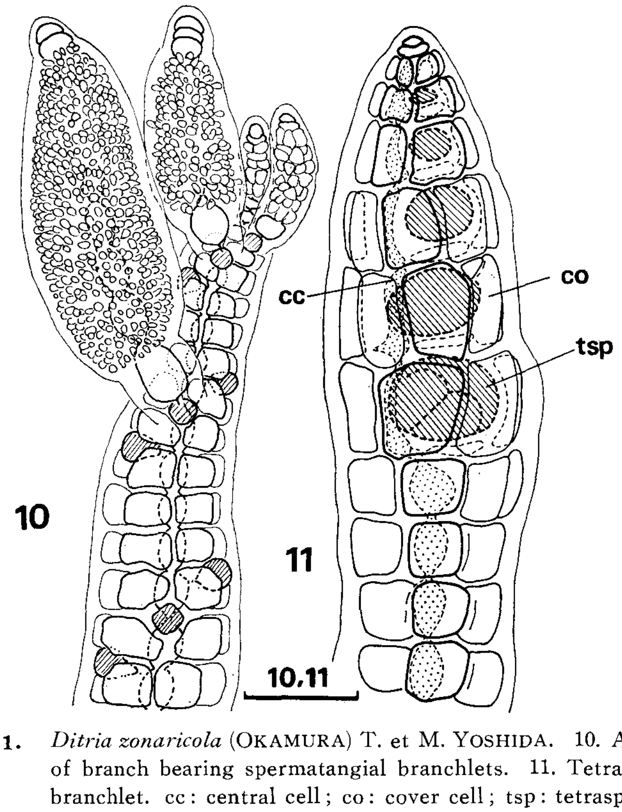
Development of female structure : In the female plant, ultimate branches of about 10 segments in length cease to grow further. Several trichoblasts are formed from lateral initials near the tip of the branch. Among them, 1 or 2 trichoblasts become fertile. The basal cell of the fertile trichoblast, which is the lateral initial, cuts off 5 pericentral cells, followed by the supra-basal cell also cutting off pericentral cells (Fig. 6). Among these pericentrals, 2 abaxial pericentrals do not divide further. Two lateral ones divide to form the pericarp. The remaining adaxial pericentral cell becomes the fertile pericentral cell (supporting cell), from which a 4-celled carpogonial branch



Figs. 6–9. *Ditria zonaricola* (OKAMURA) T. et M. YOSHIDA. 6–8. Development of procarp. 9. Mature cystocarp. ap : apical cell ; cb : carpogonial branch ; cbm : carpogonial branch mother cell ; rh : rhizoid ; sc : supporting cell ; st : sterile cell ; st_2 : second sterile cell ; tb : trichoblast ; tr : trichogyne. Scale 50 μm.

and 2 sterile cells, one lateral (Fig. 6, st) and another basal (Figs. 7, 8, st_2) in position, are cut off. The lateral sterile cell divides to give rise to a group of cells at maturity of carpogonium. The basal sterile cell seems to remain undivided. After fertilization of the carpogonium, the terminal part of the fertile trichoblast fades away leaving only one cell distal to the fertile cell. Post-fertilization processes could not be followed. Cystocarps appear to be terminal on a lateral branch. Mature cystocarp (Fig. 9), measuring ca. 400 μm in diameter and ca. 500 μm long, is globular in shape with a projecting ostiole, the whole giving a jar shaped appearance.

Male structures: Spermatangial branchlets (Fig. 10) are produced on the lateral initials near the apex of branches of male individuals. They are initiated on the lateral initials as a monosiphonous unbranched trichoblast. The basal segment, which is the lateral initial, and suprabasal segment of the fertile trichoblast remain monosiphonous, as do also the apical cell and often up to 3 segments immediately below it. The remainder of the segment



Figs. 10–11. *Ditria zonaricola* (OKAMURA) T. et M. YOSHIDA. 10. Apical part of branch bearing spermatangial branchlets. 11. Tetrasporangial branchlet. cc: central cell; co: cover cell; tsp: tetrasporangium. Scale 50 μm.

becomes polysiphonous, regularly producing pericentral cells. Spermatangia are produced by superficial cells in a spermatangial branchlet. Mature spermatangial branchlets are deciduous, and only a basal cell persists.

Development of tetrasporangia: When a tetrasporophyte becomes fertile, ultimate branches of 10–15 segments in length cease to grow further. These fertile branches (Fig. 11) also have 5 rows of pericentral cells, but lateral initials are rarely formed to give rise to trichoblasts. In the production of a sporangium, the fertile pericentral cell first cuts off 2 cover cells, which do not divide further. Then it divides once more to produce a stalk cell and a tetrasporangium, which divides tetrahedrally. The tetrasporangia are produced singly in the segments, maturing in acropetal succession. Mature tetrasporangia measure about 60–70 μm diameter.

Discussion

The genera of dorsiventral habit are met with in all subfamilies of the Rhodomelaceae: Bostrychioideae, Rhodomeloideae and Polysiphonioideae, according to the system proposed by HOMMERSAND(1963). Our alga belongs to the subfamily Polysiphonioideae as defined by HOMMERSAND with such characteristics as 1) production of trichoblasts, 2) procarpial branches having trichoblasts, 3) spermatangial branchlets borne on a trichoblast-like pedicel, 4) vegetative trichoblast deciduous, and 5) tetrasporangia borne on ordinary branches, not forming special stichidia. In this subfamily, prostrate dorsiventral genera (*Dipterosiphonia*, *Herposiphonia*, *Herpopteros*, *Jeannerettia*, *Metamorphe*, *Periphykon*, *Placophora* and *Pollexfenia*) are included in the tribe Polysiphoniae as defined by HOMMERSAND (1963). Among these genera, *Metamorphe*, *Herpopteros*, *Dipterosiphonia* and *Herposiphonia* are formerly grouped within the *Herposiphonia* Gruppe by KYLIN (1956), and each of them has a characteristic differentiation and arrangement of lateral branches into laterals of determinate growth, indeterminate branches and trichoblasts. Comparison is made here with these 4 genera of the *Herposiphonia* Gruppe.

Metamorphe, fully described by SCAGEL (1953), has a prostrate axis with 4 rows of pericentral cells. From each segment of the axis, a lateral initial is formed in a spiral of 1/4 divergence. Dorsally situated initials produce trichoblasts which fall off leaving a basal cell as a 'scar cell'. Ventrally directed initials also form deciduous trichoblasts. In older part they are recognized as 'ventral scar cells'. Branches developed in lateral position differentiate into determinate or indeterminate branches. A given segment producing a laterally directed determinate branch is followed in the segment anterior to it by a dorsally directed trichoblast. In the next segment a

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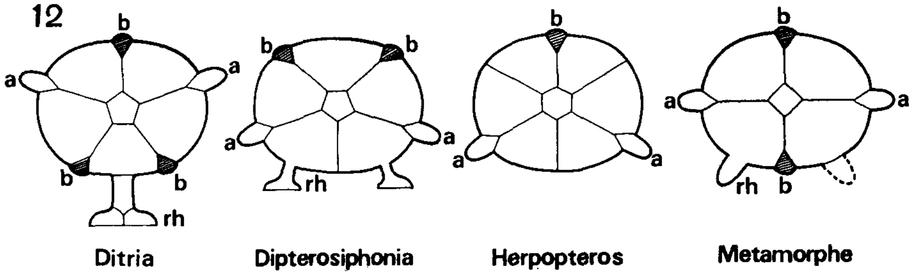

Fig. 12. Schematic representation of thallus structure in cross section of the genera *Ditria, Dipterosiphonia, Herpopteros* and *Metamorphe.* a: branch of indeterminate growth, b: lateral initial of limited growth, rh: rhizoid.

lateral determinate branch is formed on the side opposite to that 2 segments back of it, and a ventrally directed trichoblast is formed from the 4th segment. The next cycle of helix begins at 5th segment, with the production of an indeterminate branch laterally directed on the same side as the determinate branch 4 segments back. A dorsal trichoblast is produced by the 6th segment. This is followed by an indeterminate branch laterally directed from the 7th segment on the side opposite the indeterminate branch 2 segments back of it, and finally by a ventral trichoblast from the 8th segment. This sequence is schematically represented in Fig. 12. The indeterminate branches (*a* in diagram) eventually become erect axes.

In *Herpopteros* illustrated by FALKENBERG (1901), lateral initials formed from segments of the axis are arranged in a helix of 1/3 divergence. Every 3rd initial produced dorsally is an abortive trichoblast which remains always in unicellular state. The other 2 rows of laterally directed initials develop into axes similar to main axis in alternate-distichous way. Each segment cuts off 6–9 pericentral cells (Fig. 12).

Dipterosiphonia has an axis with 5 or more rows of pericentral cells. In the typical members of the genus, a given segment producing a determinate branch directed obliquely upwards is followed in the segment anterior to it by a downwardly directed indeterminate branch on the same side of the axis. In the next segment, a determinate branch is formed on the opposite to that 2 segments back, and an indeterminate branch is issued on the same side (Fig. 12). The insertion of these lateral branches do not follow spiral sequence. Arrangement of the determinate and indeterminate branches in a reverse form that described above occurs in *D. reversa* (SCHNEIDER 1975).

Herposiphonia is rather different from the above mentioned genera in the branching pattern. Three unbranched laterals of determinate growth followed by a branched lateral are produced in regular but not in spiral succession in this genus. These lateral branches extend upwardly or horizontally according to the species. Axial segment has 6–16 pericentral cells. The circinate apex of the axis is another difference to those described here.

As for the reproductive structures, position and constitution of the procarp are nearly uniform not only in the genera of *Herposiphonia* Gruppe, but also in the Polysiphonioideae.

The spermatangial branchlets are not accompanied by sterile trichoblast in our plant as in *Dipterosiphonia* and some species of *Herposiphonia*, whereas they are formed as a first branch of the trichoblast in *Metamorphe* (SCAGEL 1953). Male structures are unknown in *Herpopteros*.

Tetrasporangia are produced in each segment of the second and subsequent orders of erect indeterminate branch in *Metamorphe* (SCAGEL 1953). In *Dipterosiphonia*, the tetrasporangia are usually confined to determinate branches but occasionally in the indeterminate branches. Number of cover cells formed on a tetrasporangium is reported to be 3 in *Metamorphe* (SCAGEL 1953), and 3 or 2 according to the species of *Herposiphonia*. In our plant, 2 cover cells are always observed. Tetrasporangial branches of *Herpopteros* have 2 rows of trichoblasts on its dorsal side (FALKENBERG 1901).

Comparison of vegetative as well as reproductive structures between *Herpopteros* and our plant shows so many differences that our plant cannot be maintained in the genus *Herpopteros*.

HOLLENBERG (1967) described several new genera in the Rhodomelaceae. Among these genera, *Ditria* seemed to have a resemblance to our plant, though we could not decide conclusively in consulting his figures and description only. Examination of the holotype specimen of *Ditria reptans*, the type and only species known in this genus, revealed that the fundamental organization of the thallus structure is the same as our plant (Fig. 13). Therefore our plant is clearly congeneric with *Ditria*. We propose here a new combination as follows:

Ditria zonaricola (OKAMURA) T. YOSHIDA et M. YOSHIDA, comb. nov.
Basionym: *Herpopteros zonaricola* OKAMURA, Icon. Japan. Alg. **2**: 13, *pl. 55*. 1909.

The holotype of *D. reptans* HOLLENBERG is sterile specimen mounted on microscope slide (#US-1134). The mode of branching in *D. reptans* is different from *D. zonaricola* in that the lateral branches are simple with very few branches of next order (Fig. 13), while the laterals usually branch several times in *D. zonaricola* (Fig. 14). At present, we treat the plants of Japan and Hawaii as different at specific level. But further comparison is

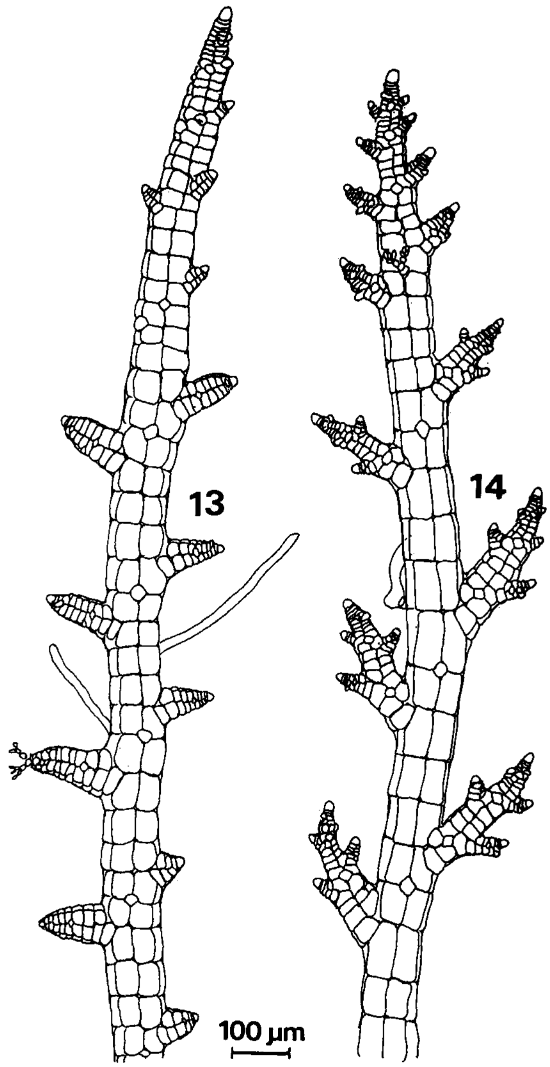

Fig. 13. Apical part of *Ditria reptans* HOLLENBERG.
Fig. 14. Apical part of *Ditria zonaricola* (OKAMURA) T. et M. YOSHIDA.

needed with fertile materials.

The genus *Ditria* can be placed in the subfamily Polysiphonioideae, the tribe Polysiphoniae as defined by HOMMERSAND (1963).

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References

FALKENBERG, P. 1901. Die Rhodomelaceen des Golfes von Neapel und der angrenzenden Meeres-Abschnitte. Fauna Flora Golf. Neapel Monogr. **25**: 1–754.

HIGAKI, M. 1975. Marine algae. *In* D. AMAKAWA *et al.*, ed., The flora and vegetation of Fukuoka Prefecture. p. 268–276. Hakuyo-sha, Fukuoka.

HOLLENBER, G. J. 1967. New genera in the Rhodomelaceae from the central Pacific. Bull. So. Calif. Acad. Sci. **66**: 201–221.

HOMMERSAND, M. N. 1963. The morphology and classification of some Ceramiaceae and Rhodomelaceae. Univ. Calif. Publ. Bot. **35**: 165–366.

KYLIN, H. 1956. Die Gattungen der Rhodophyceen. Gleerups, Lund.

MIGITA, S. and KAMBARA, S. 1961. A list of the marine algae from Hirado Island and its vicinity. Bull. Fac. Fish. Nagasaki Univ. **10**: 174–185.

OKAMURA, K. 1909. Icones of Japanese algae. **2**(1): 1–20.

SCAGEL, R. F. 1953. A morphological study of some dorsiventral Rhodomelaceae. Univ. Calif. Publ. Bot. **27**: 1–109.

SCHNEIDER, C. W. 1975. North Carolina marine algae VI. Some Ceramiales (Rhodophyta) including a new species of *Dipterosiphonia*. J. Phycol. **11**: 391–396.

SEGAWA, S. 1935. On the marine algae of Susaki, Prov. Idzu, and its vicinity. Sci. Pap. Inst. Algol. Res., Fac. Sci., Hokkaido Imp. Univ. **1**: 59–90.

YAMAMOTO, T. 1957. A list of marine algae from Nisimuro District, Wakayama Prefecture. "Watashi tachi no rika kankyo" **7**: 1–16.