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Morphological and taxonomic studies on some little-known species of *Gracilaria* (Gracilariales: Rhodophyta) from Venezuela. 1. *G. damaecornis*

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Abstract

The morphology, anatomy and reproduction (tetrasporic, male and female) of a poorly known species of *Gracilaria* i.e., *G. damaecornis* J. Agardh was studied, using material collected in eastern Venezuela. Spermatangia are produced in well-defined and deeply immersed multicavitated conceptacles ('m' type). Nutritive filaments are present both at the floor and top (outer pericarp) of the cystocarp. The lectotype of *G. damaecornis* is illustrated for the first time. *Hydropuntia albornozii* (Rodríguez) Wynne (*Polycavernosa albornozii*) is shown to be a synonym of *G. damaecornis*. In agreement with recent research, it is concluded that generic attributes of *Hydropuntia* (= *Polycavernosa*) based mainly on sexual reproductive structures are of doubtful taxonomic value.

Introduction

More than 30 years ago, Taylor (1960) recognized 20 species of *Gracilaria* (*sensu lato*) (Gracilariales, Rhodophyta) for the tropical and subtropical western Atlantic ocean (North Carolina through southern Brazil). He also listed 17 species under Uncertain Records. Incorporating the several nomenclatural and taxonomic changes published since 1960, Wynne (1986) listed 32 species. More importantly, he pointed out that many of the uncertain records listed by Taylor have their type localities in this area and hence must be retained in the flora until their status is verified. In recent years our knowledge of the species of *Gracilaria* that occur in this vast area has been greatly expanded with regard to taxonomic criteria (Oliveira *et al.*, 1983; Oliveira, 1984; Fredericq & Norris, 1985, 1992; Fredericq & Hommersand, 1989a, b), description of new species (Bird & Ol-

iveira, 1986), nomenclatural considerations (Bird *et al.*, 1986) agar structure in closely related species (Bird *et al.*, 1987), molecular taxonomy (Dutcher *et al.*, 1990), workshop reports (Abbott & Norris, 1985; Abbott, 1988, 1992), cultivation (Oliveira & Kautsky, 1990) and use as food (Smith, 1990). Nevertheless, morphological variation, anatomy and critical reproductive details, especially of sexual plants, are still unknown for many species, including *G. armata* (C. Agardh) J. Agardh, *G. cuneata* J. E. Areschoug, *G. curtisiae* J. Agardh, *G. damaecornis* J. Agardh, *G. divaricata* Harvey and *G. ornata* J. E. Areschoug. All of these species excepting *G. armata* and *G. divaricata* are recorded for Venezuela (Ganesan, 1990). As the beginning of my study on this group of neglected species, the morphology, anatomy and reproduction of *G. damaecornis* are described and illustrated in this paper.

Materials and methods

The materials for this study were collected by me between 1967 and 1991 in eastern Venezuela (see Ganesan, 1990 for maps). Both liquid preserved (5% seawater formalin) and herbarium specimens were studied. Hand sections of liquid-preserved material were made with a razor blade, stained in 1% aqueous aniline blue, washed with distilled water to remove excess stain, acidified with a dilute solution of HCL and mounted in 1% Karo corn syrup. Small bits of herbarium specimens were rehydrated in distilled water, sectioned and prepared in the same way as described above for the liquid-preserved material. Microphotography was made with automatic Zeiss MC 3 equipment. Voucher specimens of both dry and liquid-preserved specimens are filed in the herbarium of the Institute of Oceanography, Cumaná, Venezuela. For comparative purposes, reference specimens were borrowed from LAM, LD, MICH, MY, and UPR (see Holmgren *et al.* (1990) for herbarium abbreviations).

Results

Gracilaria damaecornis J. Agardh (1852: 597)

(Figs 1-7)

Lectotype: LD (Fig. 1, designated by C. J. Bird in 1979 but not illustrated; specific type locality unknown).

Synonyms: *Polycavernosa* sp. (Rodríguez, 1986); *P. albornozi* Rodríguez (1988); *Hydropuntia albornozi* (Rodríguez) Wynne (1989); *Gracilaria albornozi* (Rodríguez) Abbott (Abbott *et al.*, 1991)

Gracilaria damaecornis was described by J. Agardh (1852) on the basis of plants collected from Atlantic North America. Although Howe (1920) suggested it might have been the Virgin Islands, the type locality was unspecified in both the original description and the lectotype. This species is commonly recorded and widely distributed in the tropical western Atlantic from Bermuda to To-

bago (Taylor, 1960). Although published illustrations are available for its habit (Taylor, 1960: pl. 55, Fig. 2; Schnetter & Schnetter, 1967: Fig. 3) and cystocarps (Chapman, 1963: Fig. 108), it is still a poorly known species. The Philippine record from Cebu (Von Westernhagen, 1973, 1974) should be considered highly tentative. According to Danny Largo, University of San Carlos, Cebu City, the Westernhagen specimen is not in the herbarium of that university (J. West, pers. com.). An expanded description of *G. damaecornis* is given below:

Large bushy plants up to 20 cm long, mostly dark brown or greenish, fleshy-cartilaginous, not adhering well to paper; base small and discoid, giving rise to one to several erect axes, one of which is dominant; branching variable, but generally abundantly and irregularly dichotomous throughout in typically large, well-developed plants (Fig. 2, above), sparse to irregular and unilateral with proliferations in small or moderately developed plants (Fig. 2, below), mixed-phase plants with irregular branching and numerous proliferations giving a crowded appearance, axes characteristically terete throughout, 1-2 mm broad (up to 4 mm below forkings), apical segments frequently tending to be unilateral with acute simple, bi- to multifid apices and subsecund; cortex and subcortex thin of a few layers, outermost layer with long, deciduous or persistent unicellular hairs, hair-bearing cells notably larger, medulla with polygonal cells.

Tetrasporangia produced throughout the thallus surface *i.e.*, on the main axis and all lateral branches, 24-30 μ m diam. in surface view, 16-25 μ m broad and 28-50 μ m long in transverse sections, a basal pit-connection between the tetrasporangium and the cortical cell evident (Fig. 3), cortical cells around tetrasporangia not evidently modified to form a nemathecium.

Sexual plants unisexual, mixed-phase plants (tetrasporic & cystocarpic and tetrasporic & spermatangial) frequently observed; spermatangia in well defined conceptacles, single or in groups of 2-6 (Fig. 4), conceptacles multicavitated, deeply embedded, confluent (Fig. 5), single conceptacles of the 'verrucosa' type, 24-60 μ m

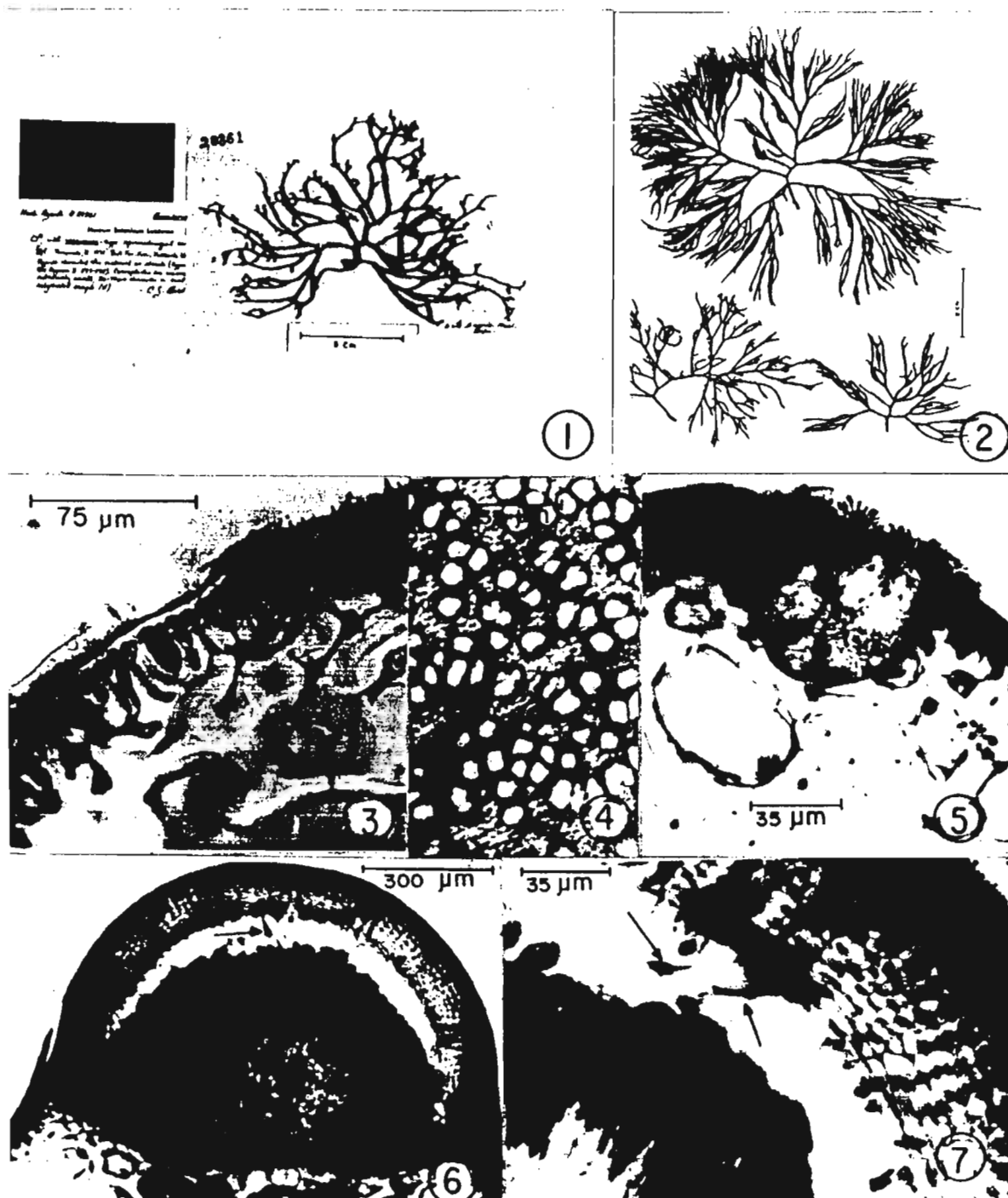


Fig. 1-7. Fig. 1. *Gracilaria danaeacornis*. Lectotype (LD Herb. Agardh); Fig. 2. Variation in thallus size and morphology of the Venezuelan plants. Fig. 3. Transverse section of a tetrasporic thallus showing a mature tetrasporangium with a basal pit-connection. Fig. 4. Surface view of a male plant showing conspicuous and grouped spermatangial conceptacles. Fig. 5. Transverse section of part of a male plant to show deeply embedded multicavitated ('m' type) conceptacles. Fig. 6. Transverse section of a cystocarp. Fig. 7. Part of outer pericarp near the ostiole enlarged to show tubular nutritive cells (arrow).

diam. and confluent conceptacles 80–100 μ m diam; cystocarps abundant, scattered throughout the thallus, hemispherical, protruding and not constricted basally (Fig. 6), 1.5 mm diam., in transverse section showing a central well-developed sterile tissue and a peripheral layer of fertile gonimoblast filaments, tubular nutritive cells common in the inner and outer pericarp (Fig. 7).

This species grows on stones in shallow, exposed areas close to the shore and considerable material can also be found washed ashore.

Chemical studies of Hong *et al.* (1969) and Duckworth *et al.* (1970) on *G. damaecornis* from Barbados have shown low gel-strengths and high contents of sulphate and ash for this species.

Representative specimens examined

Lectotype: (Herb. Agardh 29361 in LD male plant, exact locality of collection not known). Venezuela: Punta Arenas, Tortuga Island, 13. iv. 1939, sterile and female, *W. R. Taylor* 39–378 (MICH); Araya, 18. x. 1961, tetrasporic, *Gessner*, 24 (Herb. W. R. Taylor); Punta Arenas, Península de Araya, 4. xii. 1967, female and tetrasporic, *Ganesan* 67-109 (Herb. Inst. Oceanogr. Univ. Oriente, Cumaná); Punta Arenas, Península de Araya, 24. x. 1991, male, female and tetrasporic, *Ganesan* 19–91 (Herb. Inst. Oceanogr. Univ. Oriente, Cumaná); Buchuaco, Falcón, 9. vi. 1984, *N. Rodríguez de Rios & M. Lobo* 2011 (Isotype of *Polycavernosa albornozi* Rodríguez, MY); same locality, no date, male, *N. Rodríguez de Rios & M. Lobo* 2124 (MY). Puerto Rico: El Jobo, San Antonio, near Isabela, 30. v. 1962, tetrasporic, *Díaz-Piñer* 18170 (UPR); Playa Rincón, Rincón, 13. iv. 1963, tetrasporic, *Díaz-Piñer*, 14782 (UPR); Cayos San Jacinto, Caña Gorda, Guánica, 19. vi. 1969, cystocarpic, *Díaz-Piñer* 14782 (UPR).

Discussion

The lectotype of *Gracilaria damaecornis* agrees well with Venezuelan specimens in general morphology, anatomy and in the formation of sper-

matangia in deeply embedded, multicavities conceptacles. In surface view, the conceptacles were distinct and frequently grouped as in the Venezuelan specimens.

Gracilaria damaecornis is closely related to *G. armata* (C. Agardh) J. Agardh, *G. caudata* J. Agardh and the newly described species from Venezuela, *Polycavernosa albornozi* Rodríguez (1988; see also Rodríguez, 1986) in having large, erect, fleshy-cartilaginous and terete thalli of a few mm broad. *G. armata* and *G. caudata* are very poorly-known species. *G. armata* is distinguished from *G. damaecornis* by alternate to radial branching, while *G. caudata* (type from the Virgin Islands) is included under uncertain records (Taylor, 1960). Examination of isotype (MY) and liquid-preserved specimen (male) of *P. albornozi* showed thallus morphology, anatomy and spermatangial formation identical to *G. damaecornis*. By having tubular nutritive cells both at the base and top of the cystocarp, *P. albornozi* is also similar to *G. damaecornis*. I was unable to find any specific feature to warrant recognition of *P. albornozi* as different from *G. damaecornis*.

Although the order Gracilariales (Fredericq & Hommersand, 1989a) has received wide acceptance among taxonomists, recent studies on several species from the Pacific (Abbott *et al.*, 1991) and more importantly from the Mediterranean (Gargiulo *et al.*, 1992) have clearly demonstrated that distinguishing *Hydropuntia* from *Gracilaria* on the basis of tubular nutritive cells and spermatangial formation (Fredericq & Hommersand, 1990) is tenuous and hence unsustainable. Observations on a Caribbean species in the present investigation have also confirmed this viewpoint. *G. damaecornis*, by the formation of spermatangia in multicavities conceptacles ('m' type), should be placed in *Hydropuntia*, but, the cystocarp has tubular nutritive cells formed both from the base and top of the cystocarp, not restricted to the floor as is characteristic of this genus. I conclude, in agreement with Gargiulo *et al.* (1992; see also Ganesan, 1990, 1992), that generic attributes of *Hydropuntia* based on sexual reproductive structures are of very doubtful taxonomic value.

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References

- Abbott, I. A., (ed.) 1988. Taxonomy of economic seaweeds with reference to some Pacific and Caribbean species. 2. California Sea Grant College, University of California, La Jolla, Calif., 264 pp.
- Abbott, I. A., (ed.) 1992. Taxonomy of economic seaweeds with reference to some Pacific and western Atlantic species. 3. California Sea Grant College, University of California, La Jolla, Calif., 241 pp.
- Abbott, I. A., J. Zhang & B. Xia, 1991. *Gracilaria mixta*, sp. nov. and other western Pacific species of the genus (Rhodophyta: Gracilariaceae). *Pac. Sci.* 45: 12-27.
- Abbott, I. A. & J. N. Norris, (eds.) 1985. Taxonomy of economic seaweeds with reference to some Pacific and Caribbean species. 1. California Sea Grant College, University of California, La Jolla, Calif., 167 pp.
- Agardh, J. G., 1852. Species genera et ordines floridearum. Vol. 2. pt. 2, C. W. K. Gleerup, Lund, 337-1291.
- Bird, C. J., R. J. Helleur, E. R. Hayes & J. McLachlan, 1987. Analytical pyrolysis as a taxonomic tool in *Gracilaria* (Rhodophyta: Gigartinales). *Hydrobiologia* 151/152: 207-211.
- Bird, C. J. & E. C. Oliveira, 1986. *Gracilaria tenuifrons* sp. nov. (Gigartinales, Rhodophyta), a new species from the tropical western Atlantic with superficial spermatangia. *Phycologia* 25: 313-320.
- Bird, C. J., E. C. Oliveira & J. McLachlan, 1986. The correct name for the western Atlantic alga hitherto known as *Gracilaria debilis* (Rhodophyta, Gigartinales). *Can. J. Bot.* 64: 2045-2051.
- Chapman, V. J., 1963. The marine algae of Jamaica. 2. Phaeophyceae and Rhodophyceae. Institute of Jamaica, Kingston, Jamaica, 201 pp.
- Duckworth, M., K. C. Hong & W. Yaphe, 1971. The agar polysaccharides of *Gracilaria* species. *Carbohydrate Res.* 18: 1-9.
- Dutcher, J. A., R. K. Sizemore & D. F. Kapraun, 1990. Variation in nuclear DNA base composition (mol % G + C) in four genera of Rhodophyta. *Crypt. Bot.* 1: 390-395.
- Frederick, S. & M. H. Hommersand, 1989a. Proposal of the Gracilariales, ord. nov. (Rhodophyta) based on an analysis of the reproductive development of *Gracilaria verrucosa*. *J. Phycol.* 25: 213-227.
- Frederick, S. & M. H. Hommersand, 1989b. The comparative morphology and taxonomic status of Gracilariopsis (Gracilariales, Rhodophyta). *J. Phycol.* 25: 228-241.
- Frederick, S. & M. H. Hommersand, 1990. Diagnosis and key to the genera of the Gracilariaceae (Gracilariales, Rhodophyta). *Hydrobiologia* 204/205: 173-178.
- Frederick, S. & J. N. Norris, 1985. Morphological studies of some tropical species of *Gracilaria* Grev. (Gracilariaceae, Rhodophyta): Taxonomic concepts based on reproductive morphology. In I. A. Abbott (ed.), Taxonomy of economic seaweeds with reference to some Pacific and western Atlantic species. 3. California Sea Grant College, University of California, La Jolla, Calif.: 137-155.
- Frederick, S. & J. N. Norris, 1992. Studies on cylindrical species of western Atlantic *Gracilaria* (Gracilariales, Rhodophyta): *G. cylindrica* Bergesen and *G. blodgettii* Harvey. In I. A. Abbott (ed.), Taxonomy of economic seaweeds with reference to some Pacific and western Atlantic species. 3. California Sea Grant College, University of California, La Jolla, Calif.: 211-231.
- Ganesan, E. K., 1990. A Catalog of Benthic Marine Algae and Seagrasses of Venezuela. Fondo Editorial, CONICIT, Caracas, 237 pp.
- Ganesan, E. K., (1989) 1992. Taxonomy of the economically important seaweeds of Venezuela. *Gracilaria: G. lacinulata* (Vahl) Howe prox. *Bol. Inst. Oceanogr. Univ. oriente Venezuela*. 28: 85-97.
- Gargiulo, G. M., F. De Masi & G. Tripodi, 1992. Morphology, reproduction and taxonomy of the mediterranean species of *Gracilaria* (Gracilariales, Rhodophyta). *Phycologia* 31: 53-80.
- Holmgren, P. K., N. H. Holmgren & L. C. Barnett, 1990. Index Herbariorum. Pt1. The Herbaria of the World, Ed. 8. Bohn, Schellema & Hokema, Utrecht, 693 pp.
- Hong, K. C., M. E. Goldstein & W. Yaphe, 1969. A chemical and enzymic analysis of the polysaccharides from *Gracilaria*. *Proc. int. Seaweed Symp.* 6: 473-482.
- Howe, H. W., 1920. Algae In Britton N. L. & C. F. Millspaugh (eds), The Bahama Flora. New York: 553-618.
- Norris, J. N., 1985 a. *Gracilaria* from the Gulf of California:

- key, list and distribution of the common species. In I. A. Abbott (ed.), Taxonomy of economic seaweeds with reference to some Pacific and Caribbean species. California Sea Grant College, University of California, La Jolla, Calif.: 93-96.
- Norris, J. N., 1985b. Studies on Gracilaria Grev. (Gracilariaceae, Rhodophyta) from the Gulf of California, Mexico. In I. A. Abbott (ed.), Taxonomy of economic seaweeds with reference to some Pacific and Caribbean species. California Sea Grant College, University of California, La Jolla, Calif.: 123-135.
- Oliveira, E. C., 1984. Taxonomic criteria in the genus Gracilaria Grev. (Rhodophyta): an experience with the western Atlantic species. Proc. int. Seaweed Symp. 11: 55-58.
- Oliveira, E. C., C. J. Bird & J. McLachlan, 1983. The genus Gracilaria (Rhodophyta, Gigartinales) in the western Atlantic. Gracilaria domingensis, G. cervicornis and G. ferox. Can. J. Bot. 62: 2999-3008.
- Oliveira, E. C. & N. Kautsky, 1990. Cultivation of Seaweeds in Latin America. Coordenadoria de Comunicacao Social. Universidade de Sao Paulo, Sao Paulo, Brazil, 141 pp.
- Rodríguez de Rios, N., 1986. Sobre la verdadera identidad de la llamada Gracilaria verrucosa (Hudson) Papenfuss en Venezuela. Ernstia 38: 32-39.
- Rodríguez de Rios, N., 1988. Polycavernosa albornozii sp. nov (Rhodophyta, Gigartinales, Gracilariaceae), una nueva especie del sur del caribe. Ernstia 46: 1-7.
- Schnetter, R., & M. Schnetter, 1967. Notas sobre unas especies del orden Gigartinales (Rhodophyceae) en la costa atlántica de Colombia. Mitt. Inst. Colombo-Aleman Invest. Cient. 1: 45-52.
- Smith, A. H. (compiler), 1990. Annotated bibliography of the seaweeds used for food in the West Indies. OECS Fishery Report No. 3: 76 pp.
- Taylor, W. R., 1960. Marine algae of the eastern tropical and subtropical coasts of the Americas. Univ. Mich. Press, Ann Arbor, 870 pp.
- Von Westernhagen, H., 1973. A preliminary survey on the food preferences of Siganus concatenata (Cuvier & Valenciennes). Philippine Scientist (Univ. San Carlos) 10: 61-73.
- Von Westernhagen, H., 1974. Food preferences in cultured Rabbitfishes (Siganidae). Aquaculture. 3: 109-117.
- Wynne, M. J., 1986. A checklist of benthic marine algae of the tropical and subtropical western Atlantic. Can. J. Bot. 64: 2239-2281.
- Wynne, M. J., 1989. The re-instatement of Hydropuntia Montagne (Gracilariaceae, Rhodophyta). Taxon 38: 476-479.