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Taxonomy of *Hypoglossum* (Delesseriaceae, Rhodophyta) from Korea

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Five species of *Hypoglossum* from the coasts of Korea were described. They were distinguished each other by vegetative morphology as well as reproductive structures. *H. barbatum* Okamura and *H. simulans* Wynne, Price et Ballantine were similar in their subalternate branchings but they were clearly different by developmental mode of 3rd-order cell rows. *H. simulans* is distinguished from *H. barbatum* as well as from the other three species in that only innermost cells of 2nd-order rows cut off 3rd-order cell rows. *H. geminatum* Okamura and *H. caloglossoides* Wynne et Kraft are oppositely branched but the latter is characterized by regular constrictions at branching points. *H. minimum* Yamada developed simple blades. Among them, *H. simulans, H. caloglossoides,* and *H. minimum* are newly recorded from Korean waters.

Key Words: *Hypoglossum, H. barbatum, H. caloglossoides, H. geminatum, H. minimum, H. simulans*

INTRODUCTION

Hypoglossum is one of the largest genera in the family Delesseriaceae, currently including about thirty species with world-wide distribution. *Hypoglossum* was established by Kützing (1843) on the basis of *H. woodwardii* (= *H. hypoglossoides* (Stackhouse) Collins et Hervey) from European waters. Although Kützing (1849, 1869) continued making many combinations based on *Delesseria* adding new species, other workers still recognized it as a subgenus of *Delesseria* (Harvey 1853; J. Agardh 1852, 1876). J. Agardh (1898), however, finally accepted the genus *Hypoglossum* and afterward the rank has been unvariably followed.

Kylin (1923, 1924, 1956) delineated *Hypoglossum* by the absence of intercalary cell divisions, branching from the midrib, and the tertiary cell rows wholly reaching the margin. The characters frequently used to separate species in the genus were branching pattern, developmental mode of tertiary cell row, and shape of tetrasporangial and spermatangial sori.

Early species including the type were reported from the coast of Europe. Later, many species were reported from Australia, South America, Indian Ocean and East Asia (Harvey 1853; J. Agardh 1876, 1898; Okamura 1901, 1908, 1936; Yamada 1930, 1936; Wynne and Ballantine 1986; Ballantine and Wynne 1988; Wynne and Norris 1991; Silva *et al.* 1996).

Five species were described in this paper. They were previously known two species; *H. barbatum* Okamura and *H. geminatum* Okamura, and three species new to Korea; *H. simulans* Wynne, Price et Ballantine, *H. caloglossoides* Wynne et Kraft and *H. minimum* Yamada.

MATERIALS AND METHODS

Plants were collected by SCUBA diving from lower intertidal to subtidal zones of the southern to the eastern coast of Korea through the year. For anatomical study, materials were preserved in 4% formalin-seawater to make sections. Sections were stained with 1% aqueous solution of aniline blue and mounted in glycerin-seawater solution. Fresh materials were cultured in glass vessels containing 200 m*l* of PES medium under 12 : 12 h LD to investigate possible reproductive structures. Light microscopes (Olympus BH-2 and Olympus VANOX AH2-PC) were used for observation.

OBSERVATIONS AND DISCUSSION

Hypoglossum barbatum Okamura 1901

Figs 1, 6-14

Korean name: 참빗살잎

Type locality: Hyuga, Miyazaki Prefecture, Kyushu, Japan

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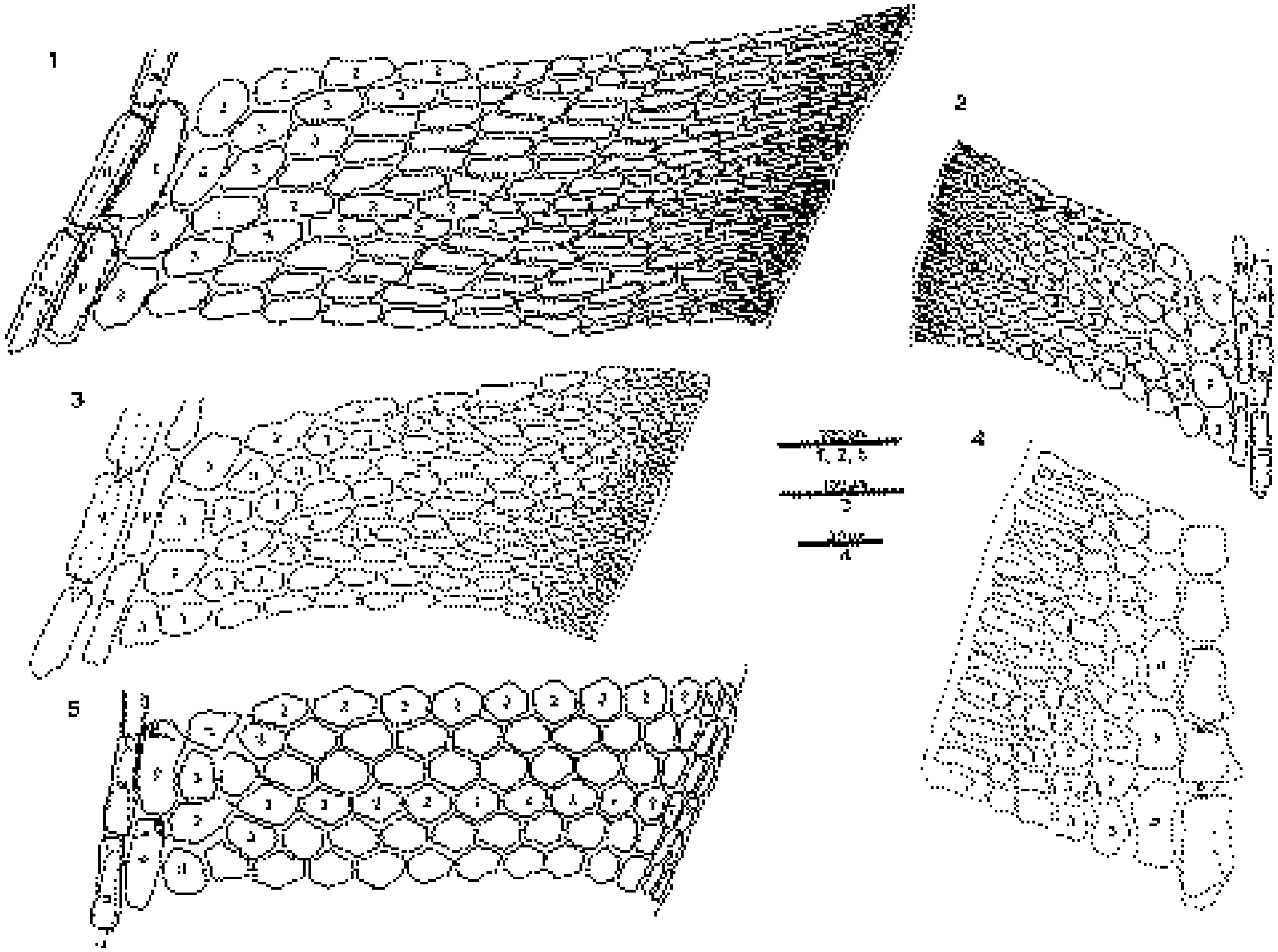


Figs 1-5. Cell arrangements of *Hypoglossum*.

Figs 1-4. Cells of 2nd-order rows (2) borne 3rd-order cell rows (3). Fig. 1. *H. barbatum*. Fig. 2. *H. geminatum*. Fig. 3. *H. minimum*. Fig. 4. *H. caloglossoides*. Fig. 5. Blades of *H. simulans*. Innermost cells of 2nd-order rows only producing 3rd-order rows (p, pericentral cell; a, axial cell).

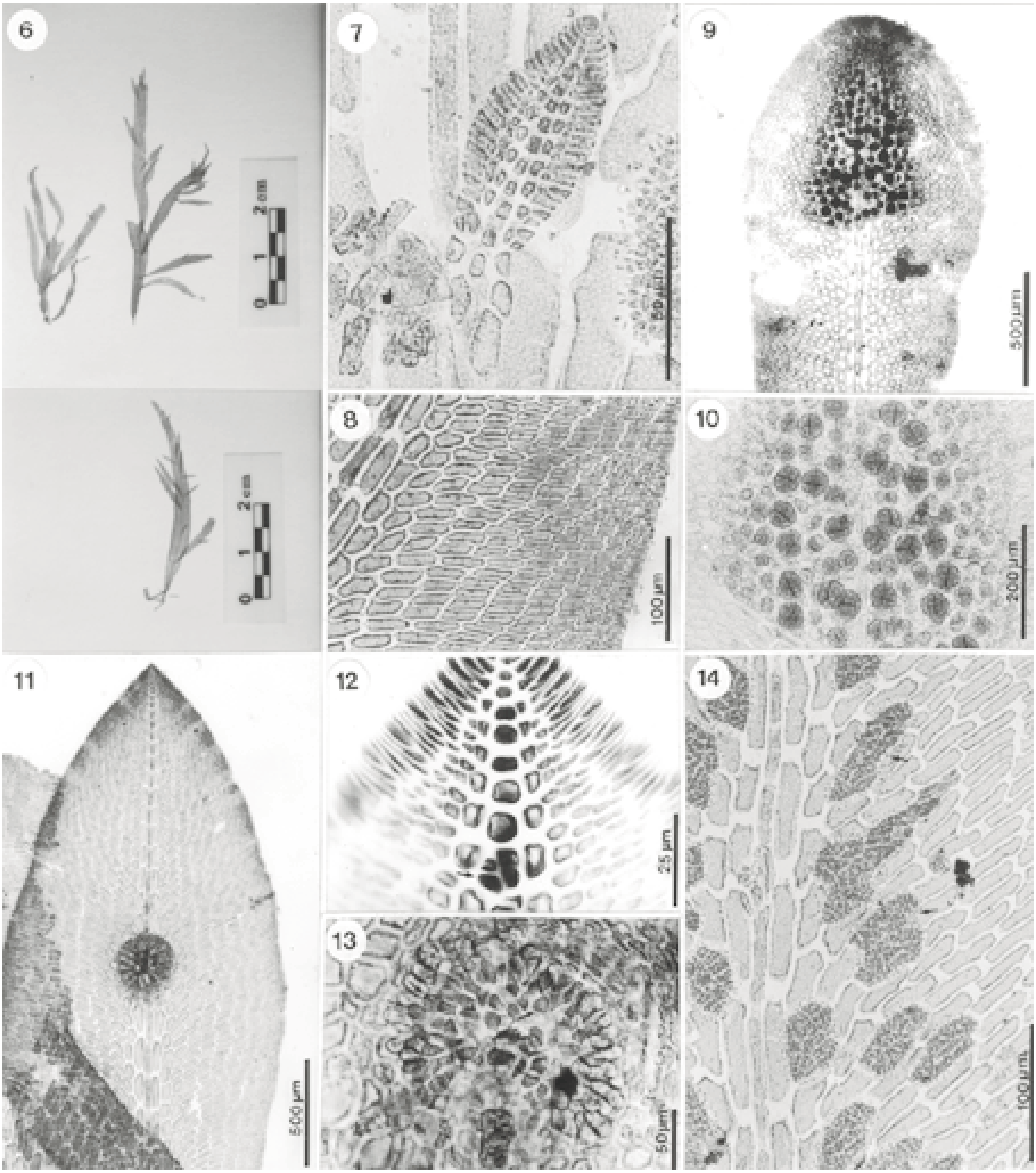
Distribution: Korea, Japan and South Africa

Collections: Guantaldo (28 viii 1988, H. Chung), Eoyoung (5 vi 1990, J.H. Oak), Seopseom (23 x 1990, J.H. Oak), Chagwido (2 vi 1991, J.H. Oak), Seogwipo (11 ii 1999, M.-R. Park), Beomseom (13 ii 2000, E.H. Bae)

Plants were creeping with one to several fronds up to 40 mm high in tufts with tiny ceramiacean algae or epiphytic on *Cladophora wrightiana* and *Amphiroa* spp. They were developed from a small disc to attach secondarily by rhizoids cut off from blade margins. Branches were subalternately developed from the midrib up to three orders (Figs 6, 7). Blades were monostromatic except for the midrib, linearly lanceolate, and 0.8-2.0 mm broad. The midrib was ecorticated. Apices were usually acute in vegetative plants, but round in tetrasporangiate ones.

A single apical cell divides transversely and the lower does longitudinally twice to make an axial cell and two lateral cells. Each lateral cell divides obliquely. The upper cell of them becomes an initial of the 2nd-order cell row, whereas lower one undergoes a longitudinal division to form a lateral pericentral cell which makes an initial of the 3rd-order cell row. Second-order cell rows are made of 15-16 cells long. Cells of 2nd-order rows wholly bear 3rd-order cell rows extend to the blade margin (Figs 1, 8). Transversal pericentral cells are cut off from axial cells after formation of the lateral pericentrals.

Tetrasporangia in an elliptical sorus are formed on upper middle part of the blades not covering the axial row (Figs 9, 10). They arise from 2nd- and 3rd-order cell rows and also from lateral pericentral cells. Tetrasporangia are 60-70 μm long and divided tetrahedrally. Several procarps are formed on the primary cell row, sequentially at rather regular intervals from the apex. A procarp consists of a 4-celled carpogonial branch



Figs 6-14. *Hypoglossum barbatum* Okamura.

Fig. 6. Habits of plants. Fig. 7. Bladelet arising singly from midrib. Fig. 8. Arrangement of cells in middle parts of blade. Fig. 9. Tetrasporangial sorus in upper middle part of blade. Fig. 10. Tetrasporangia developed from 2nd- and 3rd-order cell rows. Fig. 11. A cystocarp developed singly on midrib. Fig. 12. Carpogonial branch (arrow) in upper part of blade. Fig. 13. Mature carposporangia (arrows). Fig. 14. Spermatangial sori (arrows) spotted on blade surface.

and two sterile cell groups (Fig. 12). Cystocarps are sessile and urceolate with an ostiole, and are formed singly in middle part of the blades (Fig. 11). Carposporangia are terminal, 50-60 μm long (Fig. 13). Spermatangial sori are 50-100 μm long forming small patches, which are scattered near the midrib and rather parallel to cell rows (Fig. 14).

H. barbatum Okamura (1901) was described by the characters of minute and alternate branches, linearly lanceolate blades and marginal root-like fibres as secondary attachments. The ecorticate midrib and oblong tetrasporangial sori on the midrib are also characterized. Japanese plants described by Wynne *et al.* (1989) and South African ones by Wynne and Norris (1991) agreed well with the description by Okamura (1901) except for the features of tetrasporangial sori. Both reports described tetrasporangia formed in twin sori and not derived from lateral pericentral cells. However, the plants at hand produce tetrasporangial sori on lower subapical position of the blades. Tetrasporangia arise from lateral pericentral cells as well as 2nd- and 3rd-order cell rows. The features of infrequent marginal rhizoids, ecorticate midrib and alternate branching of our materials are consistent with Japanese and South African materials (Wynne and Norris 1991; Yoshida *et al.* 1995). Male plants are first observed in this study.

***Hypoglossum geminatum* Okamura 1908**

Figs 2, 15-33

Korean name: 쌍빗살잎

Type locality: Misaki, Kanagawa Pref., Japan

Distribution: Korea and Japan

Collections: Ulleungdo Island; Dodong (18 v 1991, J.H. Oak), Tonggumi (16 ii 1990, 18 xii 1990, 20 v 1991, J.H. Oak). Cheju Island; Seopseom (23 x 1990, J.H. Oak), Chagwido (23 x 1991, Y.S. Oh), Seongsan (24 x 1991, Y.S. Oh), Seogwipo (11 ii, 31 v 1999, M.-R. Park). Southern coast; Kojedo (18 iv 1999, M.-R. Park)

Plants are erect, growing in lower intertidal to subtidal zone. Lower intertidal plants are rather brownish red, tufted on rocks in tide pools or epiphytic on coralline algae, while subtidal ones are dark-red, growing on *Cladophora wrightiana* or corallines. Plants are up to 1.5 cm high, issuing several fronds from a holdfast and subdichotomously or irregularly branched (Fig. 15). Fronds are up to 1.0 mm broad, and oppositely branched from the central cells up to three orders (Figs 17, 31). Blade margins are undulate in mature plants, but usually entire or often fimbriate due to outgrowths of marginal cells in mature cystocarpic and tetrasporangial plants. Blades are linearly oblong, monostromatic except for the midrib, which generally becomes corticated from middle to base of the blades (Fig. 19). Growth pattern and cell arrangement are similar to those of *H. barbatum* (Figs 16, 18, 30). Cells of 2nd-order cell rows wholly bear 3rd-order cell ones (Figs 2, 18).

Tetrasporangial sori are elliptical and singly formed on middle of upper blades (Fig. 20). Tetrasporangia are produced from 2nd-order cell rows as well as from lateral pericentrals, and arranged in a single row per segment and parallel to cell rows (Figs 21, 32). They are tetrahedrally divided, and 70-80 μm long (Fig. 22).

Procarps are formed on the axes of primary and secondary blades. Several procarps are formed on the midrib of a blade, among them only one develops into a mature cystocarp (Fig. 23). A procarp consists of a 4-celled carpogonial branch and two sterile groups (Figs 24, 33). Fertile transverse pericentral cell acts as a supporting cells. The supporting cell cuts off the first sterile cell and then a carpogonial branch initial. The second sterile cell arises from the supporting cell and cuts off another cell before fertilization, while the first one remains singly. Cystocarps are sessile with conspicuous ostioles. Carposporangia are borne on terminal, and 50-60 μm long (Fig. 25). Spermatangia are produced in two rows of sori on both sides of the midrib (Figs 26, 27). Fertile cells divide periclinally twice to produce an anterior and a posterior cell. Each resulting cell anticlinally divides three times to form spermatangial mother cells, each of which develops into spermatangia subterminally or terminally (Figs 28, 29).

H. geminatum Okamura (1908) was characterized by prostrating habits, opposite branchings, and entire blades with corticated midrib. Okamura (1908) distinguished this species from the related, *H. barbatum* Okamura (1901) by branching mode and cortication of the midrib. Yoshida and Mikami (1986) examined male and tetrasporangial plants to find oval to elongate spermatangial sori and tetrasporangia cut off only from 2nd-order cells including lateral pericentral cells.

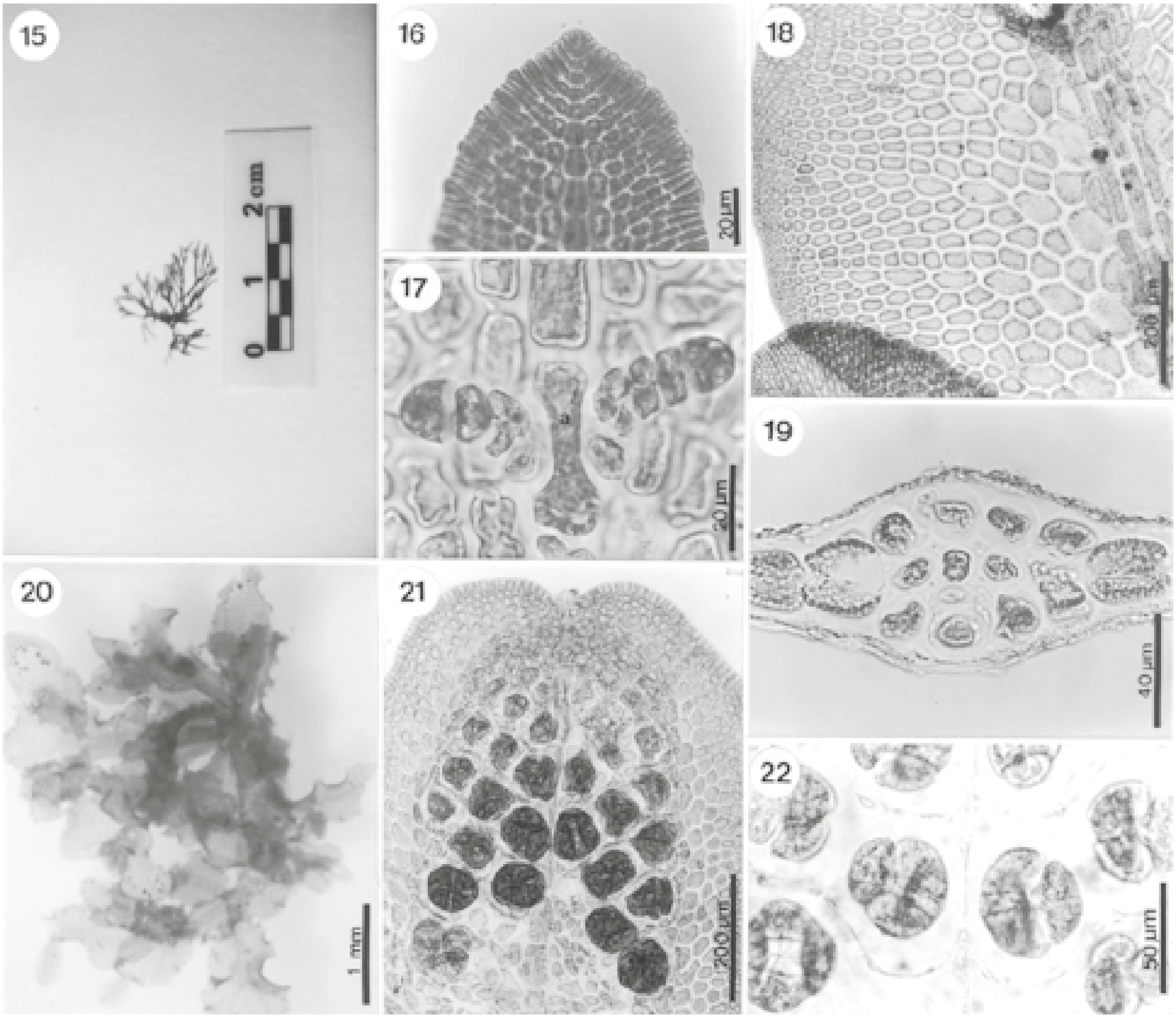
Korean plants agree with Okamura (1908) in points of fimbriate margins in old plants and marginal hair-like root fibres. Reproductive structures of the plants are closely similar to Yoshida and Mikami (1986) except for the second sterile cell division in female plants. *H. geminatum* has been restrictedly reported from the coast of Korea and Japan.

***Hypoglossum minimum* Yamada 1936**

Figs 3, 34-39

Korean name: 애기빗살잎(신칭)

Type locality: Naha, Okinawa Pref., Japan



Figs 15-22. *Hypoglossum geminatum* Okamura.

Fig. 15. Habit of plant. Fig. 16. Apical part of blade. Fig. 17. Bladelets arising oppositely from axial cell (a). Fig. 18. Cell arrangement in middle part. Fig. 19. Cross-section of ecorticate midrib in upper part. Fig. 20. Tetrasporangiate plant. Fig. 21. Tetrasporangia in serial arrangement. Fig. 22. The same developed from 2nd-order cell rows including lateral pericentral cells.

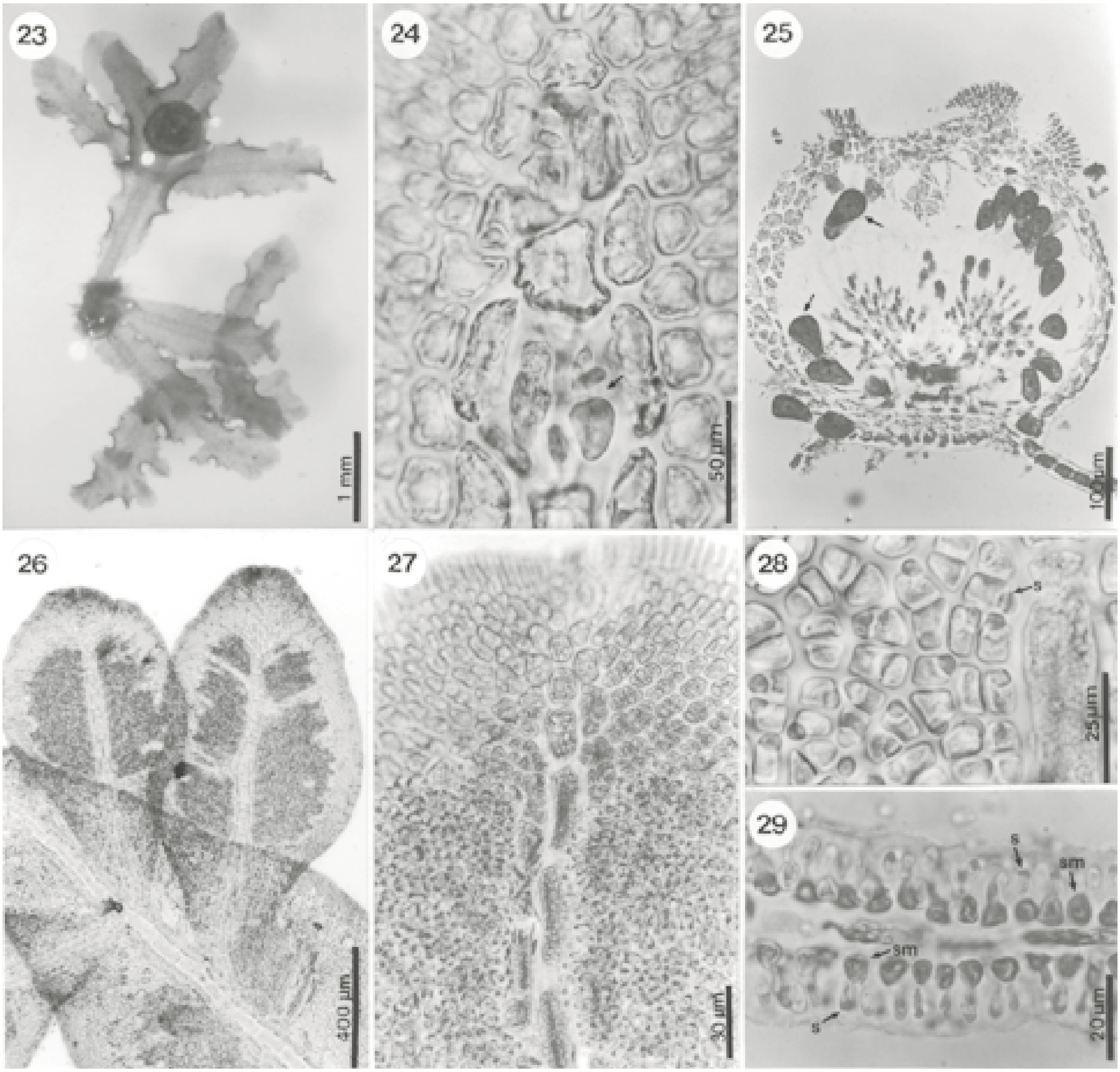
Distribution: Korea, Japan, and Maldives

Collections: Seogwipo (31 v 1999, M.-R. Park)

Plants are erect, issuing several blades from a disc with rhizoidal filaments, pinkish red, up to 3-4 mm high, and growing in subtidal zone. They are epiphytic on *Cladophora wrightiana*. Blades are oblong up to 1.2 mm broad, simple but rarely branched from the midrib, entire at margin, slightly undulate, and round in apices (Figs 34, 37). The midrib is ecorticated of the whole blades. Cells of 2nd-order rows wholly cut off 3rd-order cell rows (Figs 3, 35).

Tetrasporangial sori are round to irregular and formed on upper middle part of the blades (Figs 34, 36). Tetrasporangia are produced from 2nd- and 3rd-order cell rows as well as from lateral pericentral cells as in *H. barbatum*. They are also tetrahedrally divided and 45-55 μm long. Spermatangial sori are developed in parallel patches, but in further maturation patches tend to partly merge in one another (Figs 38, 39). Female plants were not observed.

The plants agree well with the description of Yamada (1936). Plants are very small, less than 4 mm high with simple blades, and ecorticate midrib along with rhizoids at the basal blades acting as secondary attachments. No



Figs 23-29. *Hypoglossum geminatum* Okamura.

Fig. 23. Cystocarpic plant with a fully grown cytocarp on midrib. Fig. 24. Four-celled carpogonial branch (arrow). Fig. 25. Carposporangia (arrows) in terminal position. Fig. 26. Male plant bearing mature spermatangia in continuously paired sori. Figs 27, 28. Spermatangial sori in surface view. Fig. 29. Spermatangia (s) formed terminally or subterminally from their mother cells (sm).

rhizoids are observed from blade margins. Yamada (1936) and Yoshida and Mikami (1986) described no rhizoids in this species. The features of spermatangial and tetrasporangial sori are also in agreement with Yamada (1936).

Hypoglossum caloglossoides **Wynne et Kraft 1985**

Figs 4, 40-49

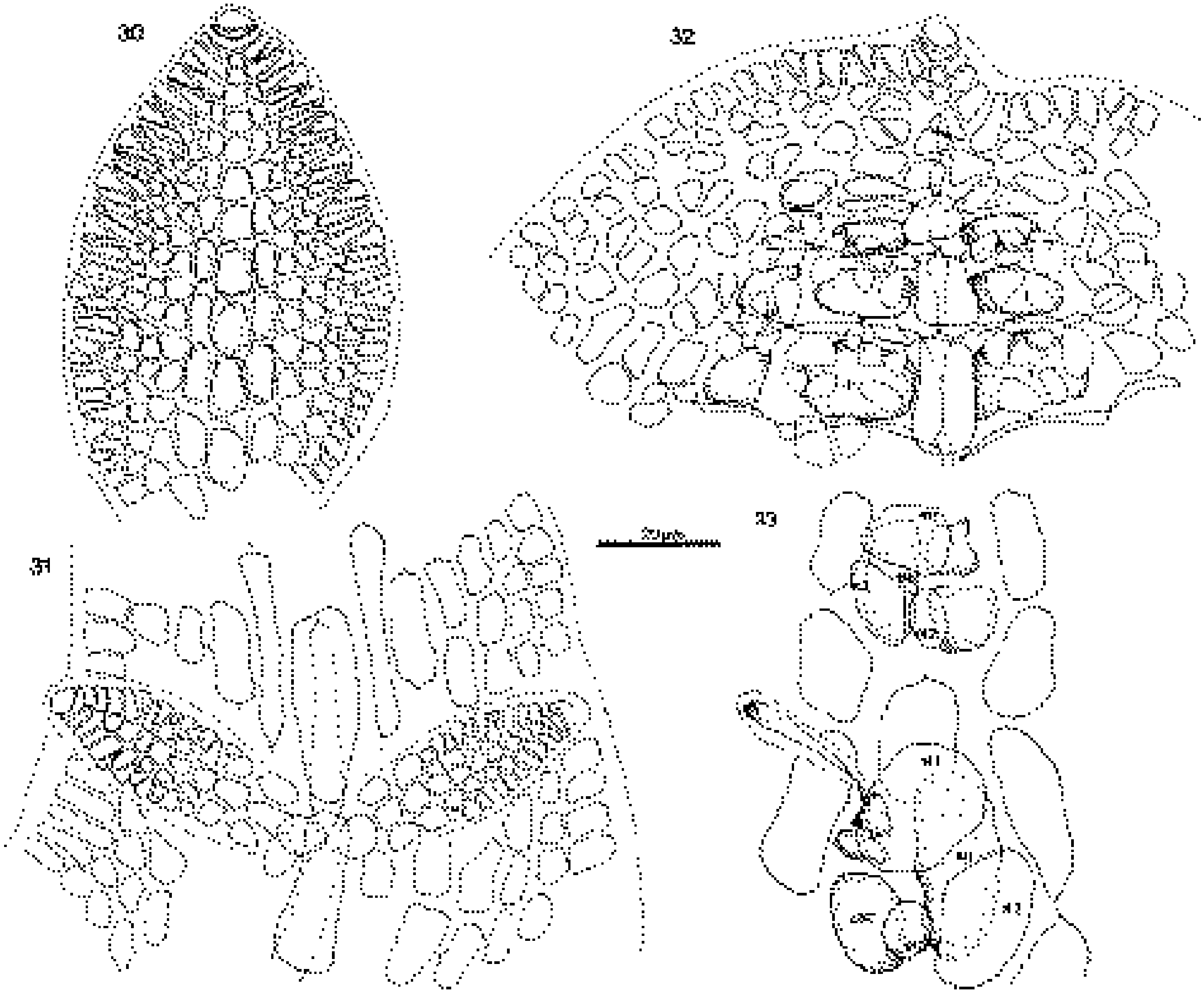
Korean name: 잘록빗살잎(신칭)

Type locality: South Passage, Lord Howe Island, New South Wales, Australia

Distribution: Korea and Australia

Collections: Geomundo (23 x 1991, Y.S. Oh), Seogwipo (11 ii 1999, M.-R. Park)

Plants are creeping, dark-red, up to 2-3 cm high, growing in subtidal zone, epiphytic on coralline algae



Figs 30-33. Internal structure of *Hypoglossum geminatum* Okamura.

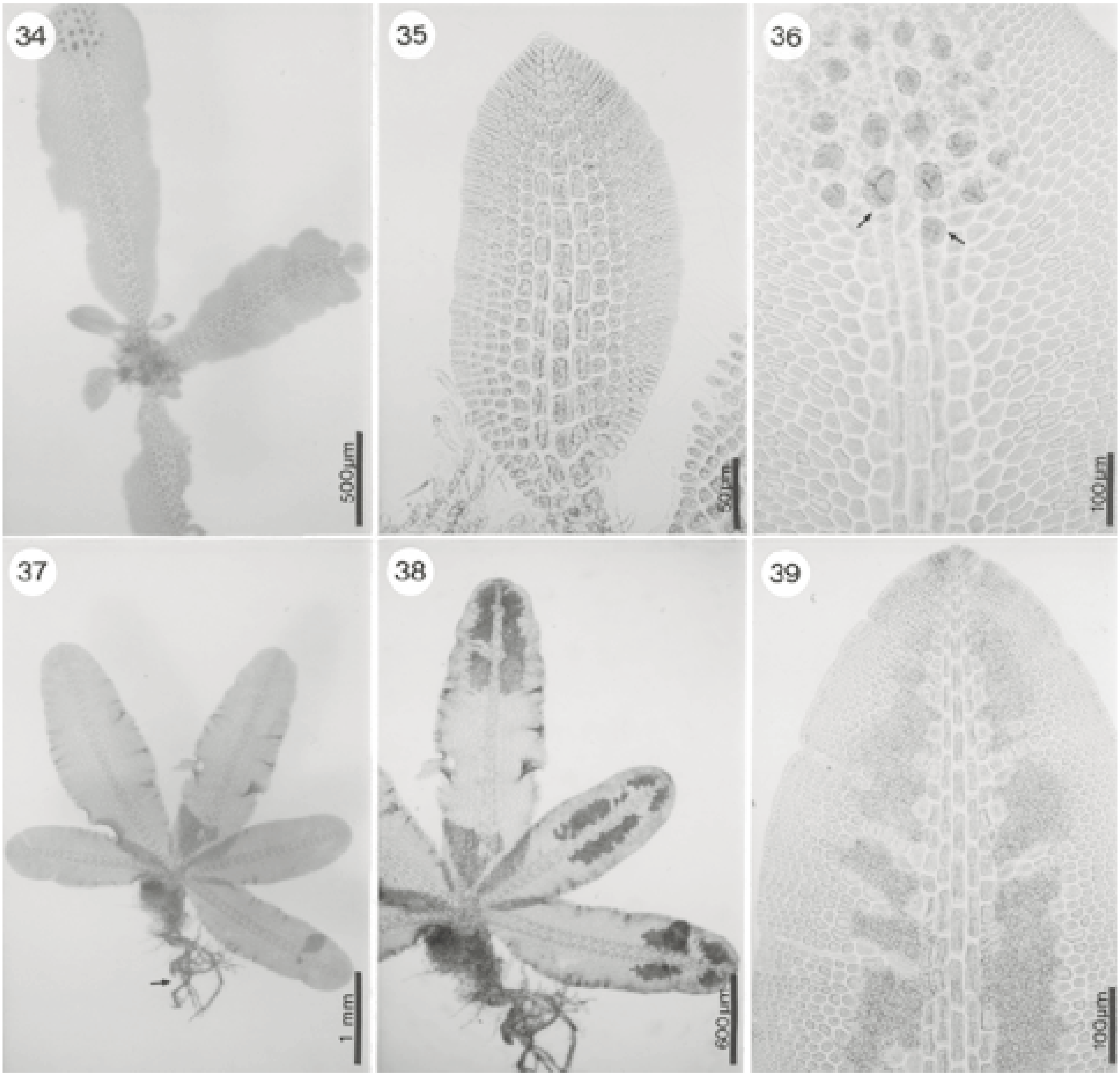
Fig. 30. Young bladelet. Fig. 31. Bladelets produced from central cell. Fig. 32. Tetrasporangia (t) developed from 2nd-order cell rows. Fig. 33. Development of procarp from transverse pericentral cells acting as supporting cell (su). Procarp of a 4-celled carpogonial branch (cb) and two sterile cell groups (st).

attached by rhizoidal holdfast, and secondarily by rhizoids originated from marginal cells at branching proportions (Figs 40, 41, 45). Blades are linearly lanceolate, ca. 0.6 mm broad. The midribs of the field materials are ecorticate while the ones of the cultured are slightly corticate over the pericentral cells (Figs 40, 43, 44).

Primary blades produce only secondary bladelets, which are opposite from the midrib with constricted branching parts. Groups of uniseriate and multicellular rhizoids are frequently found at the constrictions acting as secondary attachments (Figs 46, 47). Growth pattern and cell arrangement are similar to the preceding three species (Figs 4, 42). The 2nd-order cell rows are about 10-12 cells long.

Tetrasporangia were induced from cultured materials. Tetrasporangial sori are rather irregular in shape, and broadly spread over the blade, which are different from those of *H. barbatum*, *H. geminatum*, and *H. minimum* (Fig. 48). Tetrasporangia are cut off from 2nd- and 3rd-order cell rows and also from lateral pericentral cells. They are ca. 30 μm long. Several procarps are formed along the midrib. Cystocarps and male plants were not observed.

H. caloglossoides was distinguished by regular constrictions at branching points in sterile plants. Female plants collected from Korea showed a regular pattern of constrictions in contrast to the original description.



Figs 34-39. *Hypoglossum minimum* Yamada.

Fig. 34. Tetrasporangiate plant. Fig. 35. Young frond. Fig. 36. Tetrasporangia (arrows) in round sorus. Fig. 37. Male plants with five blades from basal disc. Figs 38, 39. Spermatangia in parallel patches and later fusion of patches in maturation.

Hypoglossum simulans **Wynne, Price et Ballantine 1989**

Figs 5, 50-57

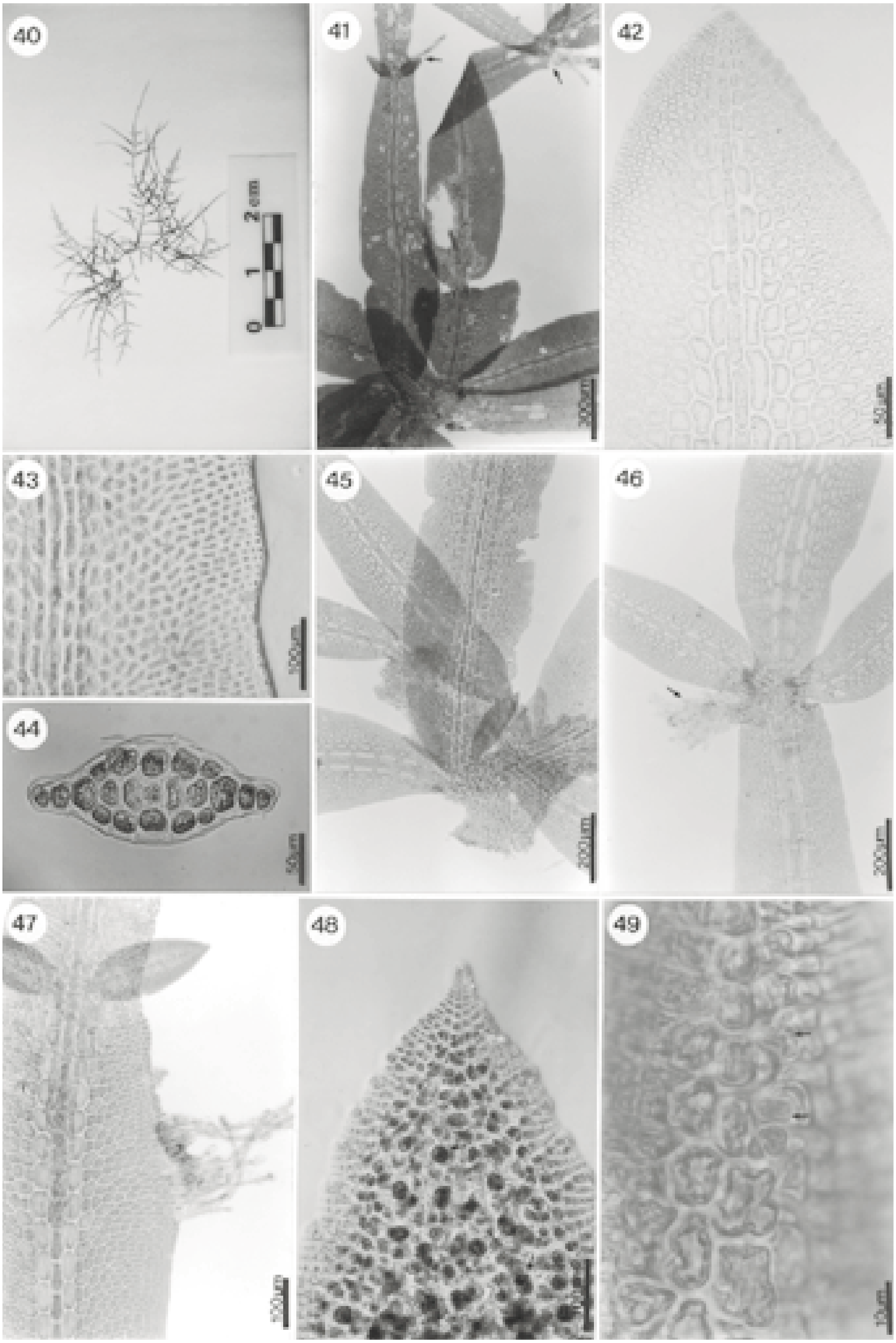
Korean name: 나도참빗살잎(신칭)

Type locality: Ilet de Pigeon, Malendure, west side of Basse-Terre, Guadeloupe, West Indies

Distribution: Korea, Australia, the South Pacific and Hawaii

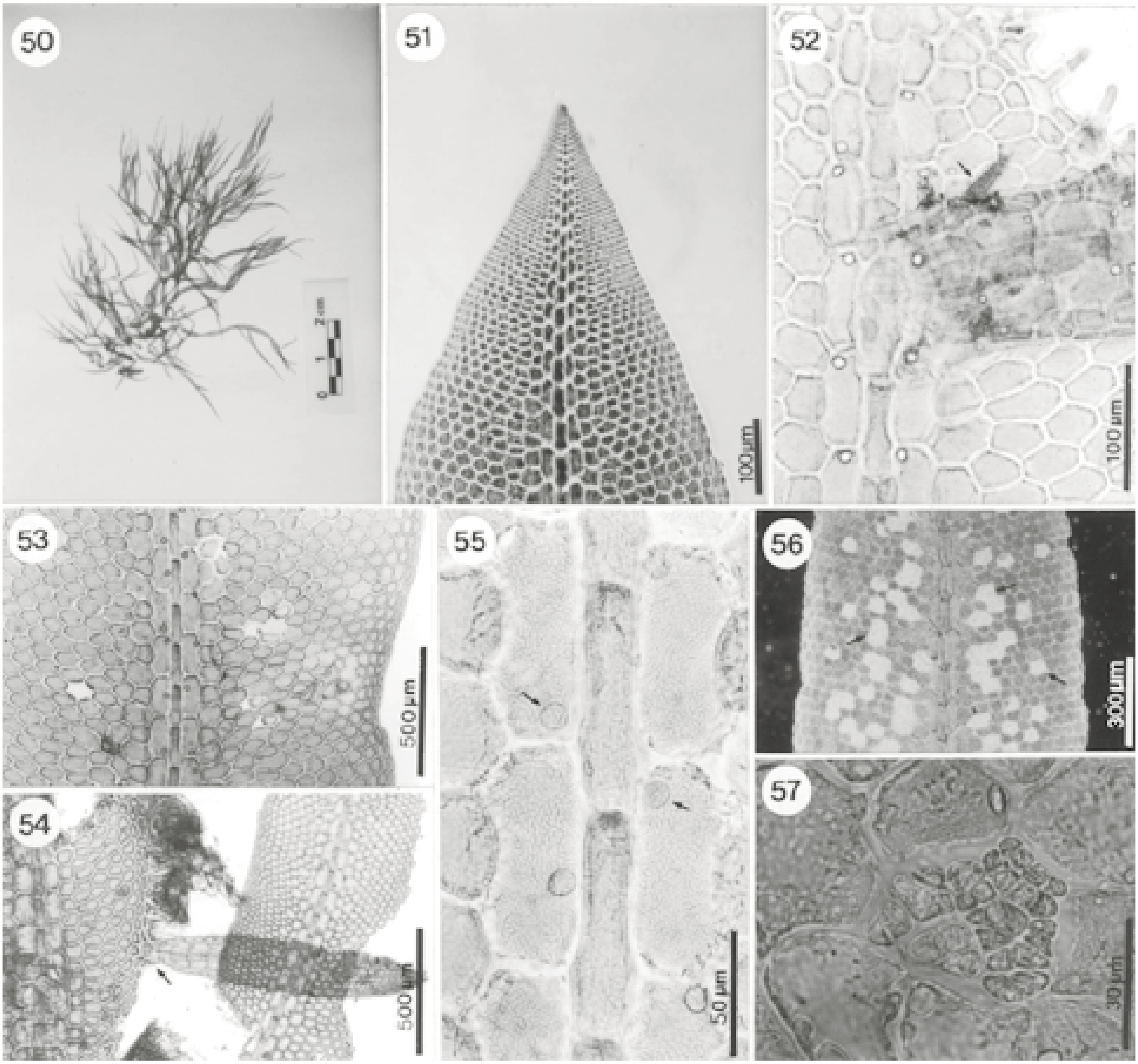
Collections: Beomseom (22 x 1991, Y.S. Oh)

Plants are darkish pink, linearly lanceolate, 1-2 cm high, epiphytic on other algae in subtidal zone, and are attached by a small basal disc and by rhizoids developed from blade margins. Cultured materials tend to be strongly branched (Fig. 50). Primary blades are entire, 1.5-2.5 mm broad, and monostromatic except for the midrib in ecortication (Fig. 51). Secondary bladelets are singly produced along the midrib at irregular intervals in upper parts of primary blades. Tertiary bladelets arise from the base of secondary bladelets not from the midrib of primary blades (Fig. 52). Marginal branches are rarely



Figs 40-49. *Hypoglossum caloglossoides* Wynne et Kraft.

Fig. 40. Tetrasporangial plant in culture. Fig. 41. Female plant with basal constrictions (arrows). Fig. 42. Apical part of blade. Figs 43, 44. Cortication in cultured plant. Fig. 45. Several blades arising from a holdfast. Fig. 46. Multicellular rhizoids (arrow) developed from margins at constriction parts to serve secondary attachments. Fig. 47. Marginal rhizoids. Fig. 48. Tetrasporangia (arrows) in cultured material. Fig. 49. Procarps (arrows) on midrib.



Figs 50-57. *Hypoglossum simulans* Wynne, Price et Ballantine.
Fig. 50. Habit of cultured male plant. Fig. 51. Apical part of blade. Fig. 52. Secondary bladelet formed singly from midrib of parent blade and cutting off small tertiary bladelet (arrow) at base. Fig. 53. Arrangement of cells in middle part, only innermost cells of 2nd-order rows bearing 3rd-order rows. Fig. 54. Marginal branching (arrow). Fig. 55. Globular granules (arrows) in lateral pericentral cells. Fig. 56. Spermatangial sori (arrows) formed in scatterd spots. Fig. 57. Spermatangial sorus in a cell.

found (Fig. 54).

Third-order cell rows are developed only from the innermost two cells of 2nd-order cell rows (Figs 5, 51, 53), which shows three cell rows per segment. Lateral pericentral cells have globular granules with 4-5 μm in diameter (Fig. 55). They are also found in 2nd- and 3rd-order cells as well as axial cells in upper part of the blades.

Male plants were induced from cultured sterile fragments. Spermatangia are irregularly spotted in one to four cell groups (Figs 56, 57). Spermatangial mother cells are ca. 5 μm in diameter. Female and tetrasporangial plants were not observed.

Wynne *et al.* (1989) distinguished *H. simulans* from *H. barbatum* by the innermost cells of 2nd-order rows bearing 3rd-order cell rows. The plants at hand apparently show this feature and also basically similar to the original description in that small tertiary bladelets from the base of secondary bladelets, ecorticate midrib, and small and scattered spermatangial sori. Although the plants at hand are different from the original description by having globular granules, it can not be significant to separate our plants from *H. simulans*.

Key to the species of *Hypoglossum* in Korea

1. Blades simple------------------------------------*H. minimum*
1. Blades branched --2
  2. Branches alternate --3
  2. Branches opposite ---4
3. Cells of 2nd-order rows wholly cut off 3rd-order cell rows--*H. barbatum*
3. Cells in innermost of 2nd-order rows cut off 3rd-order cell rows ------------------------------------*H. simulans*
  4. Branching points regularly constricted with rhizoids --*H. caloglossoides*
  4. Branching points not constricted without rhizoids --*H. geminatum*

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