Jpn. J. Phycol. (Sôrui) 39: 189–193, June 20, 1991

Taiju Kitayama, Hiroshi Kawai and Tadao Yoshida: Morphological observations on *Sphacelaria californica* Sauvageau ex Setchell et Gardner (Sphacelariales, Phaeophyceae), new to Japan

Key Index Words: *brown algae—morphology—Phaeophyceae*—Sphacelaria californica—*Sphacelariaceae—Sphacelariales.*

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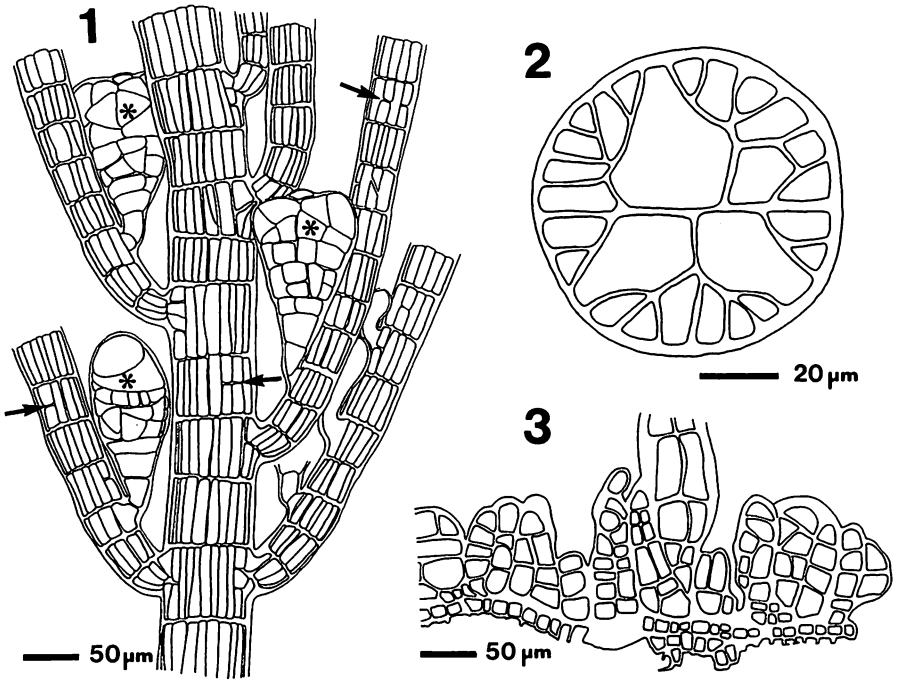
The morphology of Japanese *Sphacelaria californica* Sauvageau ex Setchell et Gardner was studied in the field and culture materials. Sauvageau (1901) described *Sphacelaria plumula* Zanardini var. *californica* Sauvageau as a new variety, based on the specimens collected at San Diego, California. He distinguished this variety from typical *S. plumula* by the following characteristics: presence of a basal disk; absence of ramifications in the lower portions of erect filaments; occurrence of transverse cell walls in the secondary segments (=secondary transverse cell walls); a slightly larger size of propagules. He also used the new specific name *Sphacelaria californica* for the taxon, although he attached a question mark to the name indicating hesitation. Setchell and Gardner (1925) treated the variety as an independent species, attributing this combination to Sauvageau. We regard *S. californica* as an independent species and follow their nomenclatural treatment. Boo and Choi (1986) mentioned the location of the propagules and the division of their lateral apical cells as the specific characteristics.

S. californica is found distributed in the Pacific Ocean (Abbott and Hollenberg 1976), but *S. plumula* has not been reported from this area. In the western Pacific Ocean, Boo and Choi (1986) reported the occurrence of drift materials of *S. californica* from the east coast of Korea, but the species has not been reported in Japan. There have been no culture works on the life history on this species. This is the first report on the distribution of *S. californica* on the Japanese coast, and on the study in culture.

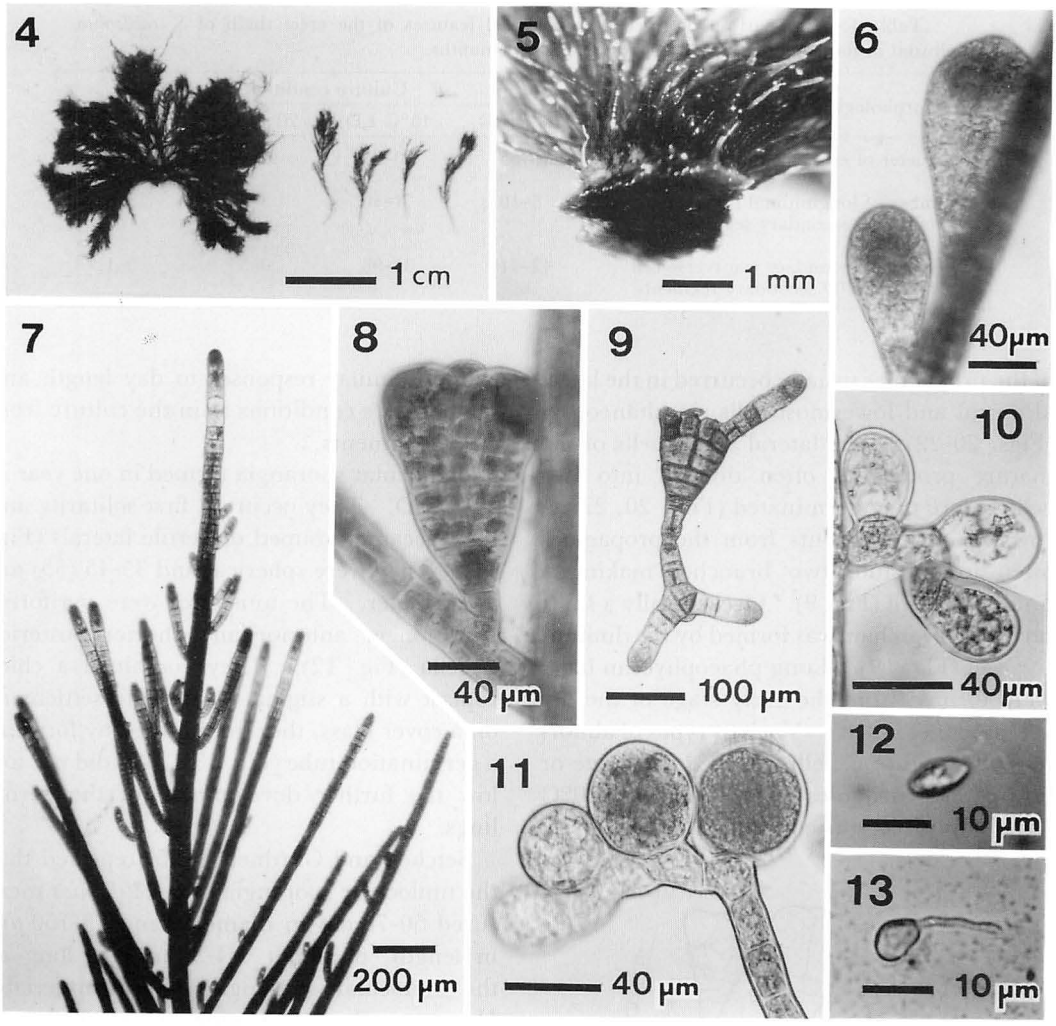
Some plants referable to *Sphacelaria californica* were collected at Ohma (41°33′N 140°55′E, 23 October 1987) and Sai (41°26′N 140°51′E, 19 January and 21 March 1988) in Aomori Pref.; Shiiya (37°28′N 138°37′E, 7 July 1990, drift) in Niigata Pref.; Seto (33°27′N 132°13′E, June 1989, coll. T. Wajima) in Ehime Pref.; and Gobo (33°52′N 135°05′E, 21 June 1989, coll. M. Matsumoto) in Wakayama Pref. The specimens examined in the present work are deposited in the herbarium of Faculty of Science, Hokkaido University, Sapporo [SAP]. They are epilithic or epiphytic and brown in color. They form erect tufts and attain to 1.6 cm in height (Fig. 4). The holdfasts are discoid (Fig. 5), polystromatic (Fig. 3), and 100–150 μm in thickness on rocks. However, when epiphytic, e.g. on *Codium fragile* (Suringar) Hariot, they become rhizoidal and penetrate into the host tissues. The erect thalli are pinnately branched and composed of main axes and laterals. The main axes are straight and terete. They are 30–50 μm in diameter in the lowermost portions, gradually increasing in diameter toward the apex, and 60–95 μm in the middle portions. The laterals are denser in the upper parts of the thalli, but sparser in the lower parts. Laterals are formed unilaterally or bilaterally. The apical cells of main axes and laterals are 45–60 μm in diameter and 90–200 μm in length. The secondary segments are 0.6–1.1 times as long as the diameter. They are divided radially into several cells in transverse section (Fig. 2). In a surface lateral view, 3–10 longitudinal walls can be observed in a large second-



Figs. 1–3. *Sphacelaria californica* Sauvageau ex Setchell et Gardner from nature (Sai, 21 March 1988). 1. Middle portion of the thallus with secondary transverse cell walls (arrows) and propagules (asterisks). 2. Transverse section of the middle portion of an erect filament. 3. Vertical section of the holdfast.

ary segment. The peripheral cells of the secondary segments are rectangular in the surface view, (3)6–15(20) μm in width. The secondary transverse cell walls often occur in the peripheral cells of the segments (Fig. 1). Phaeophycean hairs are at times observed to form adaxially. The propagules are born adaxially on the laterals (Figs. 1, 8). They are ellipsoidal when young, becoming tribuliform as they develop. Mature propagules are 140–170 μm in length and 85–105 μm in width, with three (one central and two lateral) apical cells, containing abundant discoid chloroplasts without pyrenoids. Unilocular sporangia were observed on one plant collected in March 1988. They were formed solitarily or in groups on fertile laterals, spherical to somewhat ellipsoidal, 30–50 μm in diameter and 40–50 μm in length (Fig. 10). Plurilocular sporangia were not found. Our specimens agreed well with the original description of *S. plumula* var. *californica* by Sauvageau (1901) and the description by Setchell and Gardner (1925) except for the smaller size of unilocular sporangia.

Unialgal culture was established from the apical segments of the plant collected at Sai in March 1988, using PESI medium (Tatewaki 1966). Culture conditions used were 5°C SD (short day; 8 : 16 h light : dark), 5°C LD (long day; 16 : 8 h light : dark), 10°C SD, 10°C LD, 15°C SD, 15°C LD, 20°C SD and 20°C LD, under white fluorescent light of about 30 $\mu Mm^{-2}s^{-1}$ (10°C) or 50 $\mu Mm^{-2}s^{-1}$ (5°C, 15°C and 20°C). The initial filaments grew well and many were produced in 10°C, 15°C and 20°C conditions. However, they did not elongate and finally died in 5°C conditions. Phaeophycean hairs were formed from the early stage of the development. In 10°C SD, 10°C LD, 15°C SD, 15°C LD and 20°C LD within 2 months, many laterals were formed on the filaments spirally or radially, but not pinnately as in the natural plants (Fig. 7). Movement of water may be required for the normal morphogenesis of pinnate thallus construction. In 20°C LD the filaments grew rapidly, but arrangements of



Figs. 4–13. *Sphacelaria californica* Sauvageau ex Setchell et Gardner from nature and in culture. 4–5. Habit of the erect thallus and detail of the holdfast of specimens collected at Sai on 21 March 1988. 6. Immature propagules in culture. 7. Upper part of the thallus grown at 15°C SD. 8. Mature propagule of the thallus from nature. 9. Germination of a propagule in culture. 10. Three unilocular sporangia on a fertile lateral of the thallus from nature. 11. Four unilocular sporangia on a fertile lateral in culture (15°C SD). 12. Released unispore with two flagella. 13. Germination of a unispore.

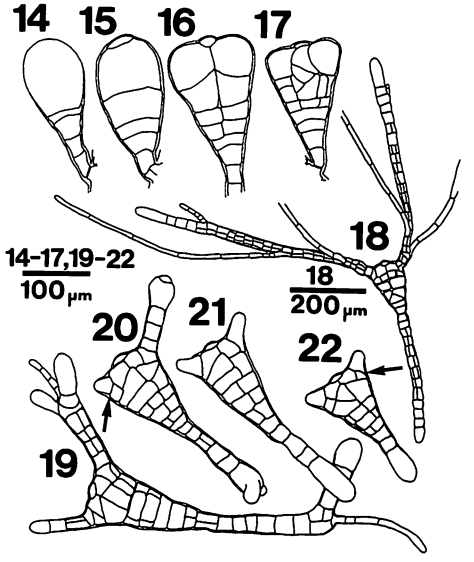
the laterals tended to be irregular. In 20°C SD the filaments remained rhizoidal for several weeks and then formed erect filaments with a few laterals after 5 months. The diameter of erect filaments and the number of longitudinal cell walls in a secondary segment were rather stable in various culture conditions. However, the number of secondary transverse cell walls tended to increase in lower temperature conditions (Table 1). Very few secondary transverse walls were observed under 20°C conditions.

The tribuliform propagules were formed within 2 months in 10°C SD, 10°C LD, 15°C SD, 15°C LD, 20°C SD. They were ellipsoidal in the early stage of the development (Figs. 6, 14). The apical cells of the young propagules were divided successively into a diminutive cell (a central apical cell) and two large cells (Figs. 15-16). The latter developed into the lateral apical cells by further unequal divisions (Fig. 17). The germinations

Table 1. Comparison of three morphological features of the erect thalli of *S. californica* cultured in four different culture conditions after 5 months.

Morphological features	Culture conditions			
	10°C LD	15°C LD	20°C LD	20°C SD
Diameter of erect filaments (μm)	48–65	50–65	30–46	45–63
Number of longitudinal cell walls in a secondary segment	5–10	4–10	3–5	3–6
Number of secondary transverse cell walls per 100 secondary segments	42–114	31–98	0–5	0–1

of the propagules usually occurred in the lateral apical and lowermost cells simultaneously (Figs. 20–22). The lateral apical cells of the mature propagules often divided into two cells before they germinated (Figs. 20, 22 arrows). New filaments from the propagules often forked into two branches making a diminutive cell (Fig. 9). Occasionally a short phaeophycean hair was formed by the diminutive cell (Fig. 19). Long phaeophycean hairs were formed from the early stage of the development (Fig. 18). Various types of abnormally shaped (e.g., ellipsoidal, bicornuate or bifurcate) propagules were formed in 20°C LD. Cultures started from the propagules showed similar responses to day length and temperature conditions as in the culture from apical segments.



Figs. 14–22. *Sphacelaria californica* Sauvageau ex Setchell et Gardner in culture (10°C LD). 14–17. Various stages of development of propagules. 18–22. Various stages of germivation of propagules showing occasional divisions of the lateral apical cells (arrows).

Unilocular sporangia formed in one year in 15°C SD. They occurred first solitarily and then became grouped on fertile laterals (Fig. 11). They were spherical and 35–45 (55) μm in diameter. The unispores were pyriform, with longer anterior and shorter posterior flagella (Fig. 12). They contained a chloroplast with a stigma. After the settlement on a cover glass, they germinated by forming a germination tube (Fig. 13). We did not follow the further development of the germlings.

Setchell and Gardner (1925) reported that the unilocular sporangia of *S. californica* measured 50–70 μm in diameter and 75–150 μm in length, or about 1.4–3 times as long as the unilocular sporangia in our materials. However, the description of Setchell and Gardner on the sizes of unilocular sporangia seems to be based on the Saunder's description on the plurilocular sporangia of *S. tribuloides* Meneghini sensu Saunders (=*S. californica*) and illustrations lacking explanations (Saunders 1898, Plate 26, Figs. 4–6). The plurilocular sporangia in the illustrations of Saunders and the unilocular sporangium in the illustration of Setchell and Gardner (1925, Plate 37, Fig. 27) resemble the young propagules in our materials. In the Sphacelariales it is sometimes difficult to distinguish young propagules from true plurilocular and unilocular sporangia. In our study, we confirmed the presence of many nuclei in a sporangium in the field materials, and observed actual release of swarmers in culture materials.

Accordingly, the solitary unilocular sporangium illustrated by Setchell and Gardner could be an immature propagule.

Our plants also resemble *S. novae-hollandiae* Sonder from South Australia (Womersley 1987) in having cymose unilocular sporangia and tribuliform propagules with occasional divided lateral apical cells. However, this species differs from *S. californica* in lacking pinnate ramifications and the secondary transverse cell walls.

Acknowledgements

We are grateful to Dr. W. F. Prud'homme van Reine, Rijksherbarium, Leiden, for his critical reading of the manuscript. We are also grateful to Dr. H. B. S. Womersley, University of Adelaide, for sharing his specimens with us. We thank Mr. T. Wajima and Mr. M. Matsumoto for collecting the specimens.

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北山太樹・川井浩史・吉田忠生：日本新産褐藻 *Sphacelaria californica* Sauvageau ex Setchell et Gardner（ハネグンセンクロガシラ：新称，クロガシラ目）の形態観察

青森県大間などから *Sphacelaria californica*（クロガシラ目，クロガシラ科）と同定される藻体を採取し，その形態学的観察と培養による生活史の研究を行った。自然藻体は盤状の付着器と主に上部で羽状分岐する直立部からなり，長さ 140–170 μm，幅 85–105 μm の胚芽枝をつけていた。また，secondary segments には時折，横の隔壁が認められた。3 月の藻体には集散状に形成された単子嚢が見られた。本種の単子嚢については先に Setchell and Gardner (1925) の報告があるが，それは未熟な胚芽枝を誤認したものと考えられるので，本種における単子嚢形成の報告はこれが初めてである。藻体の頂端部と胚芽枝を 5–20°C の長日・短日条件で培養した結果，20°C 長日で最も生長が速く，5°C では生長しなかった。15°C 短日では単子嚢を形成した。（060 札幌市北区北10条西 8 丁目　北海道大学理学部植物学教室）