

Apoglossum minimum and *A. gregarium* (Delesseriaceae, Rhodophyta), Two New Records from Korea

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Two species of *Apoglossum* is newly recorded in Korea collected from subtidal habitats of Jeju Island. *Apoglossum minimum* Yamada has previously been known only from the coast of Japan. It is characterized by having corticated midrib but lacking microscopic veins. *Apoglossum gregarium* (Dawson) Wynne is reported for the first time from the north western coast of Pacific Ocean. It has been distinguished by its ecorticate midrib from the former species. Their morphological characteristics in detail and taxonomic issues are discussed.

Key Words: *Apoglossum gregarium*, *A. minimum*, new record in Korea

INTRODUCTION

Collections from subtidal habitats often include various tiny delesseriacean algae. Assigning them to appropriate positions has frequently been difficult, especially between *Delesseria* and *Apoglossum*. *Apoglossum* was erected as a subgenus of *Delesseria* Lamouroux by J. Agardh (1876) and later was elevated to the generic level by the same author (Agardh 1898). Agardh (1898) distinguished *Apoglossum* from *Hypoglossum* Kützing, considered as a related genus, primarily by the presence of conspicuous microscopic lateral veins and the irregular arrangement of cells.

Confusions in generic criteria, however, occurred in relation to *Delesseria* rather than to *Hypoglossum* because the above characteristics can be found in both. Kylin (1923) clarified the both genera after a close examination of their type species. Currently accepted features to identify *Apoglossum* are mainly based on Kylin (1923) and Wynne (1984): 1) intercalary cell divisions are absent in the primary cell row but occur in the higher order cell rows, 2) not all the third order cell rows reach the blade margin, 3) branches arise from the midrib, 4) lateral pericentral cells remain undivided, 5) when the midrib is cross sectioned, rhizoidal cells are confined to either side of the central large cells, 6) the fourth order cell rows are

on the adaxial but not on the abaxial side of the third order rows, and 7) each sterile cell group remains single.

When establishing *Apoglossum*, J. Agardh (1898) included six species, *A. decipiens* (J. Agardh) J. Agardh, *A. montagneanum* (J. Agardh) J. Agardh, *A. oppositifolium* (Harvey) J. Agardh, *A. tasmanicum* (Mueller) J. Agardh, *A. violaceum* (J. Agardh) J. Agardh, and the type species *A. ruscifolium* (Turner) J. Agardh. Two of them, *A. violaceum* and *A. decipiens*, were transferred to *Delesseria* by Kylin (1924). Five more species, *A. minimum* Yamada, *A. punctatum* Dawson, *A. spathulatum* (Sonder) Womersley et Shepley, *A. gregarium* (Dawson) Wynne and *A. unguiculescens* Millar, were newly added from Japan, Mexico and Australia (Yamada 1944; Dawson 1966; Womersley and Shepley 1982; Wynne 1985; Millar 1990; Millar and Wynne 1992); among them, *A. punctatum* was reduced to a synonym of *Grinnellia lanceolata* Dawson (Wynne 1985). The genus *Apoglossum*, therefore currently including eight species, has been known to occur in British waters, the Mediterranean, South Africa, the eastern Pacific Ocean, Australia, New Zealand, and Japan (Greville 1830; Harvey 1849; Yamada 1944; Womersley and Shepley 1982; Wynne 1984, 1985; Ballantine and Wynne 1985; Millar and Wynne 1992; Maggs and Hommersand 1993; Silva *et al.* 1996).

We collected *Apoglossum* species from the subtidal zone as a first record in Korea and identified as previously known species, *A. minimum* from Japan and *A. gregarium* from the Gulf of California. We described their mor-

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phological characteristics in detail with taxonomic discussion.

MATERIALS AND METHODS

All materials were collected from subtidal rocky habitats up to 10 m depth off Eoyoung (33°30'N, 126°28'E) and Seogwipo (33°14'N, 126°34'E) of Jeju Island. Plants were preserved in 5% Formalin seawater solution to make prepared slides and dried specimens. For anatomical study, fragments of plants were hand sectioned and stained with 1% aqueous solution of aniline blue and mounted in glycerin seawater solution (1:1) on microscope slides. Light microscopes (Olympus BH 2, and Olympus VANOX AH2 PC) were used for observation. Specimens are deposited in Seoul National University Herbarium (SNU).

RESULTS AND DISCUSSION

Apoglossum minimum Yamada 1944

(Figs 1-13)

Type locality: Hayama, Kanakawa Pref., Japan.

Korean name: 외톨난장이혀 (Oe-tol-na-zang-i-hyeo)

Distribution: Japan and Korea.

Specimens examined: Seogwipo, Jeju Island, 11 Feb. 1999 (M. R. Park).

Vegetative structures: Plants are erect, up to 1.2 cm high, and dark red. They grow on *Cladophora wrightiana* Harvey or corallines in subtidal habitats up to 10 m depth. A few to several blades arise from a discoid holdfast (Fig. 4). Blades are generally linear to elliptical but ovate to oblong in young bladelets, undulate from the margins to near the midrib, and about 1.5-1.8 mm broad (Figs 1-3). Blades are monostromatic except for the midrib which is conspicuous and heavily corticated. Microscopic lateral veins are absent but inconspicuous in upper parts of the blades (Figs 4, 8, 9). Terete axes with eroded wings are frequent in lower parts of the blades (Figs 3, 5). Bladelets arise only from the midrib on both surfaces, singly at irregular intervals (Figs 7, 8).

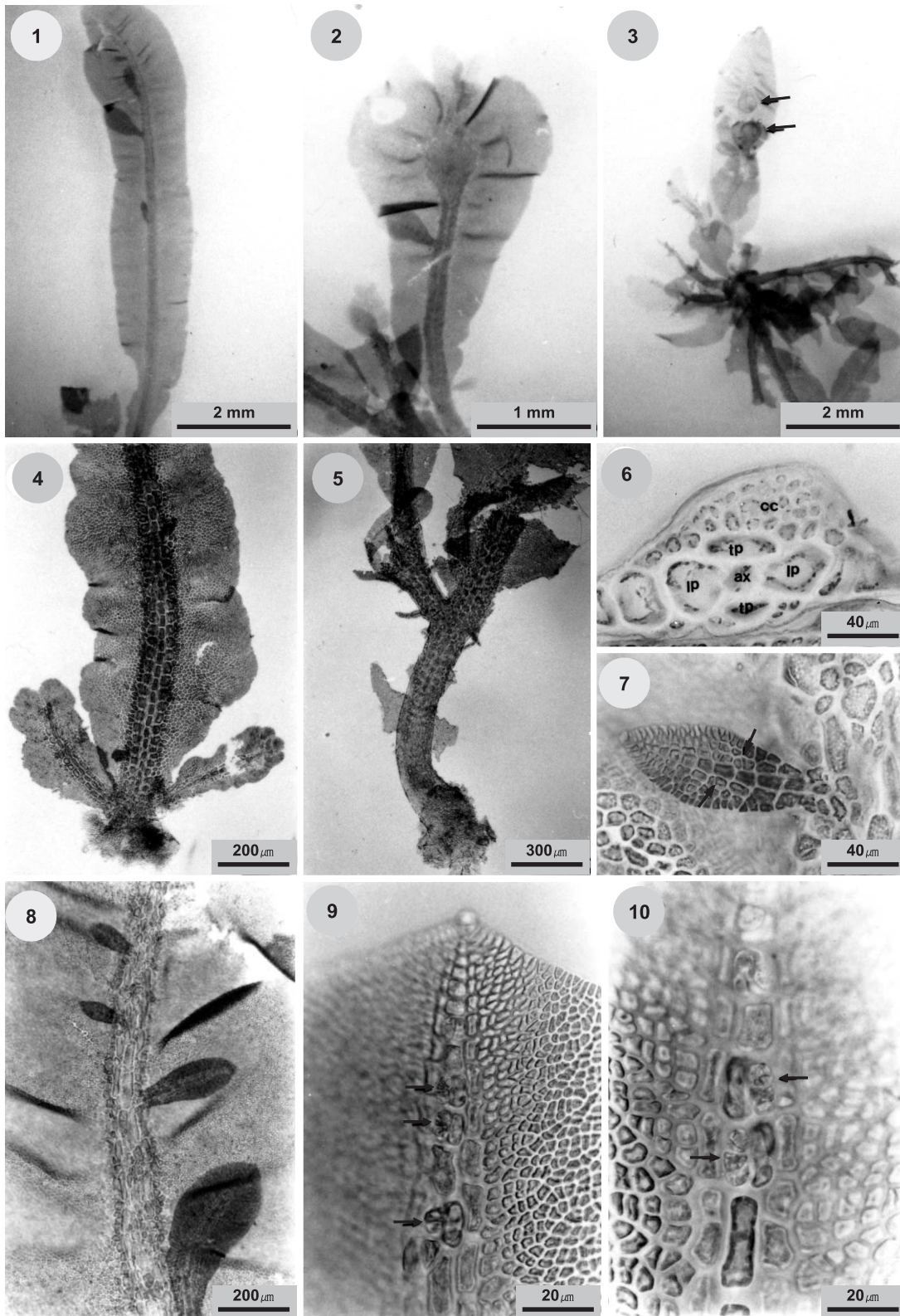
Plants grow by a single transversely dividing apical cell. The resultant lower cell divides twice longitudinally to make a central axial cell and two lateral cells. The lateral cells then divide obliquely. The upper cell acts as an initial of the second order cell rows, whereas the lower cell divides longitudinally to leave a lateral pericentral cell and also to make an initial of the third order cell rows. The second order cell rows produce the third abax-

ially and the thirds does the fourth adaxially. Among the third order cell rows, outer ones only reach out to the blade margin. Intercalary cell divisions are absent in the primary cell rows but occur in the higher order rows (Fig. 11). Lateral pericentral cells may not divide transversely at least in parent blades, but sometimes do in lower segments of young bladelets (Fig. 7). Transverse pericentral cells arise from axial cells after the formation of lateral pericentral cells. Small cortical cells are cut off from the pericentral cells. When the midrib is cross sectioned, four pericentral cells surround an central axial cell, and small cells are restricted to outer sides. Pericentral cells are 35-40 μm long and 30-35 μm broad, and the small cortical cells are 4-8 μm long and 4-7 μm broad (Fig. 6).

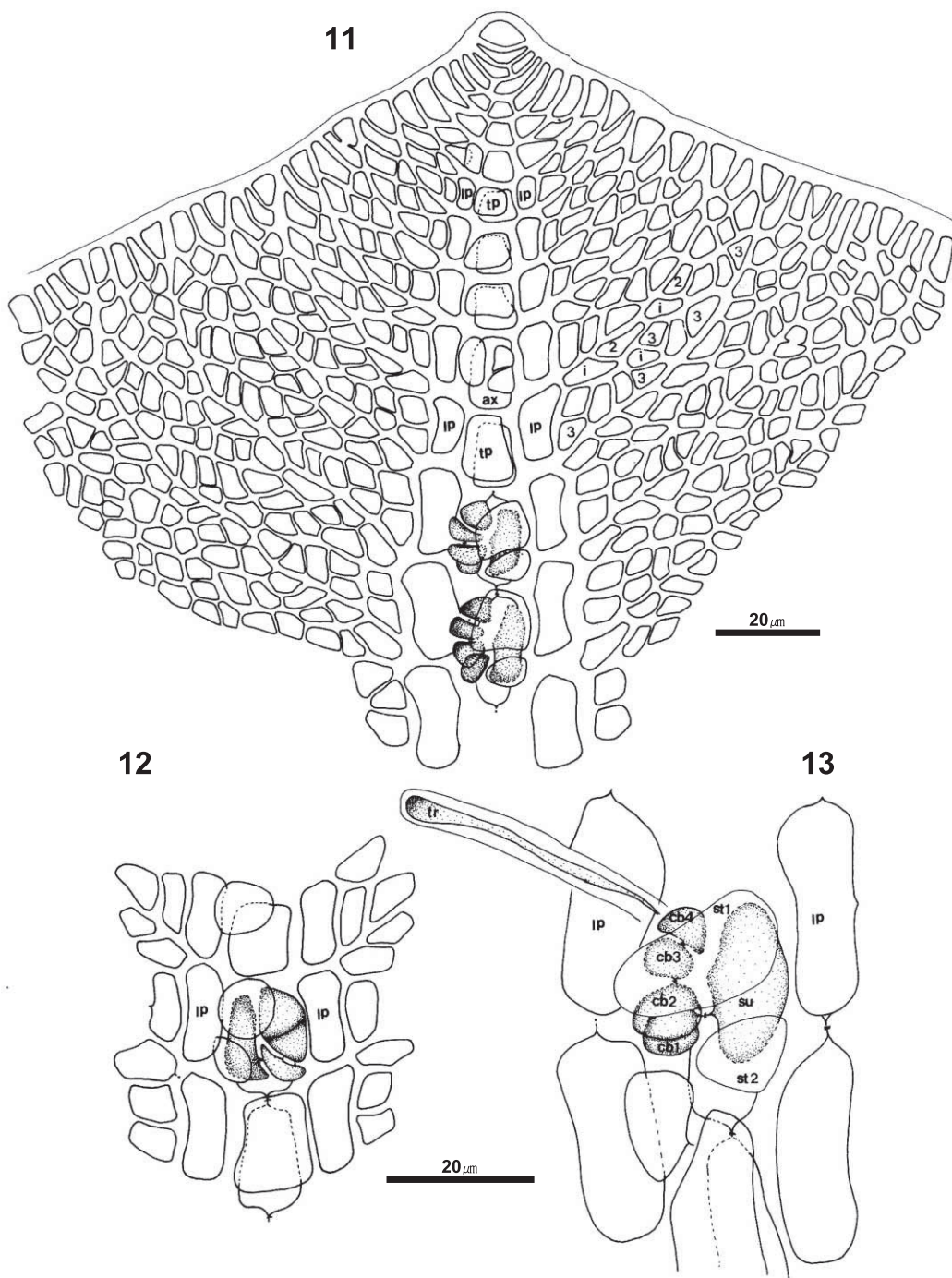
Reproductive structures: Several procarps grow successively on the primary cell rows in upper parts of the main blades as well as of the young bladelets (Figs 9, 10). A procarp consists of a 4 celled carpogonial branch and two single celled sterile cell groups (Figs 12, 13). The first sterile cell is formed over a fertile transverse pericentral cell acting as a supporting cell, and then a carpogonial branch initial is cut off laterally from the supporting cell. The second sterile cell arises from the supporting cell before the carpogonial branch is formed. Mature cystocarps with prominent ostioles are sessile on the midrib, about 0.4 mm in diameter (Fig. 3). Male and tetrasporic plants were not found.

Remarks: *Apoglossum minimum* is superficially similar to South African *A. spathulatum* (Wynne 1984) by the small size of 5-11 mm high and subalternately branched fronds. However, the original plants represented by Kützinger (1869) as *Delesseria spathulata* differ from *A. minimum* by being much branched and resembles *A. ruscifolium* rather than *A. minimum* in external appearance. In any case, *A. minimum* is separated from all the above species by absence of microscopic lateral veins, which is unusual among *Apoglossum* species.

Apoglossum minimum was originally reported from Japan (Yamada 1944). The fronds are 12 mm high and 1.5 mm broad, and having a corticated midrib without microscopic veins. This was the first record of plants lacking microscopic veins in *Apoglossum*, although Yamada (1944) himself did not emphasize it. However, the cross sectional structure of midrib seems to be the most significant feature for him to assign his new plants to *Apoglossum*. Mikami (1985) observed additional features of *Apoglossum* from the original specimens, such as undivided lateral pericentral cells and two one celled



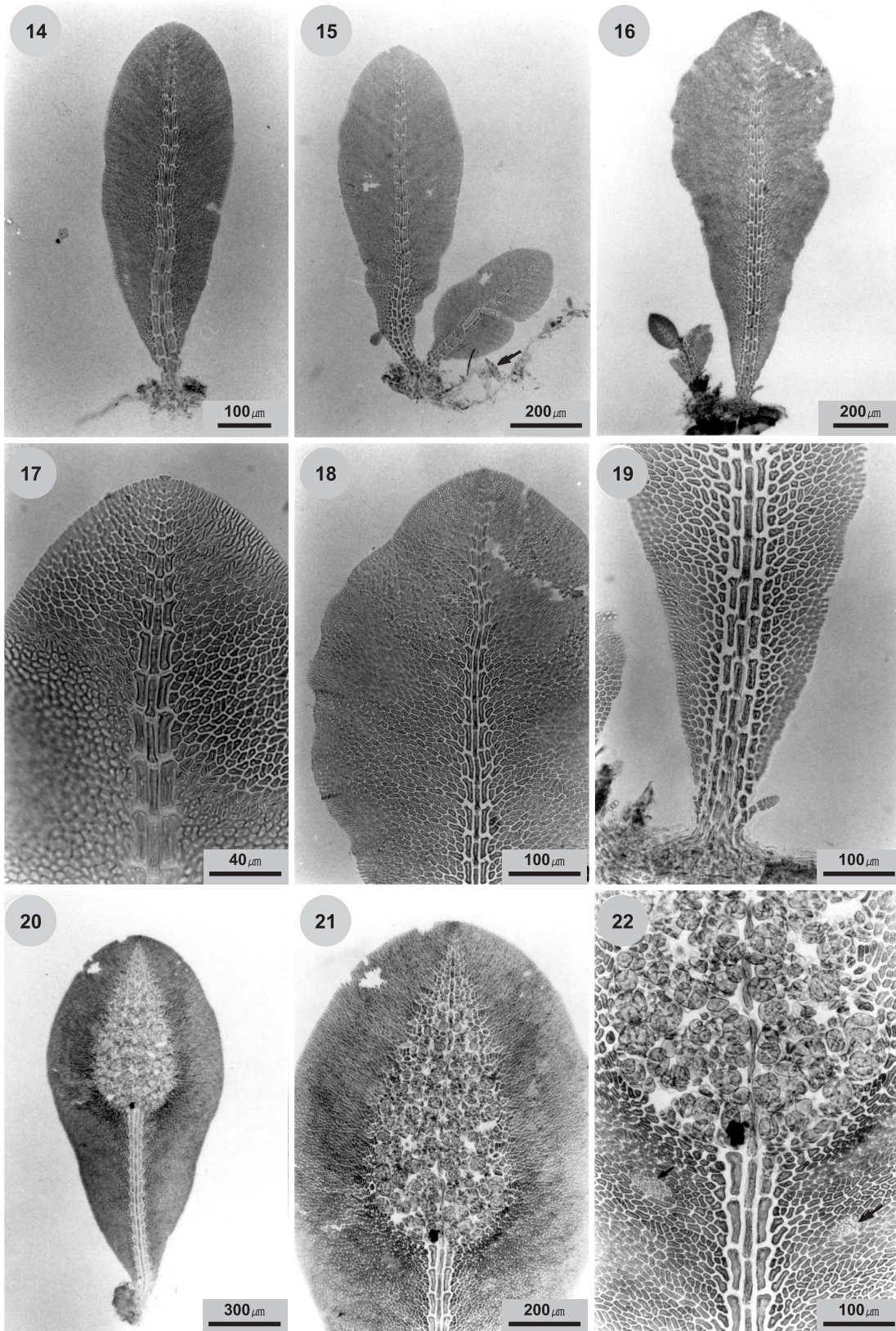
Figs 1-10. *Apoglossum minimum* Yamada. **Fig. 1.** Habit of female plant bearing procarps. **Fig. 2.** Plant with early cystocarp on midrib. **Fig. 3.** Mature cystocarps (arrows) with conspicuous ostioles. **Fig. 4.** Young plant showing well developed midrib without microscopic lateral veins. **Fig. 5.** Terete axis with eroded wings in lower part of plant. **Fig. 6.** Cross section of midrib showing typical form of *Apoglossum*. Lateral (lp) and transverse pericentral cells (tp) surrounding axial cell (ax) are in the central layer and small cortical cells (cc) in outer layers. **Fig. 7.** A bladelet from midrib with some divisions of transverse pericentral cells (arrows). **Fig. 8.** Bladelets from midrib at irregular intervals. **Figs 9, 10.** Procarps (arrows) in upper parts of parent blade and young bladelet, respectively.



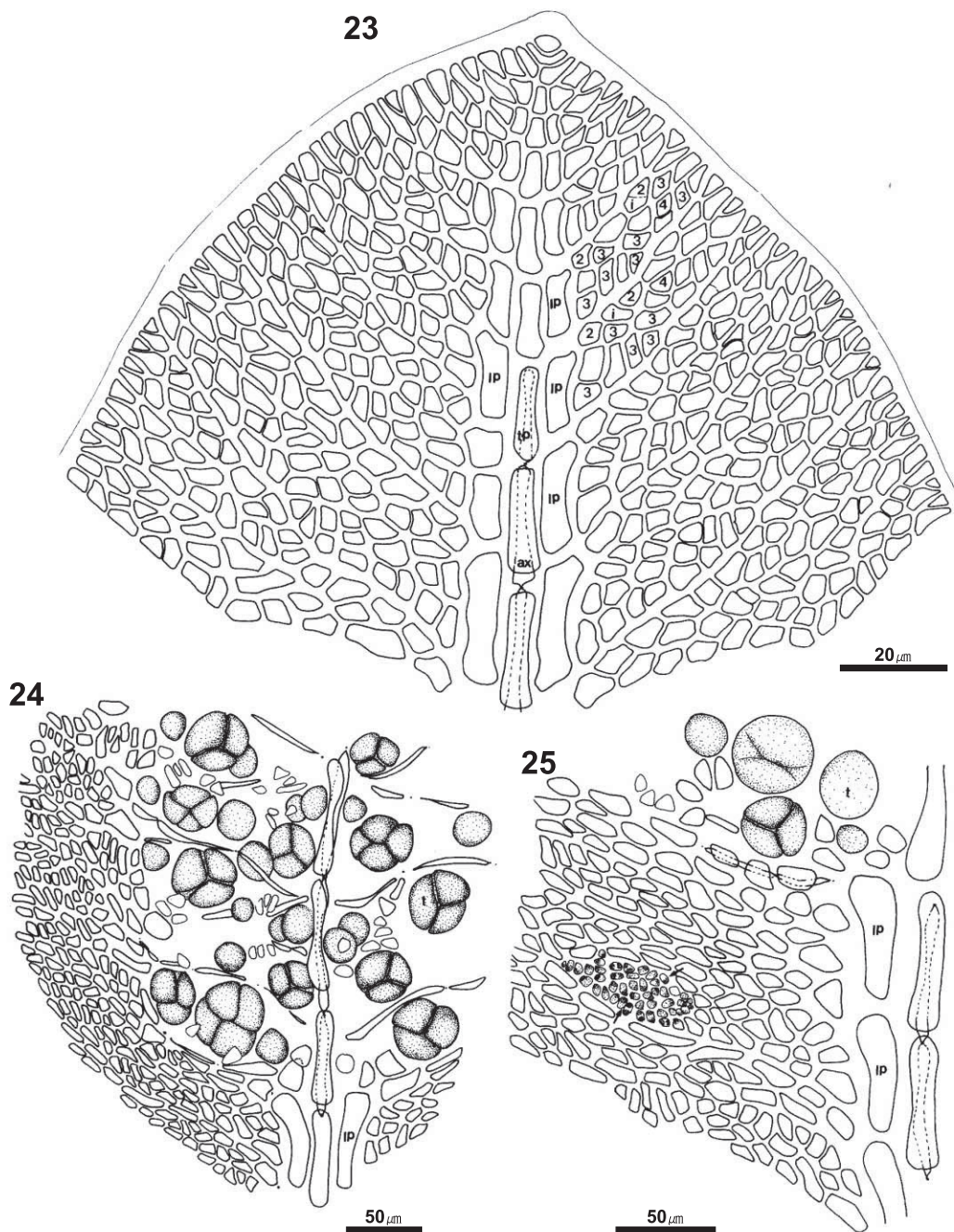
Figs 11-13. *Apoglossum minimum* Yamada. **Fig. 11.** Apical part showing axial cells (ax), lateral (lp) and transverse pericentral cells (tp). Intercalary cells (i) are in higher orders of cell rows (numerals). **Figs 12, 13.** Development of procarps. Procarps consisting of a 4 celled carpogonial branch (cb) with elongated trichogyne (tr) and two single celled sterile groups (st), originating from fertile transverse pericentral cell, i.e. supporting cell (su).

sterile groups, and therefore confirmed Yamada's (1944) generic assignment. As specific characters of *A. minimum* reproductive structures have been rather unclear because Yamada (1944) mentioned briefly that tetrasporangial and spermatangial sori were on both sides of the midrib, which has been the only information on those structures.

Apoglossum minimum, therefore, can be characterized mostly by vegetative features, i.e. irregularly subalternate branching, the corticated midrib and lack of microscopic lateral veins in addition to its minute size. *Apoglossum minimum* collected from Jeju Island corresponds well with previous descriptions in those basic vegetative char-



Figs 14-22. *Apoglossum gregarium* (Dawson) Wynne. **Fig. 14.** Habit of sterile plant. **Fig. 15.** Young bladelet (arrow) arising from prostrate filament. **Fig. 16.** Plant showing clear microscopic veins. **Fig. 17.** Distinct interstices in upper part of blade. **Fig. 18.** Upper blade with distinct network of veinlets. **Fig. 19.** Midrib ecorticate with much elongated cells. **Fig. 20.** Tetrasporic plant. **Fig. 21.** Tetrasporangia in oblong sorus in upper blade. **Fig. 22.** The same plant also bearing spermatangial islands (arrows) as well as tetrasporangial sorus.



Figs 23-25. *Apoglossum gregarium* (Dawson) Wynne. **Fig. 23.** Arrangement of cell rows (numerals) with intercalary cells (i). Ecorticate midrib consisting of axial cells (ax), lateral (lp) and transverse pericentral cells (tp). Pericentral cells are much elongated. **Fig. 24.** Tetrasporangial sorus. Tetrasporangia (t) are tetrahedrally divided. **Fig. 25.** Spermatangial sorus (arrows) near the base of tetrasporangial sorus on same blade.

acters.

***Apoglossum gregarium* (Dawson) Wynne 1985**

(Figs 14-25)

Type locality: Isla San Lorenzo del Norte, Baja California, Mexico.

Basionym: *Hypoglossum gregarium* Dawson 1966

Synonyms: *Membranoptera spatulata* Dawson 1950

Phrix gregarium (Dawson) Stewart 1974

Korean name: 복슬난장이혀 (Bog-seul-na-zang-i-hyeo)

Distribution: The Gulf of California, Caribbean Sea, South Africa, and the Mediteranean .

Specimens examined: Eoyoung, Jeju Island, 5 June 1990 (J.H. Oak), Seogwipo, Jeju Island, 11 Feb. 1999 (M. R. Park).

Vegetative structures: Plants are up to 2 mm high,

deep red, growing in subtidal zone. They are epiphytic mostly on *Cladophora wrightiana* at Seogwipo, and on corallines at Eoyoung. One to several blades arise from basal rhizoids (Figs 14-16) and occasionally from their prostrate filaments (Fig. 15). Blades are spatulate, simple, entire, up to 0.8 mm broad, and are monostromatic except at the midrib. The midrib is unthickened but conspicuous due to its distinctly elongated cells. Microscopic veins and veinlets can also be seen.

Growth by a single transversely dividing apical cell and development of cell rows are typical features of *Apoglossum* (Fig. 23). Cells of the second order rows are elongated forming microscopic lateral veins (Figs 16-18). Microscopic veinlets, formed by the third order cell rows, can be seen especially in reproductive plants. These microscopic veins and veinlets are usually distinct in adult plants with broader blades, but not conspicuous in younger ones with narrower blades. Interstices are clear among cell groups with different origins. Lateral pericentral cells usually remain undivided but can divide on rare occasions. Each pericentral cell is 50-58 μm long and 8-11 μm broad, and is 5-7 times longer than broad. There is no cortication of the midrib except at basal parts of occasional plants (Fig. 19).

Reproductive structures: Tetrasporangia occur in a single elliptical sorus in upper to middle parts of blades (Figs 20, 21). They are developed from the second and the third order cell rows as well as from the lateral pericentral cells (Figs 21, 24). They are tetrahedrally divided, 40-50 μm long and 35-50 μm broad.

A few spermatangial sori were found near the base of a tetrasporangial sorus on the same blade (Figs 22, 25). These mixed phase spermatangial sori occur in discrete islands as described previously from male plants (Stewart 1974; Ballantine and Wynne 1985; Wynne 1985). Each island is about 65 μm long, 30 μm broad. Spermatangial mother cells are about 5 μm broad and spermatangia about 1 μm broad. Female and independent male plants were not observed.

Remarks: *Apoglossum gregarium* (Dawson) Wynne (1985) had been first reported by Dawson (1966) from the Gulf of California but later became the basis for the genus *Phrix* by Stewart (1974). Stewart (1974) concluded that it did not belong to *Hypoglossum* based on the holotype of *Hypoglossum gregarium* doing intercalary cell divisions and not all the third order cell rows reaching out to the margin. The species was characterized by small size of 7-10 mm, generally unbranched but with rare exceptions, undivided lateral pericentral cells and elongated

midrib cells. Since the unthickened midrib had not been reported in *Apoglossum*, Stewart (1974) erected a new genus *Phrix* for the species. Wynne (1985), however, broadened the circumscription of *Apoglossum* to include the above species with ecorticate midribs. And also he placed Dawson's (1950) other species *Membranoptera spatulata* Dawson in synonymy with it. The epithet, '*gregarium*' was adopted instead of '*spatulatum*' due to a possible confusion with *A. spathulatum* (Sonder) Womersley and Shepley (1982). *Apoglossum gregarium* has been characterized also by reproductive structures clearly contrasting to those of the type species *A. rusci-folium*, which has tetrasporangia in paired linear sori and spermatangia in parallel patches. In *A. gregarium*, tetrasporangial sori are formed singly and spermatangial sori in discrete islands.

The plants from Jeju Island have typical features of *A. gregarium*. Plants arise from rhizoidal creeping bases. Blades are usually simple but have extremely rare bladelets from the midrib as Stewart (1974) pointed out before. The midrib is ecorticate and microscopic veins are more visible in reproductive blades. Tetrasporangia are formed in an elliptical sorus. An occasional plant showed some transverse divisions of lateral pericentral cells as mentioned by Stewart (1974). *Apoglossum gregarium* has been known to be very consistent in all characteristics even in its small size with 1 cm or less on different habitats.

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