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A New Variety of *Dasya rigidula* (Dasyaceae, Rhodophyta) from the Sea of Japan*

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Abstract A new variety of *Dasya rigidula* (Kützing) Ardissone is reported from the Sea of Japan. The female reproductive structure and the development of the carposporophyte are newly reported for the species. Rarely two procarps per segment in this new variety is a unique character among the known species of the genus *Dasya*.

Thalli are brownish red, 0.3-2 cm in height. The main axes are 0.3-2.3 mm in diameter, lower pericentral cells are 40-70 μm in diameter, 107-227 μm in length. The axes usually have no cortication. Pseudolaterals are 1-3.3 mm in length, branching 2-3 times, arranged radially or bilaterally on the indeterminate axes. Procarps are one rarely two per segment, arranged spirally. Two gonimolobes are formed in the cystocarp. Connecting cell is one. The third carpogonial branch cell is small or large. Mature pericarp is two- or three-cell-layered. Mature cystocarps are *c.* 0.3 mm in diameter. Spermatangial stichidia are simple or branched. Tetrasporangial stichidia are more or less curved to one side and simple, sometimes bifurcate, 130-270 X 280-530 μm. Mature tetrasporangia are up to 57 μm in diameter.

Key Index Words: *Dasya rigidula* var. *okiensis*, Dasyaceae, Rhodophyta, Sea of Japan.

Introduction

Dasya rigidula (Kützing) Ardissone (Ardissone 1878) has been reported from North Carolina, Bermuda, southern Florida, Gulf of Mexico, the Caribbean, Brazil, the Mediterranean, British Isles to Portugal, Azores, Canary Islands, West Africa (Schneider and Searles 1991) sinceits basionym *Eupogonium rigidulum* Kützing (Kützing 1843) was described, which was transferred to the genus *Dasya* (Ardissone 1878). Female reproductive structure and development of carposporophyte have not been reported for the species. This species is a deep-water alga (Schneider and Searles 1991).

The present writer collected minute red alga which appeared most closely allied to *Dasya rigidula* from deep water in the Oki Islands which lie between 35° 59′ 18″ and 36° 21′ 12″ N. and between 132° 56′ 52″ and 133° 23′ 20″ E. Detailed study on the present alga has led the present writer to a conclusion that it is a new variety of *D. rigidula*, and it is described herein together with the results of detailed observations on the female structure as well as the development of carposporophyte which are new in *D. rigidula*.

Materials and Methods

Numerous female and spermatangial as well as tetrasporic plants of the new variety were collected at 10 m depth offshore from Tsudo, the Oki Islands,

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various times from November 11, 15 in 1993 to September 5 in 1996. They were growing on *Sargassum piluliferum* (Turner) C. Agardh as well as *Zostera marina* Linné.

Fresh specimens as well as herbarium specimens and material preserved in formalin-seawater were used in this study. Material was stained for 15 min. with a 1% aqueous solution of aniline blue to which acetic acid was added in the ratio of about 1:9 (v/v), and stained material was mounted in a 50% aqueous solution of rice syrup to which acetic acid was added in the ratio of about 1:33 (v/v).

Observations

***Dasya rigidula* var. *okiensis* var. nov.**

Thalli rufescentes, 0.2-2 cm alt. Axes principales 0.3-2.3 mm diam., cellulae infernae pericentrales 107-227 μm long., 40-70 μm lat. Rami pseudolaterales 1-3.3 mm long., 2-3-plo ramosi, in axo radialiter vel bilateraliter dispositi. Procarpia 1 vel 2 in quoque segmento. Stichidia spermatangiorum simplicia vel ramosa. Stichidia tetrasporangiorum simplicia, arcuata, aliquandi bifurcata, 130-270 X 280-530 μm, unum in quoque ramo pseudo-laterali. Tetrasporangia matura ad 57 μm diam.

***Dasya rigidula* var. *okiensis* var. nov.**

Thalli brownish red, 0.3-2 cm in height. The main axes 0.3-2.3 mm in diameter, lower pericentral cells 107-227 μm in length, 40-70 μm in diameter. Pseudolaterals 1-3.3 mm in length, branching 2-3 times, arranged radially or bilaterally on the axis. Procarps one or two per segment. Spermatangial stichidia simple or branched.

Tetrasporangial stichidia curved and simple, sometimes bifurcate, 130-270 X 280-530 μm, single per pseudolateral. Mature tetrasporangia up to 57 μm in diameter.

Holotype collection: 10 m depth, offshore from Tsudo, the Oki Islands, Sea of Japan, 17 November 1995.

Holotype (female) os 10129, isotypes (male) os 10130 and (tetrasporic) os 10131, all deposited in the Phycological Herbarium of the National Science Museum, Tokyo (TNS).

Etymology: The varietal epithet refers to the Oki Islands, which is the type locality.

Additional specimens examined: Numerous specimens from the type locality at various times of the year from 1993 to 1996.

Vegetative structure

Thallus is erect, brownish red, up to 0.3-2 cm in height, consists of one to several axes (Fig. 1) of 0.3-2.3 mm in diameter, arising from a discoid holdfast (Fig. 9). Axes are cylindrical with five pericentral cells in each segment, usually no cortication but rarely light cortication in lower part, and sparsely branched dichotomously up to 10 times in two to several dimensions (Fig. 1).

The growth of the axis is sympodial (Fig. 2). The subapical cell or occasionally the cell below this cuts off a lateral cell which grows out and forward, becoming the new apical cell and displacing the old apical cell to one side. The old apical cell develops further into a pseudolateral. Segments of the axis

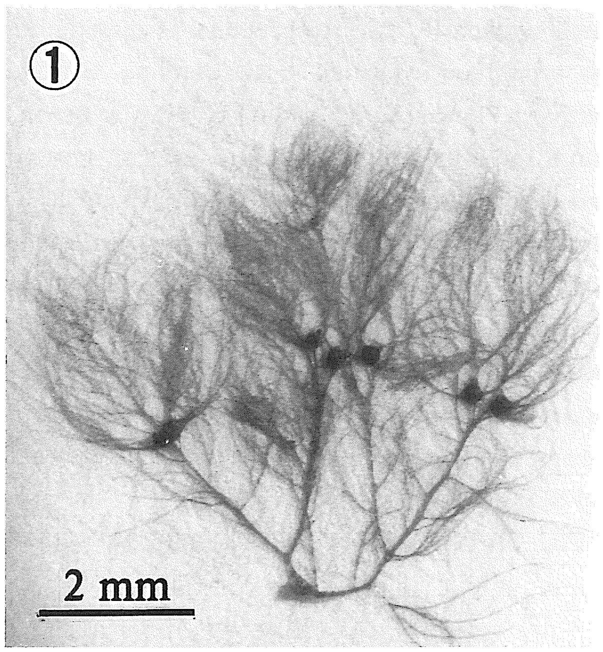


Fig. 1. *Dasya rigidula* var. *okiensis* var. nov. Habit of cystocarpic holotype specimen.

bear a pseudolateral successively or at intervals of one to four segments. Pseudolaterals are frequently caducous, pigmented, monosiphonous, subdichotomously branched 2-3 times and 1-3.3 mm in length, and they are arranged spirally in the portion of axes where they are formed in successive segments and displaced *c.* 144° to the left (2/5 spiral), so that the pseudolateral on the sixth segment lies in a similar position on the axis to that of the pseudolateral on the first, but often arranged bilaterally in the portion of axes where they are formed at intervals of segments.

The mature pseudolateral has two to three successive subdichotomies along any filament, at intervals of one cell (Fig. 11). In the young pseudolateral the first branch is cut off on the left side of the pseudolateral, from the second or third occasionally the first cell (Fig. 3). Further branches of the first order of branching are cut off every second or third cell up the main filament. Successive branches are cut off usually adaxially. Growth of the pseudolateral is by apical cell division. The lower segments of the pseudolateral do not become polysiphonous.

The first of five pericentral cells is formed usually on the sixth to ninth segment from the apex, on the right side of the pseudolateral (seen from the outside). The second pericentral cell is separated to the left of the first and lies under the pseudolateral. The other pericentral cells form in a circular, clockwise sequence to the left of the second pericentral cell. The pericentral cells are slightly shorter than their central cell, as they are each formed from a bud-like outgrowth which is cut off from the central axial cell. Young pericentral cells or the basal cell of pseudolateral transversely divide usually proximally but rarely distally to cut off a short cell (Fig. 2) which fuses with a pericentral cell or the basal cell in the same row of the neighbouring segment. Those fused pericentral cells are constricted just after the fusion. Therefore, secondary pit connections form between mature pericentral cells of successive segments longitudinally, but not between adjacent pericentral cells in the same segment. Mature pericentral cells are *c.* 15-36 X 107-227 μm. Lower pericentral cells are 40-70 μm in diameter, 107-227 μm in length.

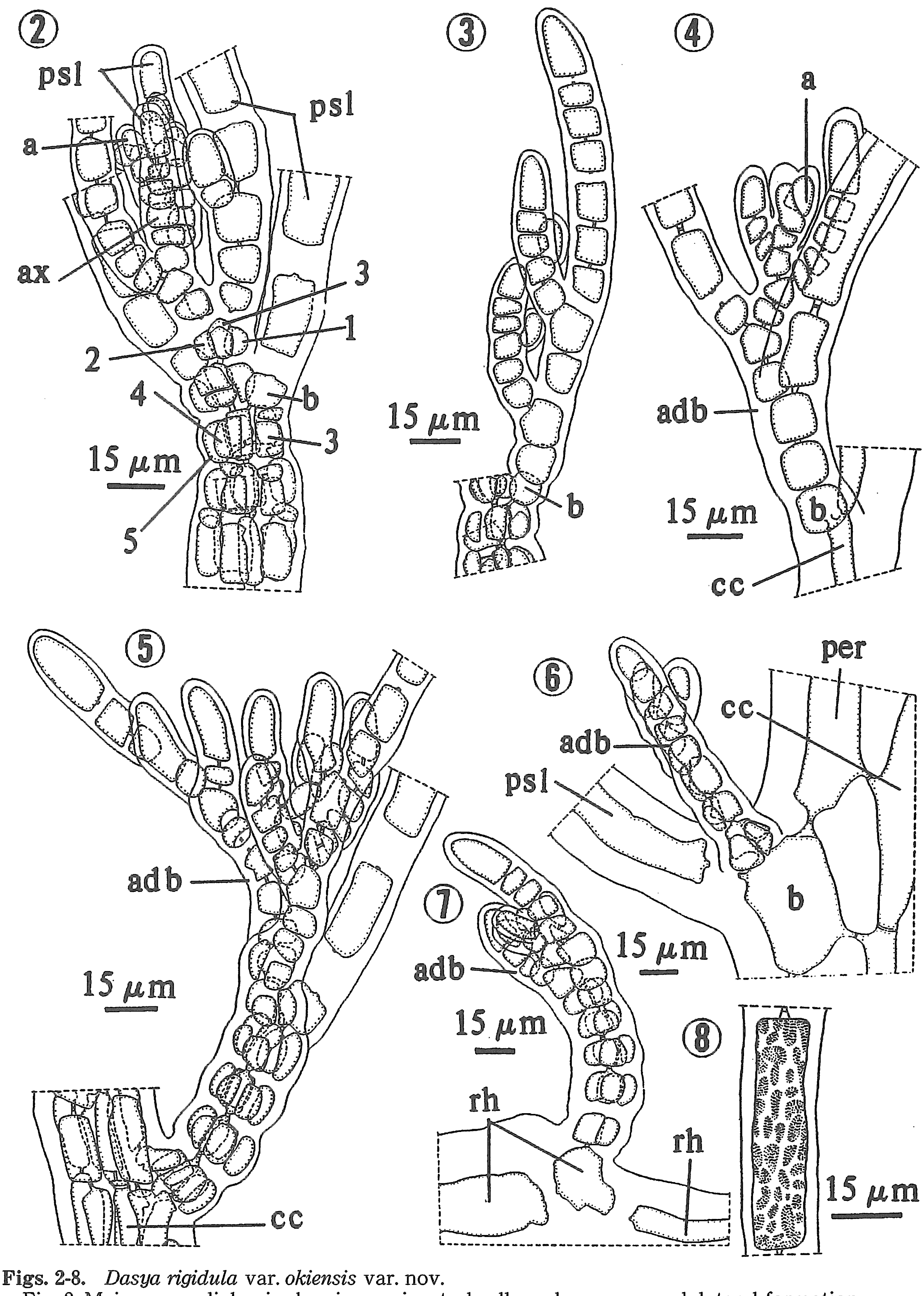
The adventitious sympodial polysiphonous branch arises exogenously from the basal cell of the pseudolateral and rhizoidal cells arising from the proximal end of pericentral cells as well as endogenously from the central cell of the axis (Figs. 4-7), some of which may develop into the indeterminate branch. However, the monosiphonous adventitious branches are not formed.

The indeterminate branch arises endogenously from the central cell of the indeterminate axes (Fig.5).

A few to several axial cells in the basal part which lack pericentral cells as well as pericentral cells in a few segments in the suprabasal part produce a few rhizoidal filaments which are simple or irregularly branched and each terminated in a more or less digitate attachment organ taking part in the formation of the discoid holdfast. Pericentral cells of the basal segment of the polysiphonous adventitious branch arising from the rhizoidal filament also produce one to several rhizoidal filaments. Simple adventitious rhizoids of *c.* 30 μm in diameter are sometimes formed from the proximal part of pericentral cells in the segments of lower part of axes or lower cells of pseudolaterals singly or in pairs and terminate in a digitate attachment organ at maturity (Fig. 10). Chloroplasts are irregularly shaped (Fig. 8).

Procarp

Gametophytes are dioecious and isomorphic with tetrasporophytes. Procarps are borne on the polysiphonous segments of the sympodial axes which develop endogenously from the central cell, but sometimes from the adventitious branches. Five pericentral cells of the fertile segments from in a circular, clockwise sequence as on all sympodial axial segments (Fig. 12). The third pericentral cell, which always lies to the left of the pseudolateral, when the pseudolateral is present in the fertile segment, usually gives rise to the procarp (Fig. 12). Since the third pericentral cells on successive segments are



Figs. 2-8. *Dasya rigidula* var. *okiensis* var. nov.
Fig. 2. Main sympodial axis showing pericentral cells and young pseudolateral formation.
Fig. 3. Young pseudolateral.
Fig. 4. Young adventitious sympodial branch arising from a central cell.
Fig. 5. Developing indeterminate sympodial branch arising from a central cell.
Fig. 6. Juvenile adventitious polysiphonous branch arising from the basal cell of pseudolateral.
Fig. 7. Young adventitious polysiphonous branch arising from a rhizoidal cell.
Fig. 8. Chloroplasts in a cell of pseudolateral.

spirally arranged, so also are the successive procarps. On the fertilization of a carpogonium, the fertile sympodial axes cease growth, so the mature cystocarps are sessile on the upper or subterminal part of the polysiphonous axes.

Usually the third but rarely also the fifth pericentral cells cut off from its upper end the first sterile group initial. The carpogonial branch initial is then cut off usually on the right side (nearest to the second but sometimes also to the fourth pericentral cell) of the fertile pericentral cell, the residual cell becoming the supporting cell. Sometimes the carpogonial branch initial is cut off on the left side of the supporting cell. When the carpogonial branch has become 2-4-celled, the lower end of the supporting cell cuts off another sterile group initial. The 4-celled carpogonial branch, with the first cell the largest and the third wedge-shaped cell the smallest, curves upward around the supporting cell (Fig. 13). The carpogonial branch is terminated by a long trichogyne (Fig. 13). Unfertilized procarps degenerate, beginning with the trichogyne, then the carpogonium.

Carposporophyte

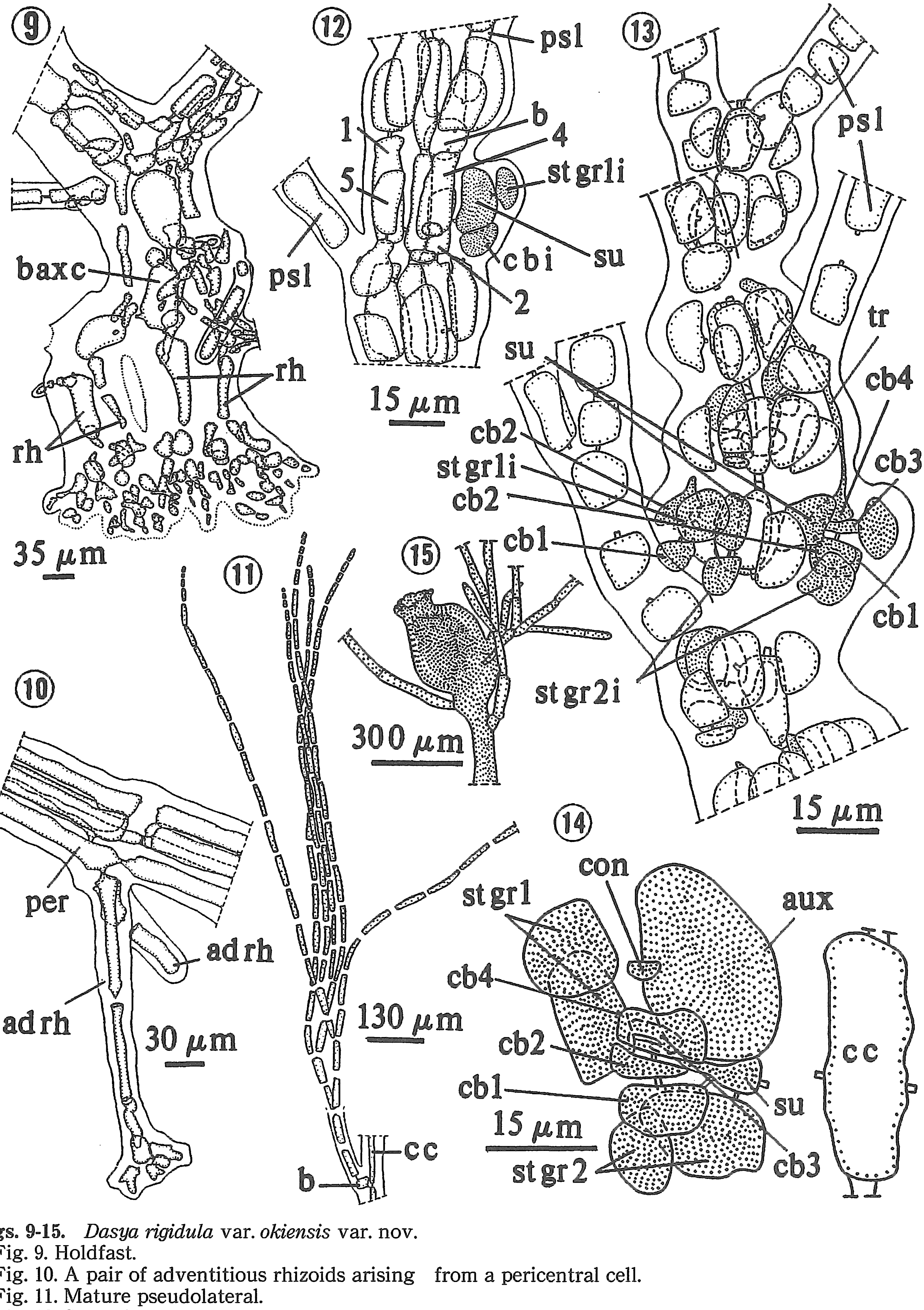
Following fertilization, the supporting cell elongates towards the carpogonium and cuts off an auxiliary cell from its upper end (Fig. 14). The carpogonium then cuts off one small connecting cell which fuses with the auxiliary cell (Fig. 14). The two sterile group initials each divide once after fertilization, giving four cells (Fig.14). As the carposporophyte develops, the sterile cells, adjacent pericentral cells and the pericarp initials all become more densely stained.

The auxiliary cell cuts off a gonimoblast initial which produces two gonimolobe initials, which in turn gives rise to two or three main gonimoblast filaments each (Figs 17, 18). A fusion cell develops when the auxiliary cell forms a new connection to the central cell of the fertile segment (Fig. 18). This is followed by the supporting cell fusing with the fusion cell (Fig. 18). The pit connections of the lower gonimoblast filaments, and those of the pericentral cells of the fertile segment in pit connection with the fusion cell, enlarge considerably and those cells become incorporated into the fusion cell (Fig. 18). The four sterile cells appear to remain separate but may be incorporated into the fusion cell later as they have not been seen in advanced stages of development. The gonimoblast develops monopodially and one to several carposporangia are formed on the terminal or subterminal cells and mature basipetally (Figs 19, 20). Mature carposporangia are clavate to pyriform and 13-33 X 36-99 μm (Fig.20).

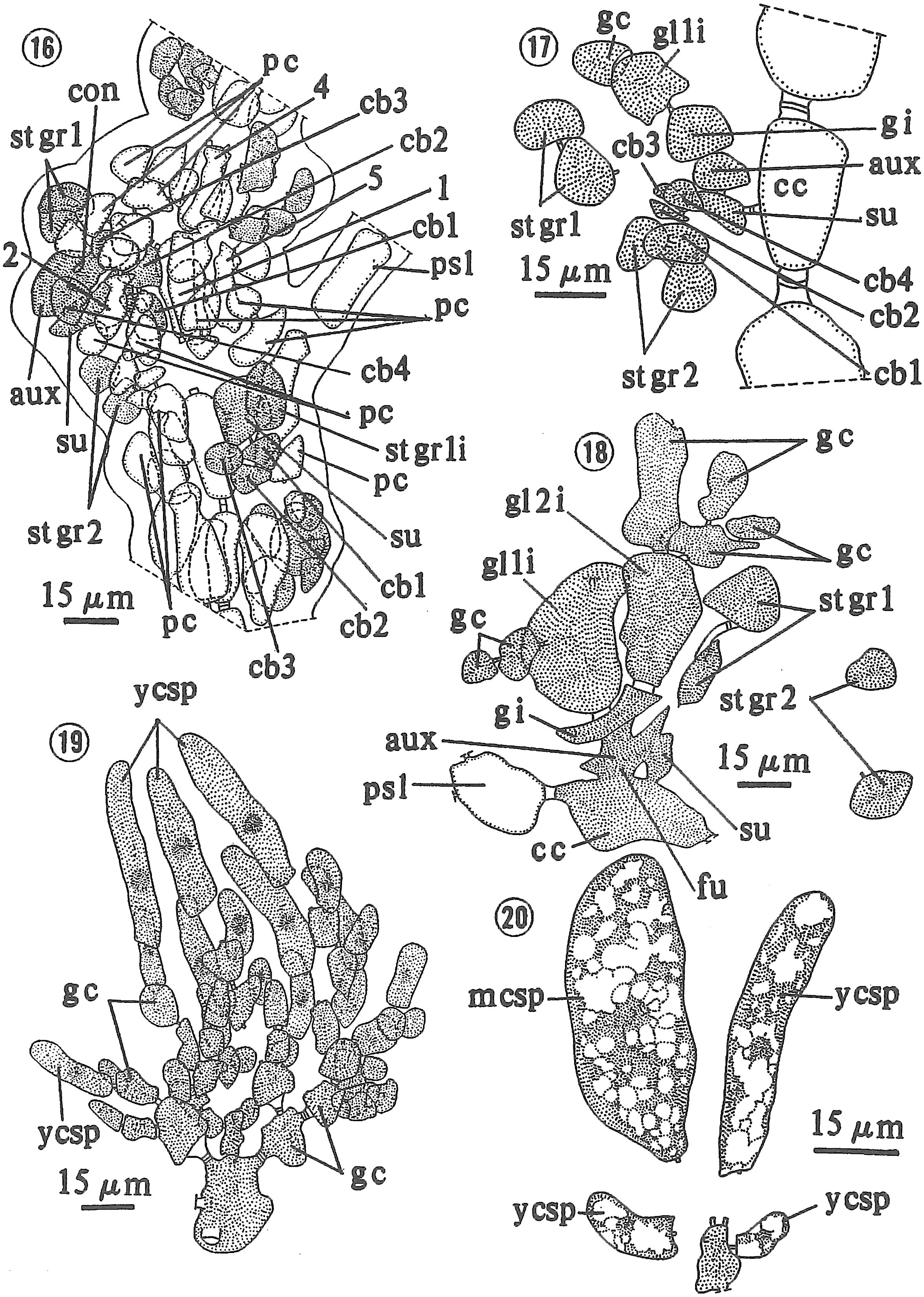
No pericarp initials are present before fertilization, but as soon as fertilization occurs, the pericentral cells adjacent to the procarp and the basal cell of the pseudolateral of the fertile segment produce a few pericarp initials each (Fig.16). Thereafter, pericentral cells and basal cells of adjacent segments to the fertile segment also produce pericarpial filaments. The mature pericarp consists of 13-15 pericarpial axial filaments growing apically, each cell cutting off two or three pericentral cells outwardly (Fig. 21). These pericentral cells may or may not in turn cut off one more layer of pericarpial cortical cells so that the mature pericarps are 2-3 layers thick. The mature cystocarp is spherical to subspherical with a terminal ostiolate beak-like short protrusion (Figs 1, 15). Mature cystocarps are *c.* 0.3 mm in diameter, and sessile in the upper part of the polysiphonous indeterminate branch (Figs 1,15).

Spermatangia

Pericentral cells forms on the abaxial surface of the young spermatangial stichidia with others developing alternately. The pericentral cells divide periclinally and successively three times, thereafter divide anticlinally and successively two or three times to form a single layer of many spermatangial mother cells surrounding the central cell (Figs 22, 23). Each spermatangial mother cell produces 1-3 spermatangia (Fig. 26). While usually only a single branch of the pseudolateral forms spermatangia, production of spermatangial mother cells may spread below a subdichotomy giving a branched spermatangial stichidium (Figs 24, 25). Spermatangial



Figs. 9-15. *Dasya rigidula* var. *okiensis* var. nov.
Fig. 9. Holdfast.
Fig. 10. A pair of adventitious rhizoids arising from a pericentral cell.
Fig. 11. Mature pseudolateral.
Fig. 12. Second division of fertile pericentral cell.
Fig. 13. Part of a female plant showing a pair of procarps in a single fertile segment.
Fig. 14. Sectional view of post-fertilization stage with auxiliary cell and a connecting cell from the carpogonium.
Fig. 15. Mature cystocarp.



Figs. 16-20. *Dasya rigidula* var. *okiensis* var. nov.
Fig. 16. Post-fertilization stage with auxiliary cell, a connecting cell and juvenile pericarpial cells.
Fig. 17. Sectional view of juvenile carposporophyte.
Fig. 18. Sectional view of part of a developing carposporophyte, showing supporting cell part, auxiliary cell part, gonimoblast initial part and central cell part of fusion cell as well as two developing gonimolobe parts.
Fig. 19. Developing gonimoblast filament with some young carposporangia.
Fig. 20. One mature and three young carposporangia formed on a terminal cell of gonimoblast.

stichidia usually have one-celled pedicel (Fig. 24) but sometimes they are sessile (Fig. 25).

Tetrasporangia

Tetrasporangial stichidia develop usually from a simple but sometimes from a bifurcate branch of the pseudolateral (Fig. 29). Usually five or six sometimes less than five pericentral cells are formed in a segment, and the first on the abaxial side with the others following in an alternate sequence. Usually all the pericentral cells become fertile. The first division of a fertile pericentral cell is transverse, forming an upper tetrasporangium and a lower stalk cell (Fig. 27). The stalk cell then cuts off two or three postsporangial cover cells to the exterior, the third forming between the other two (Figs 27, 28). Postsporangial cover cells usually remain short and don't cover the tetrasporangium completely, but sometimes grow considerably in length to cover the tetrasporangium almost completely. Tetrasporangial stichidia usually have one-celled pedicel but sometimes they are sessile. Mature simple tetrasporangial stichidia are linear-lanceolate and more or less curved to one side, 130-270 X 280-530 μm (Figs 27, 28), and the bifurcate ones are heart-shaped and *c.* 170 μm long by 130 μm broad (Fig. 29). Tetrasporangia are spherical to subspherical up to 57 μm in diameter, mature acropetally within the stichidium and tetrahedrally divided.

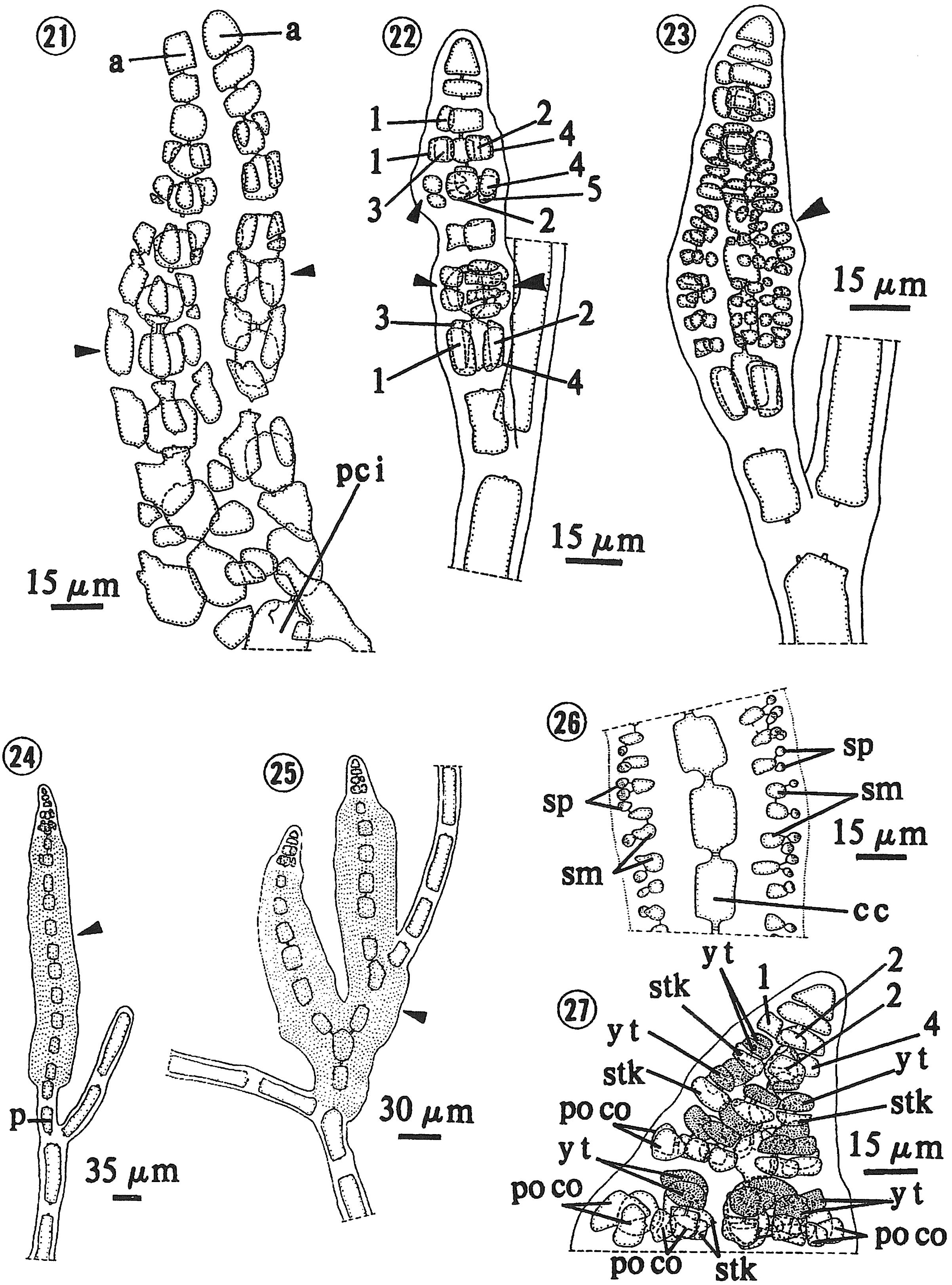
Remarks

Dasya rigidula var. *okiensis* conforms well to diagnostic features for the genus *Dasya* (Parsons 1975, de Jong *et al* 1997). *Dasya rigidula* var. *okiensis* usually lacks cortication on the axes in common with the autonym *D. rigidula* var. *rigidula*. However, the main characters distinguishing *D. rigidula* var. *okiensis* and *D. rigidula* var. *rigidula* are, as shown in Table I, length of pseudolaterals, branching of pseudolaterals, arrangement of pseudolaterals, shape and size of tetrasporangial stichidia, and diameter of tetrasporangia. There are also small differences between *D. rigidula* var. *okiensis* and *D. rigidula* var. *rigidula* with regard to the color of thalli, size of lower pericentral cells, number of tetrasporangial stichidia per segment, and shape of spermatangial stichidia. *D. rigidula* var. *okiensis* is considered to be

Table I. Comparison of varieties in *Dasya rigidula*.

Character	D. *rigidula* var. *okiensis* var. nov.	D. *rigidula* var. *rigidula*[1]
Color of thalli	Brownish red	Purplish to rosy red
Height of thalli	0.3-2 cm	1-8 cm
Diameter of main axes	0.3-2.3 cm	0.3-0.5 cm
Size of lower pericentral cells	40-70 X 107-227 μm	70-180 X 350-400 μm
Length of pseudolaterals	1-3.3 mm	0.4-1.0 mm
Branching of pseulolaterals	2-3 times	3-5 times
Arrangement of pseudolaterals	Radial, sometimes bilateral	Radial
Adventitious branches	Present, polysiphonous	Absent?
Number of procarp per segment	1 rarely 2	?
Shape of spermatangial stichidia	Simple or branched	Simple
Number of tetrasporangial stichidia per segment	Single	Single, rarely paired
Shape of tetrasporangial stichidia	More or less curved, simple, sometimes furcate	Straight, simple
Size of tetrasporangial stichidia	130-270 X 280-530 μm	30-60 X 80-220 μm
Diameter of tetrasporangia	Up to 57 μm	Up to 20 μm
Distribution	Japan	Warm temperate and tropical Atlantic Ocean

[1]Taylor (1960), Schneider and Searles (1991), Olivieira F and Ugadim (1974).



Figs. 21-27. *Dasya rigidula* var. *okiensis* var. nov.

Fig. 21. Surface view of a pair of two-cell-layered developing pericarpial filaments (arrowheads).

Fig. 22. Young spermatangial stichidium showing a pericentral cell divided transversely once (small arrowheads) and another divided transversely three times (large arrowhead).

Fig. 23. Developing spermatangial stichidium (arrowhead) bearing many spermatangial mother cells in the middle part.

Fig. 24. Simple mature spermatangial stichidium (arrowhead).

Fig. 25. Branched mature spermatangial stichidium (arrowhead).

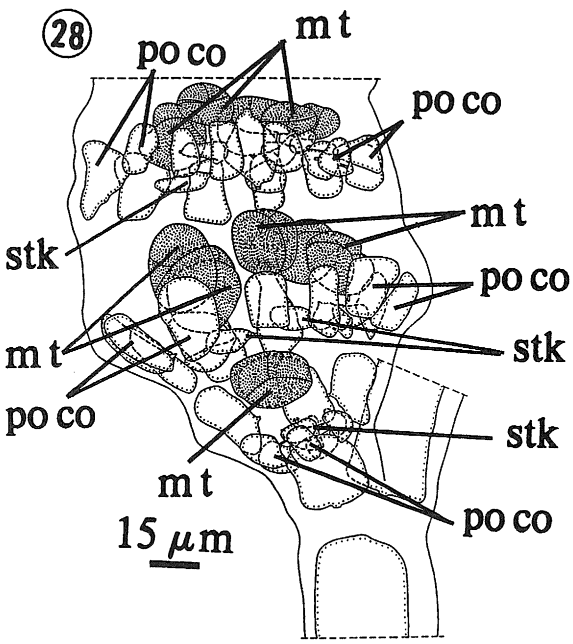


Fig. 28. *Dasya rigidula* var. *okiensis* var. nov. Lower part of a mature tetrasporangial stichidium in Fig. 27, showing mature tetrasporangia and cover cells.

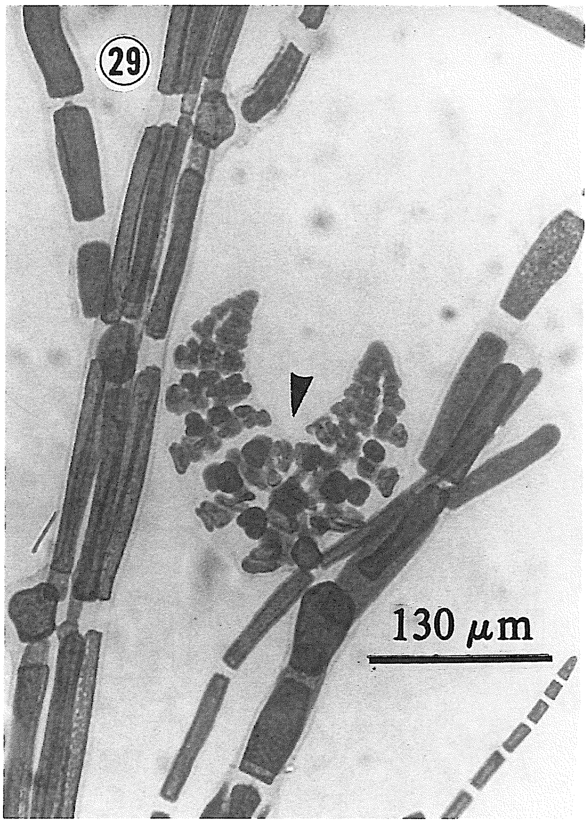


Fig. 29. *Dasya rigidula* var. *okiensis* var. nov. Part of a mature tetrasporophyte showing a bifurcate tetrasporangial stichidium (arrowhead).

unique among the known species in the genus *Dasya* in having rarely two procarps per segment.

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Abbreviations used in Figures

a	apical cell
adb	adventitious branch
adrh	adventitious rhizoid
aux	auxiliary cell
ax	axial cell
b	basal cell of pseudolateral
baxc	basal axial cell
cbi	carpogonial branch initial
cb1, cb2, cb3, cb4	carpogonial branch cells
cc	central cell
con	connecting cell
fu	fusion cell
gc	gonimoblast cell
gi	gonimoblast initial
gl1i, gl2i	first gonimolobe initial, second gonimolobe initial
mcsp	mature carposporangium
mt	mature tetrasporangium
p	pedicel
pc	pericarpial cell
pci	pericarp initial
per	pericentral cell
poco	postsporangial cover cell
psl	pseudolateral
rh	rhizoidal cell
sp	spermatangium
sm	spermatangial mother cell
stgr1, stgr2	first sterile group, second sterile group
stgr1i, stgr2i	first sterile group initial, second sterile group initial
stk	stalk cell
su	supporting cell
tr	trichogyne
ycsp	young carposporangium
yt	young tetrasporangium
1, 2, 3, 4, 5	pericentral cells in sequence of formation

Fig. 26. Longitudinal section of mature spermatangial stichidium.
Fig. 27. Upper part of a mature tetrasporangial stichidium showing young tetrasporangia and formation of cover cells.

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