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Observations on flattened species of *Gracilaria* (Gracilariaceae, Rhodophyta) from Taiwan

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Abstract

Four flattened *Gracilaria* species have been reported from Taiwan: *G. spinulosa, G. vieillardii, G. textorii* and *G. punctata*, identified based on branching pattern, the presence or absence of spines, and characters that often vary seasonally. *Gracilaria spinulosa* was originally described from the type locality, Tainan. Species with toothed margins are usually referred to *G. "vieillardii"*; those with smooth margins to *G. "textorii"*, and those with smooth margins and dark spots scattered over the blade to *G. "punctata"*. Molecular analyses show that specimens with marginal teeth cluster in three different groups: a *G. "vieillardii"* clade, a *G. spinulosa* clade, and a clade sister to *G. spinulosa*. An undescribed species comprises the third clade, which is distinguished by its relatively large gonimoblast cells and weakly developed tubular nutritive cells. The three clades can be separated by the character of the tubular nutritive cells, the size of gonimoblast cells and certain vegetative features. Plants with entire margins form a single clade characterized by cystocarps with basal tubular nutritive cells and their absence in the cystocarp cavity. They are nested in the *Hydropuntia* complex and are referred to as *Gracilaria "punctata"* here. The records of *G. textorii* and *G. punctata* from Taiwan require reinvestigation in comparison with the Japanese species.

Introduction

Species in the red algal genus *Gracilaria* (C. Agardh) Greville 1830 in the family Gracilariaceae include some economically important agarophytes. Historically, there were eighteen species recorded from Taiwan (Chiang, 1985; Lewis & Norris, 1987; Huang, 1999); among them, four flattened species, *G. spinulosa* (Okamura) Chang et Xia 1976, *G. vieillardii* Silva in Silva, Meñez et Moe 1987, *G. textorii* (Suringar) De Toni 1895, and *G. punctata* (Okamura) Yamada 1941. These were identified based on branching pattern and the presence or absence of marginal spines. *G. spinulosa* was originally described from Tainan, Taiwan, based on *Rhodymenia spinulosa* Okamura 1934. Species with toothed margins were usually referred to *G. "vieillardii*" (Chiang, 1985), those with smooth margins to *G. "textorii"* (Huang, 1999), and those with smooth margins and dark spots scattered over the blade to *G. "punctata"* (Yamada, 1941; Ohmi, 1958). Recent collections around the coasts of Taiwan have permitted a new interpretation of the Taiwan species. In this study, the vegetative and reproductive morphology of the four flattened species are described in detail and their taxonomic status is discussed based on *rbc*L sequence analyses.

Material and methods

Collections were made either by SCUBA or snorkel. Treatment of the algal samples, sectioning and staining techniques used in the morphological studies, DNA sequencing procedures and phylogenetic analyses are as described in Lin et al. (2004). Voucher specimens are deposited in the Herbarium of the National Taitung University, Taiwan. Collection information and new *rbc*L sequences generated in this study and those available from GenBank are shown in Table 1.

Table 1. List of species used in *rbc*L analysis and accession numbers in GenBank. The number after the accession number is the percentage of the gene sequenced

Species	Collection information/GenBank accession number
Gracilaria "punctata"	Sail Rock, Kenting National Park, southern Taiwan, coll. S.M. Lin, 1.×.2002. AY737447, 98%
Gracilaria "punctata"	Lungkeng, Kenting National Park, southern Taiwan, coll. S.M. Lin, 2.iv.2001. AY737446, 96.1%
Gracilaria "punctata"	Five Caves, Orchid Island, Taiwan, coll. S.M. Lin, 17.iv.2003. AY737448, 98.4%
Gracilaria "vieillardii"	Houwan, Kenting National Park, southern Taiwan, coll. S.M. Lin, 24×.2001. AY737436, 99.5%
Gracilaria "vieillardii"	Five Caves, Orchid Island, coll. S.M. Lin, 17.iv.2002. AY737437, 98.3%
Gracilaria beckeri (J. Agardh) Papenfuss	AY049377*, 96.3%
Gracilaria bursa-pastoris (Gmelin) Silva	AY049376*, 91.6%
Gracilaria capensis Schmitz ex Mazza	AY049378*, 96.5%
Gracilaria flabelliforme (P. et H. Crouan) Fredericq et Gurgel	AY049343*, 98.8%
Gracilaria hayi Gurgel, Fredericq et J. N. Norris	AY049319*, 95.6%
Gracilaria multipartite (Clement) Harvey	AY049322*, 98.6%
Gracilaria occidentalis (Børgesen) Bodard	AY049322*, 98.6%
Gracilaria smithsoniensis Gurgel, Fredericq et J. N. Norris	AY049321*, 97.3%
Gracilaria sp.	Yeliu, northern Taiwan, coll. Allen Liu, 26.vii.2002. AY737438, 98.1%
Gracilaria sp.	Sail Rock, Kenting National Park, southern Taiwan, coll. S.M. Lin, 14.iii.2002. AY737439, 96.8%
Gracilaria sp.	Keelung, northern Taiwan, coll. S.M. Lin, 1.v.2002. AY737440, 98.1%
Gracilaria spinulosa	Wind Blow Sand, Kenting National Park, southern Taiwan, coll. S.M. Lin, 21.vii.2001. AY737441, 95.7%
Gracilaria spinulosa	Ya Din, Tainan, western Taiwan, coll. D.T. Lin, 26.v.2003. AY737442, 98.3%
Gracilaria spinulosa	Lin Ping, Pingtung County, southwest Taiwan, coll. Y.S. Huang, 10.ii.2002. AY737443, 98.4%
Gracilaria spinulosa	Little Yeliu, Taitung, eastern Taiwan, coll. S.M. Lin& F.K. Huang, 18.iii.2003. AY737444, 98.3%
Gracilaria textorii (Suringar) De Toni	AY049325*, 97.5%
Gracilaria venezuelensis Taylor	AF539603*, 95.4%
Gracilaria vieillardii	Bulusan, N. Philippines, coll. Allen Liu, 18.ii2003. AY737445, 98.4%
Gracilaria yoneshigueana Gurgel, Fredericq et J. N. Norris	AY049372*, 93.4%
Gracilariopsis bailiniae Zhang et Xia	AY049411* regarded as *Gracilariopsis heteroclada* 91.1%
Gracilariopsis lemaneiformis (Bory de Saint-Vincent) E.Y. Dawson, Acleto et Foldvik	AY049415*, 97.6%
Hydropuntia caudata (J. Agardh) Gurgel et Fredericq	AY049358*, 76.4%
Hydropuntia cornea (J. Agardh) Wynne	AY049338*, 98.8%
Hydropuntia crassissima (P. et H. Crouan) Wynne	AY049351*, 98%
Hydropuntia eucheumatoides (Harvey) Gurgel et Fredericq	AY049389*, 93.3%
Hydropuntia urvillei Montagne	AY049402*, 97.4%
Hydropuntia usneoides (C. Agardh) Gurgel et Fredericq	AY049346*, 98%

*Refers to Gurgel and Fredericq (2004).