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Aplanospore production in *Porphyra maculosa* (Rhodophyta)

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Margins of immature *Porphyra maculose* CONWAY blades collected from semi-sheltered coastal regions of British Columbia, Canada at the beginhing of the growing season (April-May) consisted of packets of 2 or 4 aplanospores which developed into bipolar sporelings in culture. Mature blades did not develop aplanospores but produced spermatia and carpospores, which subsequently germinated into the conchocelis phase. This is the first report of aplanospore production in a *Porphyra* species which reproduces sexually.

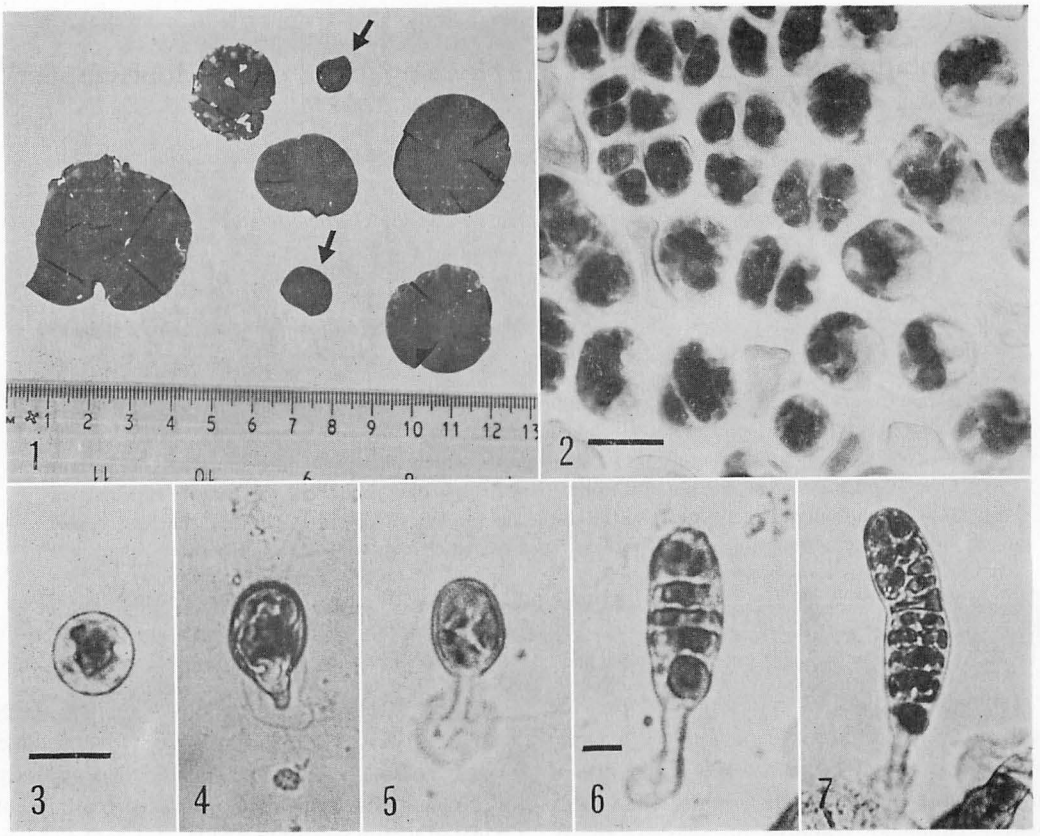
Key Index Words: *Asexual reproduction*; *aplanospore*; *Bangiophyceae*; Porphyra maculosa; *Rhodophyta.*

Asexual modes of reproduction provide means for rapid increase of *Porphyra* populations (COLE and CONWAY 1980) and are of considerable commercial value (HAWKES 1980). However, reports of asexual reproduction of the macroscopic thallus are uncommon for the 17 species of *Porphyra* which have been identified from the northwest coast of North America (CONWAY *et al.* 1975, GARBARY *et al.* 1980). Differentiation of whole vegetative cells and subsequent release of monospores from margins of young plants, usually prior to sexual development, have been observed in only three of these species, *P. gardneri* (SMITH & HOLLENBERG) HAWKES, *P. torta* KRISHNAMURTHY, and *P.* sp. (HAWKES 1977, COLE and CONWAY 1980). One species, *P. sanjuanensis* KRISHNAMURTHY, is strictly asexual; vegetative cells along the margins divide into packets of 8 or 16 aplanospores (KRISHNAMURTHY 1969).

P. maculosa CONWAY (1975) is a delicate, small, orbicular species which occurs at mid-intertidal levels in semi-sheltered coastal regions of British Columbia. It appears in the spring and is relatively short-lived. *P. maculosa* is monostromatic and has a haploid chromosome number of 3 (CONWAY *et al.* 1975). According to previous reports (CONWAY 1975, CONWAY *et al.* 1975), it reproduces only sexually. However, in the current study, the margins of sexually immature thalli collected at the beginning of the growing season consisted of packets of 2 or 4 cells similar to the aplanospores of *P. sanjuanensis.* These aplanospores were released in culture and germinated quickly into bipolar sporelings. The following is a report of this discovery.

Materials and Methods

Porphyra maculosa CONWAY grows during the spring months (April-June) attached to mussels at mid-intertidal regions of the beach at Point No Point, Vancouver Island, British Columbia (48°123°SW). Plants ranging in size from 1 to 4 cm in length were collected in May 1981 and 1983. Most of the larger thalli were sexually mature with characteristic pale patches of spermatangia amongst dark red carposporic areas along the margins (Fig. 1). The margins of smaller blades consisted of vegetative cells undergoing several divisions, forming packets of 2 or 4 cells [Figs. 1 (arrows), 2]. Small pieces from the margins of sexually mature and



Figs. 1-7. *Porphyra maculosa*. 1. Immature (arrows) and mature blades of *P. maculosa* CONWAY. Scale in cm; 2. Portion of an immature blade showing packets of 2-4 aplanospores. Bar =14 μm; 3-7. Bipolar development of aplanespores in cullture. Figs. 3-5, Bar=12 μm. Figs. 6 and 7, Bar=15 μm.

immature blades were placed in separate petri dishes with ES culture mediun (MC LSCHLAN 1973) at 10°C and 12 : 12 L : D photoperiod. Cultures were observed periodically for several months using an Olympus inverted microscope, and micrographs were taken using Kodak Pan-X film in a Nikon microflex photomicrographic unit.

Observations and Discussion

Cultured immature (non-sexual) material of *P. maculosa* shed aplanospores measuring approximately 12 μm in diameter which germinated into bipolar sporelings over a two-week period (Figs. 3-7). These developed into small blades ranging in size from 0.5 cm to 3 cm (Fig. 1) which also released aplanospores when transferred into fresh culture medium. Subsequent growth of the spores resulted in a large number of developing thalli in each culture dish within several months of the original setting up of cultures from the field material. Mature sexual material in culture released carpospores approximately 10 μm in diameter which germinated into the conchocelis phase of the biphasic life history. No bipolar development of spores indicative of asexual reproduction was observed in any of these dishes.

This is the first observation of aplanospore production in young blades of a *Porphyra* species which reproduces sexually. In fact, there are few accounts of aplanospores in the bangiacean genera *Porphyra* and *Bangia* and, to our knowledge, these have been reported

in species (or populations of species) which reproduce exclusively asexually: asexual populations of *B. atropurpurea* (ROTH) C. AG. (=*B. fuscopurpurea*) (northwest North America, marine; Great Lakes, freshwater) (COLE 1972, SHEATH and COLE 1980, COLE *et al.* 1983), *P. sanjuanensis* (northwest North America (KRISHNAMURTHY, 1969, COLE and CONWAY 1980), *P. subtumens* J. AG. (South Africa) (CONWAY and WYLIE 1972), and *P. argentinensis* PIRIZ (South America) (PIRIZ 1981). According to previous reports of some biphasic species, young plants at the beginning of the growing season reproduce asexually by a monosporic cycle, e.g. the three northwest North American species mentioned in the Introduction, *P. gardneri*, *P. torta* and *P.* sp., and many Japanese species (e.g. *P. crispata* KJELLMAN, *P. tenera* KJELLMAN, *P. yezoensis* UEDA, *P. akasaki* MIURA, KUROGI 1972, MIURA 1975). In *P. gardneri*, *P. kuniedai* KUROGI, *P. suborbiculata* KJELLMAN, *P. yezoensis* and *P. tanegashimensis* SHINMURA, monospore production also continues along distal margins during sexual differentiation, spermatangia and carpospores developing along lateral margins (KUROGI 1961, 1972, SHINMURA 1974, HAWKES 1977). Aplanospores were not produced by sexually mature thalli of *P. maculosa* observed in the current study. Considering the above data, they may be the products of a type of parthenogenetic development of vegetative cells which are potential carpogonia.

Obviously, species which form aplanospores rather than monospores are capable of producing many more asexual reproductive units per plant. This leads to rapid and massive population increase, as observed in cultures of *P. maculosa*, which ensures preservation of the species on the shore and is also of industrial importance. The advantages to small species such as *P. maculosa* and to species which reproduce only asexually such as *P. sanjuanensis* would be particularly significant.

It is difficult to explain why asexual reproduction appears to be rare in *Porphyra* species from the northeast Pacific Ocean, while it is relatively common in those from the northwest Pacific. Possibly species in the northwest are better adapted and the asexual system would tend to stabilize the desirable genotype. All *Porphyra* species reported to date which have some form of asexual reproduction are monostromatic and all have a haploid chromosome number of 3, except *P. gardneri* with n=4 (HAWKES 1980).

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B. J. ハイメス・K. M. コール：*Porphyra maculosa*（紅藻植物）の不動胞子形成

カナダのブリテイッシュ・コロンビア海岸地方の半閉鎖的な海岸から4—5月の生育期に採集した *Porphyra maculosa* CONWAY の葉状体の縁辺部には2又は4コの packet からなる不動胞子嚢が形成されていた。この不動胞子は培養すると2極性の発芽体を生じた。成長した葉状体は不動胞子を形成することなく精子と果胞子とを生じ，続いてコンコセリス期の体を生じた。この報告は有性生殖を行なうアマノリの種で不動胞子を生ずることを報告した最初の報告である。(Department of Botany, University of British Columbia, Vancouver, B. C., Canada V6T 2B1)