

Symphyocladia pennata Okamura (Rhodophyta, Rhodomelaceae) in Korea

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韓國產 紅藻 *Symphyocladia pennata* Okamura

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The morphological characters and life history of *Symphyocladia pennata* Okamura were investigated with field and laboratory culture. The species is well defined by a small size and ecorticated thallus without vegetative trichoblasts. Although a degree of congenital fusion varies rather broadly, the species is safely included within a range of the genus. Female sexual structure is described for the first time in this study, and all the reproductive structures of the species, however, are basically similar to those of the Rhodomelaceae. The plants show a *Polysiphonia*-type of life history in culture. However, unusual reproduction such as female/male or female/tetrasporic is also observed during the culture. The species is endemic, and recorded in Japan and Korea. In Korea, the regions connected by 10°C isothermal line seem to be a northern boundary in their distribution.

Key Words: Morphology and Reproduction, *Symphyocladia pennata*, Rhodophyta, Taxonomy

The *Symphyocladia*, a member of the Pterosiphoniae, Rhodomelaceae, was established by Falkenberg(1897: cf. Kylin, 1956). In monographic study of the Rhodomelaceae, he (1901) included there three species assigned previously in *Rytipholoea*, *Placophora*, and *Pterosiphonia*. *Symphyocladia* differs from the other genera of the subfamily by alternate-distichous erect branches, several orders of which may be conjoined laterally (Hommersand, 1963). At present four species are known in the genus.

Symphyocladia pennata Okamura is characterized by a small thallus, long and slender outer branches with denticulate branchlets, and entirely ecorticate frond by Okamura(1923). However, the species is still suspected as not an independent species. Okamura(1923) doubted whether it was a dwarf variety of *S. linearis* (Okamura) Falkenberg, or a narrower form of *S. marchantioides*(Harvey) Falkenberg. Ardré(1973) mentioned *S. pennata* to be conspecific with *S. linearis*.

Therefore, in order to clarify the taxon, the morphology and reproduction of the species are investigated in this paper with the plants collected from Korea, specially dealing with a life history in laboratory culture.

MATERIALS AND METHODS

Materials were collected along the coasts of Korea during 1982 and 1985. Description and illustration were based on field and laboratory cultured plants. Materials for culture were obtained both from Geomun do Island (34°00 N, 127°00 E), 17 August 1984 and Cheju Island (33°30 N, 127°00 E), 5 August 1984. Unialgal culture was followed to Boo and Lee (1983).

Specimens examined were preserved in the Herbarium, Seoul National University (SNU).

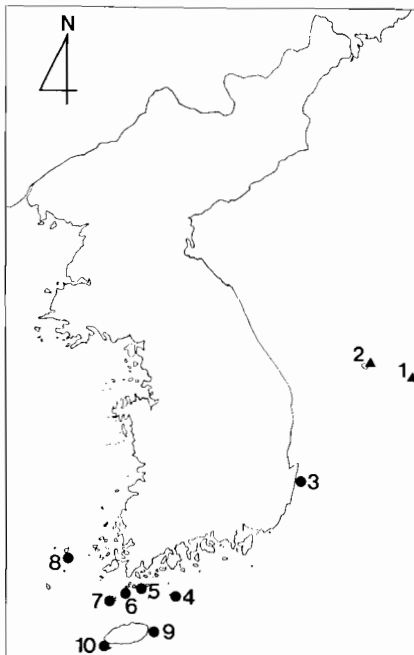


Fig. 1. Geographical distribution of *Symphyocladia pennata* Okamura along the coasts of Korea. (▲, Lee and Boo (1981); ●, this study)
1. Dock-do 2. Ulreung-do 3. Gampo 4. Geomun-do 5. Chungsan-do 6. Soan-do 7. Chuja-do 8. Huksan-do 9. Sungsanpo 10. Mosulpo

RESULTS

Field Observations. *Symphyocladia pennata* Okamura was collected at several sites in Korea (Fig. 1). The plants were epiphytic on other algae such as *Acrosorium yendoi*, *Corallina pilulifera*, *Spermothamnion* sp. and *Cladophora* sp. Among the plants collected in the South Coast, the female gametophyte and tetrasporophyte were found in July and August from Cheju Island, and male gametophyte and tetrasporophyte in July from Geomun-do Island, and tetrasporophyte in October from Chungsan-do Island.

Without mentioning the reproductive structures, Lee (1972), Lee and Boo (1981), Lee and Lee (1982), and Boo and Lee (1982) reported to occur them at several places in South Coast, as well as Dock-do and Ulreung-do Islands.

Considering the above collections, *S. pennata* distributes the South Coast alone, including Dock-do and Ulreung-do Islands. It grows through the year in Korea, while sexual plants are expected to appear in summer.

Vegetative Thallus. The vegetative structure of *S. pennata* was partly described and illustrated by Okamura (1923) and Lee (1972). Our plants agree well with Okamura (1923) in description. The following was based on the plants from Geomun-do and Chungsan-do Islands.

The plant adheres to other algae by emitting rhizoids from undersurface. It becomes up to 1.5cm high (Pl. 1 A) and 330 μ m broad, and is reddish purple in color, adhering imperfectly to paper in drying.

The erect fronds are partly compressed, and pinnately branched in a plane. The branches issue alternately from every second segment of main axes to show an alternate-distichous manner. The lateral branches base at in 3-5 segments fuse with row of axial cells in a con-

genital manner. However, a degree of this fusion varies among portions of a thallus, as well as among individuals from different habitats (Figs. 2,3: Pl. 1 B,C,D). Each lateral provides an isolated well-define single apical cell, which

cuts off segments obliquely downwards in alternate manner (Figs. 4-6).

Rhizoids arise from distal side of the pericentral-cell facing to substrate. They are single-celled first, but become multicellular in

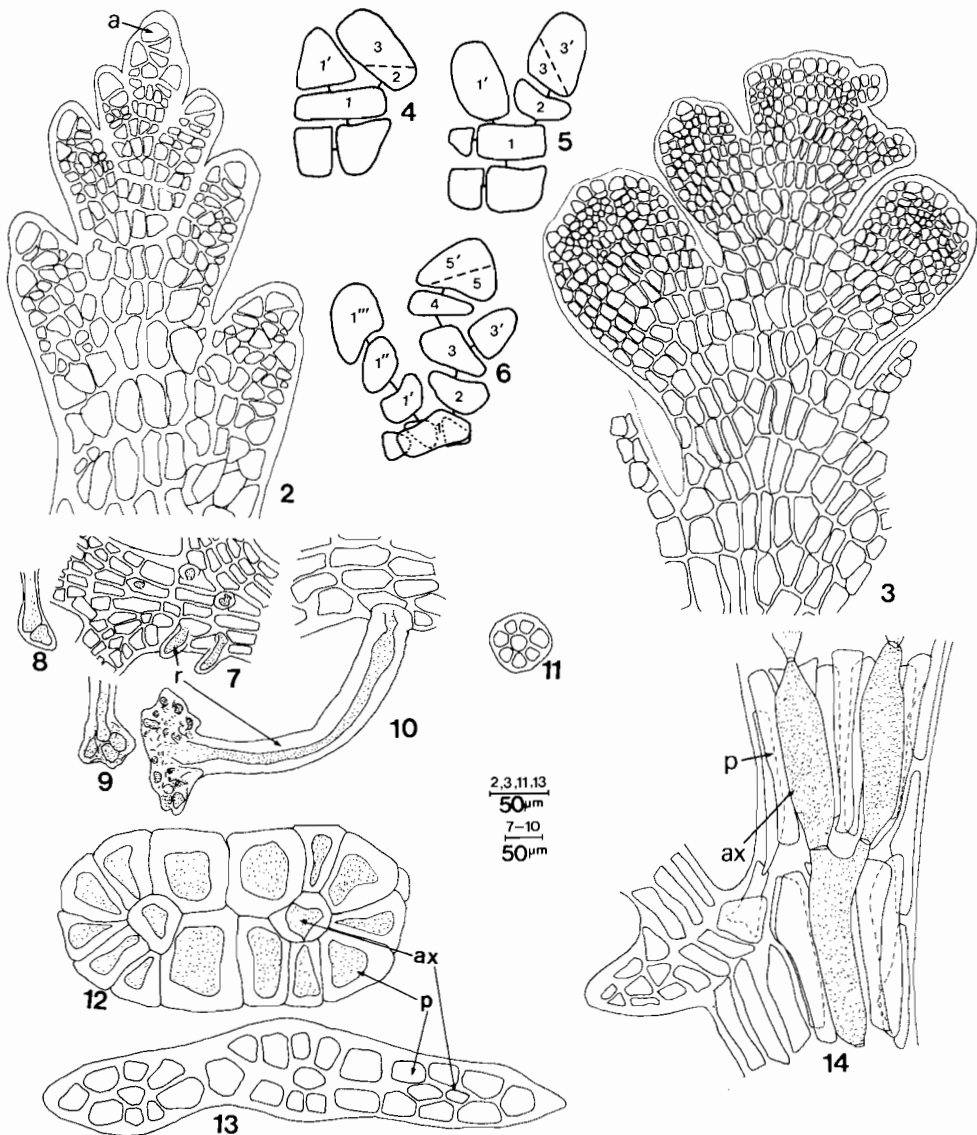


Fig. 2-14. Vegetative structure of *Symphyocladia pennata* Okamura.

Figs. 2,3. Narrow and broad apical portions of vegetative thallus. Figs. 4-6. Branching pattern of apical parts. Figs. 7-10. Development of rhizoids. Figs. 11-13. Apical, middle and lower portions of thalli in cross section. Figs. 14. Longitudinal view of erect axes.

(a, apical cell; ax, axial cell; p, pericentral cell; r, rhizoid)

about 65 μm broad disc when attached (Figs. 6–10).

The plants are thoroughly ecorticated. A single central axis is surrounded by 7–8 pericentral cells (Fig. 11). In most cases, however, a few central axes are surrounded by the common pericentral cells (Figs. 12, 13). In each segment, the pericentral cells are same as axial cell (Fig. 14). The both are connected by secondary pits.

The trichoblasts are not observed in vegetative thallus.

Male Gametophyte. The spermatangial structure of *S. pennata* was partly illustrated by Noda (1967). Our plants agree well with his illustration. Spermatangia are developed from monosiphonous determinate branchlet derived from axial cell. In a fertile axis, every segment at distal end bears a spermatangial branchlet. Accordingly, the arrangement of branchlets shifts from an alternate–distichous to a spiral manner (Figs. 15, 16, 17: Pl. 1 E). The spermatangial branchlets are polysiphonous, except for the two proximal segments and the two or three distal ones. The basal segment is always embedded in axial frond; whereas the suprabasal segment is protruded out freely (Fig. 17). Each segment of spermatangial branchlet develops only four pericentral cells. The first pericentral cell is cut off at the abaxial side, and the fourth is on the adaxial side opposite to the first (Fig. 17). The pericentral cells are ternately branched. All the terminal cells derived from the pericentral cell, including pericentral cell itself, become spermatangial mother cell. They produce two to three spermatangia, respectively. A mature spermatangial stichidium is a cone-shaped, slightly incurved and 50–57 μm broad and 170–220 μm long (Fig. 18: Pl. 1 F). Spermatia released are elliptical, 3–4 μm broad and 4–5 μm long. No trichoblast is seen in the male gametophyte. As the spermatangium

formation begins, the fertile branch stops to grow.

Female Gametophyte. Fertile branches in female plant are formed in a similar manner to those of vegetative thallus (Fig. 19). The procarp are borne on the branchlets modified to a trichoblast. The branches bearing procarps remain with an alternate–distichous manner, in contrast to a spiral manner of fertile male plant. The suprabasal segment of fertile branch produces procarp and the subsequent segments are modified into the trichoblast (Fig. 20: Pl. 1 G). In fertile segment five pericentral cells are formed in turn. The first pericentral cell is cut off abaxially from axial cell, and the fifth is on the adaxial side between the third and fourth. The fifth pericentral cell develops into the procarp (Figs. 21–23). The procarpal pericentral cell divides longitudinally, cutting off the initial cell of the first sterile group, and it divides again to produce the initial cell of the carpogonial branch. The latter cell divides twice to form a three-celled carpogonial branch. In this stage, the supporting cell cuts off the initial cell of the second sterile group at the lower portion. A trichogyne begins to grow while the carpogonial branch is three-celled. Then, the carpogonium cuts off one cell to form a four-celled carpogonial branch, and the trichogyne elongates fully (Fig. 23: Pl. 1 H). After that, the initial cell of the lateral sterile group is divided transversely to form a two-celled branch.

The four sterile pericentral cells produce cortical filaments that are ternately branched. These filaments extend over the procarp in a valve-like cover, a prefertilization pericarp.

Immediately after fertilization, an auxiliary cell is cut off from the distal end of the supporting cell. The fertilized carpogonium fuses directly with the auxiliary cell. Then, the auxiliary cell also fuses with the supporting cell, and cuts off a primary cell of the gonimoblast,

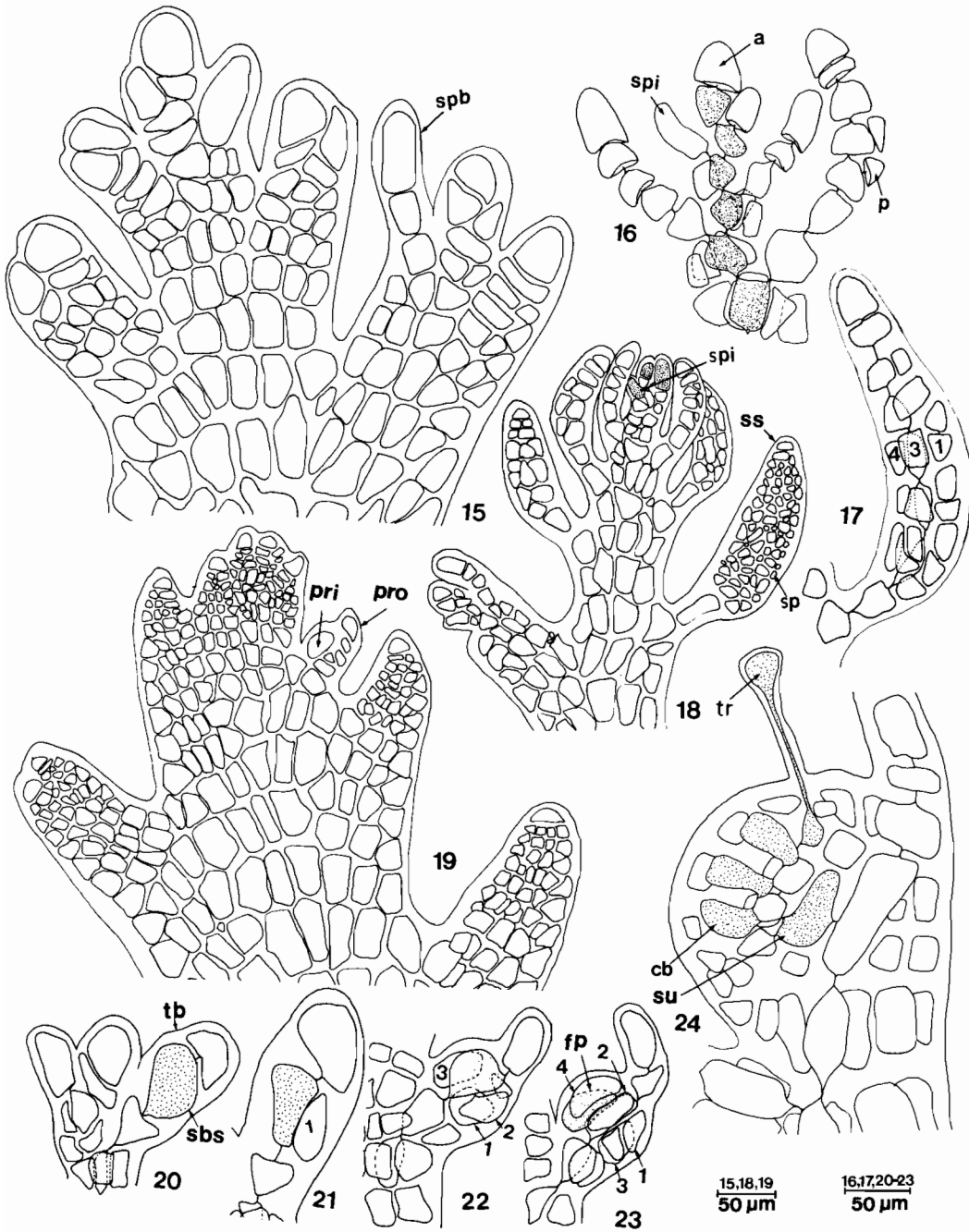


Fig. 15–24. Development of reproductive structure in *Symphyocladia pennata* Okamura.

Fig. 15. Apical portion of young male gametophytic thallus. Fig. 16–18. Development of spermatangia. Fig. 19. Apical portion of young female gametophytic thallus. Figs. 20–24. Development of a procarp.

(cp, carpogonial branch; fp, fertile pericentral cell; pri, procarpal initial; pro, procarp; sbs, suprabasal segment; sp, spermatium; spb, spermatangial branch; spi, spermatangial initial; ss, spermatangial stichidium; su, supporting cell; tb, trichoblast; tr, trichogyne)

which divides branches sympodially. A mature cystocarp is sessile, globular, and 1.9mm long and 1.5mm broad (Pl. 1.I).

Tetrasporophyte. The structure of tetrasporangium was described and illustrated by Okamura (1923) and Lee (1972). Our plants agree well with description by them. The developmental pattern of tetrasporangium is basically similar to that of other Rhodomelaceae (Hommersand, 1963; Masuda, 1982; Suneson, 1940). The tetrasporangial stichidium is trans-

formed from determinate branch. The tetrasporangia occur on denticulate branchlets or lacininae in a longitudinal row (Pl. 2 A). They appear at the central portion of the branchlet base and develop along its mid-rib upwards. They are mature from the lower ones in turn.

The apical cell of fertile lateral branch produces first pericentral cell on the abaxial side and the second toward the adaxial side. Next, the third is destined to produce a tetrasporangium. The fertile pericentral cell is easily dis-

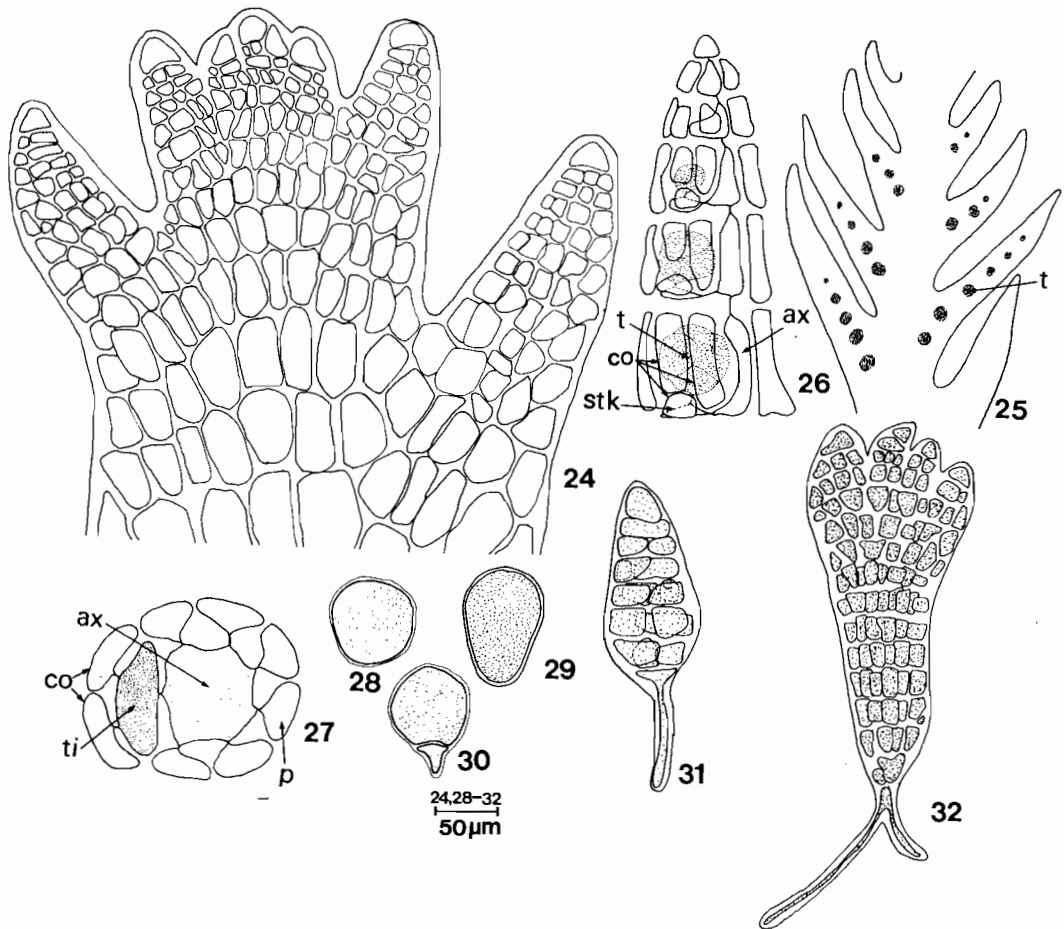


Fig. 24-27. Development of tetrasporangia in *Symphyocladia pemata* Okamura.

Fig. 24. Apical portion of young tetrasporic thallus. Fig. 25. Pattern of tetrasporangia formation. Fig. 26. Fertile apex, showing stages in the formation of the tetrasporangia and their cover cells. Fig. 27. Transverse section of the fertile axis. Fig. 28-32. germination of tetraspores. (co, cover cell; t, tetrasporangium; ti, tetrasporangial initial; stk, stalk cell)

tinguished by an almost spherical shape and dense contents from the beginning (Pl. 2 B). It first cuts off two cover cells, and then divides transversely into a tetrasporangium and a stalk cell. Finally the stalk cell cuts off a small triangular, third cover cell toward the outside (Figs. 26,27). This last-formed cover cell is always produced after the formation of the tetrasporangium.

A mature tetrasporangium is spherical, divided tetrahedrally, and $75-95\ \mu\text{m}$ in diameter. No trichoblast is observed in tetrasporophyte.

Laboratory Culture. Unialgal cultures were obtained from isolated tetraspores as well as excised apical tips of the female gametophyte. Released tetraspores are spherical and $55-56\ \mu\text{m}$ in diameter (Pl. 2 C). Spores attached to the glass begin to germinate in six hours. It elongates until the first division occurs to two unequal cells (Pl. 2 D). In four days the plant becomes filamentous, consisting of seven to eight cells and rhizoid (Figs. 28-32). The early germlings (Pl. 2 E, F) showing a distal erect type agree well with the germination of *S. latiuscula* (Inoh, 1948; Matsuyama and Masaki, 1975).

Spermatia are produced in six weeks, and

procarpic structures in seven weeks. The both plants are crossed successfully. A cystocarp matures in two weeks after fertilization, and released carpospores, which develop into tetrasporophytes in twelve weeks after germination.

The trichoblasts are not observed in vegetative thallus of the cultured plants.

About 5% tetraspores released from Geomun-do Island isolates grow into monoecious plants. They formed spermatangia on the female thallus. These monoecious plants were isolated and cultured for two months. However, they did not show a self-fertilization. A cross between normal dioecious male and monoecious female only was successful. On the other hand, female gametophytes from Cheju Island isolates formed tetrasporangia during culture. These tetraspores released were not attached or imperfectly attached to substrate and showed no viability.

We also cultured the excised apical tips of vegetative thallus under various conditions such as 10°C , 500 lux, 16:8; 10°C , 1,000 lux, 16:8; 10°C , 1,500 lux, 16:8; 10°C , 2,000 lux, 16:8; 10°C , 500 lux, 12:12; 10° , 2,000 lux, 12:12; 15° , 500 lux, 16:8; 15°C , 1,000 lux, 16:8; 15°C , 1,500

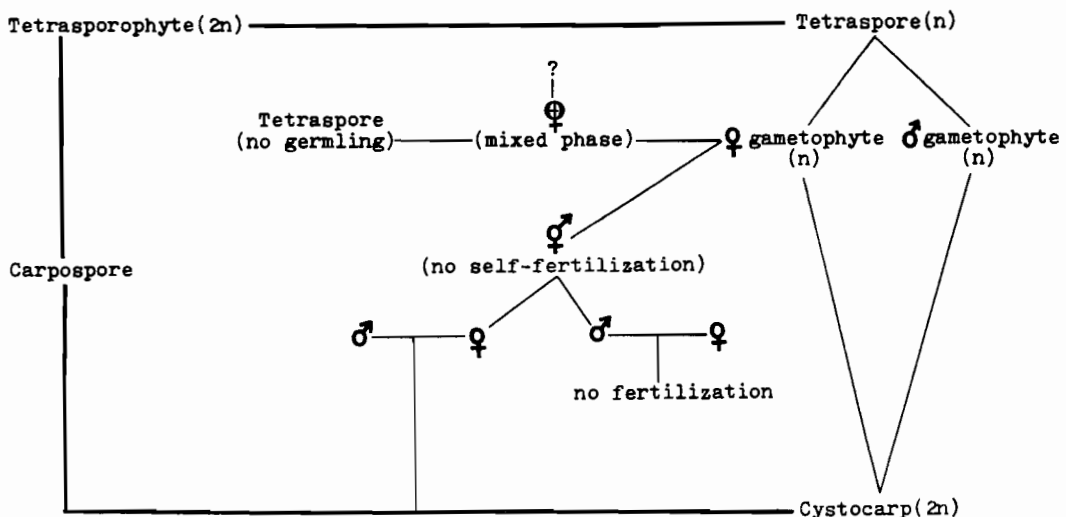


Fig. 33. A life history of *Symphyocladia pennata* Okamura in culture.

lux, 16:8; 15°C, 2,000 lux, 16:8; 15°C, 500 lux, 12:12; and 15°C, 2,000 lux, 12:12. We carried out these to investigate the degree of congenital fusion of laterals. Under the condition of 15°C, 1,500 lux, 16:8, the plants showed both narrow and broad fronds in apical portion, and formed tetrasporangia. But, under 10°C, 2,000 lux, 16:8, the plants only showed a narrow frond, growing vegetatively alone. Although much variation of breath in the apical portion of thallus existed, we could find that the degree of congenital fusion of laterals in various culture conditions always extended over more than two internodes.

As a result, *S. pennata* requires about three to four months to complete a full life history in laboratory culture. According to our experiment, it shows basically a *Polysiphonia*-type of life history. However, some unusual reproduction such as female/male (Pl. 2 G) or female/tetrasporic are also observed in laboratory culture (Fig. 33).

DISCUSSION

Symphyclocladia pennata Okamura was first recorded as *Pterosiphonia parasitica* Falkenberg by Yendo (1918) from Echigo, Japan, based on characters of an external morphology. However, Okamura (1923) removed it to *Symphyclocladia*, giving the above new name, because of a congenital nature of apical portion in branches, especially in young ones. He distinguished it from the other species of *Symphyclocladia* by a small size and no cortication. The diagnostic characters of our plants agree well with description by Okamura (1923).

This species was once confused with other species of *Symphyclocladia* by Okamura (1923) and Ardré (1973). Introducing the present alga as a new species, Okamura (1923) doubted

whether it was not a dwarf variety of *S. linearis* or a narrower form of *S. marchantioides*. Ardré (1973) mentioned it to be conspecific with *S. linearis*. However, according to the present investigation, this species is well defined not only by the vegetative thallus mentioned by Okamura (1923), but also by absence of vegetative trichoblasts.

The vegetative trichoblast is recognized as one of the important taxonomic characters to distinguish *Symphyclocladia* from *Pterosiphonia* by Ardré (1967, 1973). It occurs commonly in *S. latiuscula* and *S. marchantioides* (Okamura, 1936; Ardré, 1973; Matsuyama and Masaki, 1975). Thus, it seems not to be valid to define the genus by having this character.

Trichoblasts are observed only in the fertile plants with sexual structure. In female fertile plants the trichoblasts develop into an alternate-distichous manner, whereas in male plants they develop into a spiral manner. A tendency to shift from an alternate-distichous arrangement to a spiral one is rather common among closely allied genera of the Rhodomelaceae (Hommersand, 1963).

The male and female reproductive structures are found among our plants. Their developmental characters are basically similar to those of Rhodomelaceae (Scagel, 1953; Hommersand, 1963; Masuda, 1982; Suneson, 1940). The female reproductive structure is described for the first time in this study.

Our plants showed a *Polysiphonia*-type of life history in culture. However, female/male or female/tetrasporic unusual reproductions were also observed during the culture. Thus, the species genetically is considered rather unstable.

This species is endemic, and is recorded in Japan and Korea. In Korea, it distributes to the South Coast alone, including Dock-do and Ulreung-do Islands (Fig. 1), where the Kuroshio warm current influences, and the wa-

ter temperature never becomes below 10°C through the year in open sea (Kang, 1966). The regions connected by this isothermal line, therefore, seem to be a northern boundary in distribution of the species.

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摘 要

홍조 애기보라색우무(*Symphyocladia pennata* Okamura)의 형태적 특징을 야외 및 실내배양 재료를 통해 구명하고 생활사를 밝혔다. 본 식물의 식별형질은 원기재와 잘 일치되었고, 엽체가 작고 영양체모상엽과 피층이 형성되지 않는다는 점에서 *Symphyocladia*속의 다른 종들과 구별되어진다. 비록 주축과 측지의 융합정도가 동일한 식물체내에서 조차 다양하게 나타나기는 하지만, 이와 같은 특징은 본 속의 한계내에 잘 포함된다. 본 종의 자성생식기관은 본 연구를 통해 처음으로 기재되며, 생식기관의 구조 및 발달과정은 Rhodomelaceae과의 것들과 기본적으로 유사하다. 실내배양에서 본 식물은 *Poly-siphonia*형 생활사를 반복하나 자웅동주 또는 사분포자체/자성배우체의 이상생식현상도 관찰된다. 본 종은 지역고유종으로 일본과 한국에서 생육이 확인되었고, 분포북한계는 동계표면해수의 수온이 10°C 이상인 남해안 지역임을 추정할 수 있다.

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PLATE 1

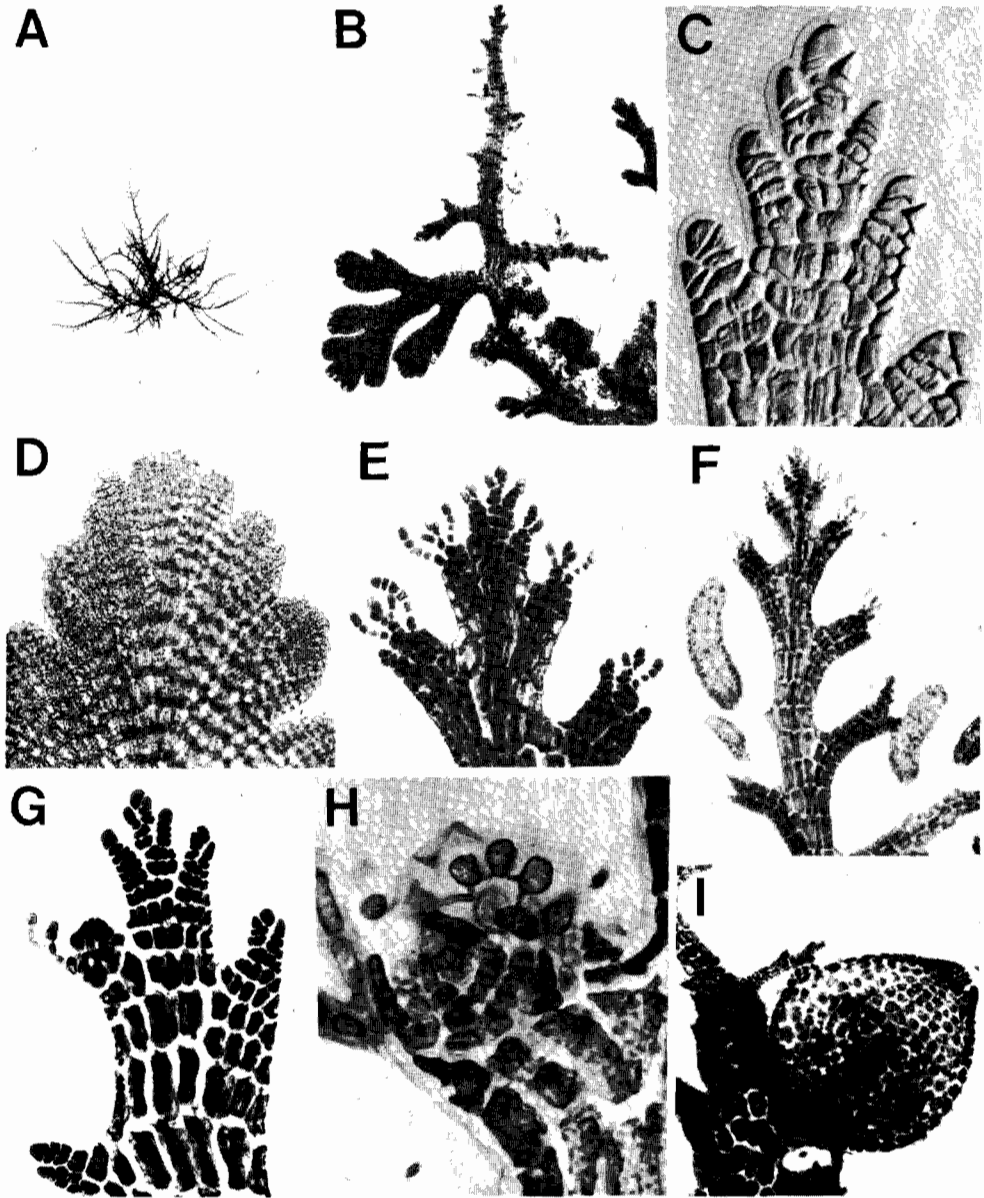
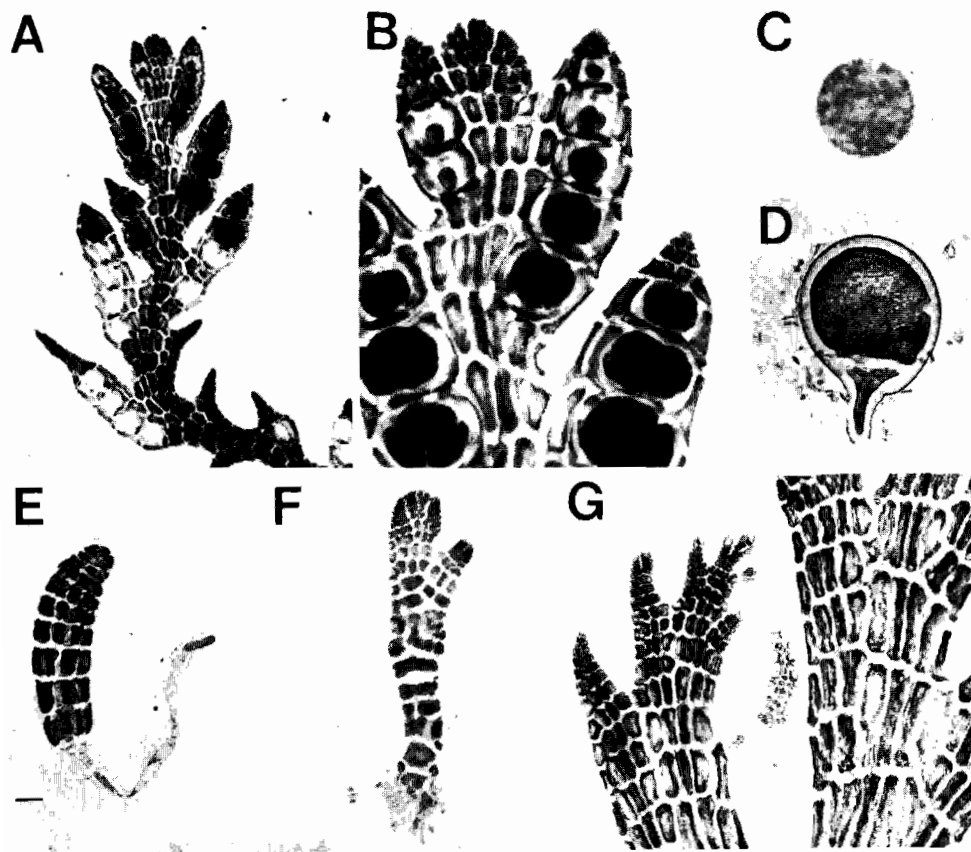


PLATE 1

- A. Vegetative thallus collected at Geomun-do (height, 2cm).
 B. Vegetative thallus, showing narrow and broad apical portions (40 X).
 C,D. Apex of vegetative thallus (200 X).
 E. Tips of fertile axis of male plant, showing young spermatangial branches arranged spirally (200 X).
 (→continued)

PLATE 2



- A. Mature tetrasporophytic thallus (100 X).
 B. Fertile apices, showing stages in the formation of the tetrasporangia (400 X).
 C. Released tetraspore (600 X).
 D. Sporeling after 12 hours (600 X).
 E. Typical distal erect sporeling after four days (400 X).
 F. Initiation of first lateral branch after two weeks (400 X).
 G. Monoecious plant derived from tetraspore, showing procarp and spermatangia in same plant (200 X).

- F. Mature spermatangial stichidia (200 X).
 G. Tips of fertile axis of a female plant, showing young procarp (200 X).
 H. Fully mature procarp before fertilization, showing four-celled carpogonial branch (600 X).
 I. Mature cystocarp in culture (40 X).

