RESEARCH ARTICLE

Genetic and morphological analyses of *Gracilaria firma* and *G. changii* (Gracilariaceae, Rhodophyta), the commercially important agarophytes in western Pacific

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Abstract

Many studies classifying *Gracilaria* species for the exploitation of agarophytes and the development of the agar industry were conducted before the prevalence of molecular tools, resulting in the description of many species based solely on their morphology. *Gracilaria firma* and *G. changii* are among the commercially important agarophytes from the western Pacific; both feature branches with basal constrictions that taper toward acute apices. In this study, we contrasted the morpho-anatomical circumscriptions of the two traditionally described species with molecular data from samples that included representatives of *G. changii* collected from its type locality. Concerted molecular analyses using the *rbcL* and *cox1* gene sequences, coupled with morphological observations of the collections from the western Pacific, revealed no inherent differences to support the treatment of the two entities as distinct taxa. We propose merging *G. changii* (a later synonym) into *G. firma* and recognize *G. firma* based on thallus branches with abrupt basal constrictions that gradually taper toward acute (or sometimes broken) apices, cystocarps consisting of small gonimoblast cells and inconspicuous multinucleate tubular nutritive cells issuing from gonimoblasts extending into the inner pericarp at the cystocarp floor, as well as deep spermatangial conceptacles of the *verrucosa*-type. The validation of specimens under different names as a single genetic species is useful to allow communication and knowledge transfer among groups from different fields. This study also revealed considerably low number of haplotypes and nucleotide diversity with apparent phylogeographic patterns for *G. firma* in the region. Populations from the Philippines and Taiwan were divergent from each other as well as from the populations from Malaysia, Thailand, Singapore and Vietnam. Establishment of baseline data on the genetic diversity of this commercially important agarophyte is relevant in the context of cultivation, as limited genetic diversity may jeopardize the potential for its genetic improvement over time.

OBSERVATIONS

The description of *G. changii* and *G. firma* as distinct species was based on the morphological traits of the thalli, cystocarps and conceptacles. The former species was characterized by thalli with abrupt basal constrictions that taper gradually toward acute apices, while the latter exhibited more gradual tapering of branches. The cystocarps of *G. changii* were reported to consist of small gonimoblast cells, while those of *G. firma* were said to be multinucleate and tubular.

Molecular analyses of the *rbcL* and *cox1* genes from samples collected in the western Pacific region showed no significant genetic differences between the two species. The phylogenetic tree constructed from these molecular data revealed a single cluster for both species, indicating that they are not distinct at the species level. Therefore, we propose that *G. changii* be merged into *G. firma* as a later synonym.

The study also highlighted the low genetic diversity of *G. firma* populations in the region. The limited number of haplotypes and nucleotide diversity observed is a cause for concern, as it may affect the genetic potential of the species for improvement through genetic manipulation.

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