


The complete plastid genome and phylogenetic analysis of *Gracilaria edulis*

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ABSTRACT

Gracilaria edulis, a marine red macroalgae, is a rich source of sulfated polysaccharides, carbohydrate, vitamins, and minerals, and showed multiple bioactivities such as antibacterial, antitumour, and cholinesterase inhibitory activity. The plastid genome sequence of *G. edulis* is 179,410 bp. A total of 235 genes were determined, including 201 protein-encoding genes, 30 tRNA genes, 3 rRNA genes, 1 ribonuclease gene, and 1 intron inserted into the *trnM* gene. Phylogenetic analysis showed that *G. edulis* clustered together with *Gracilaria salicornia*, *Gracilaria tenuistipitata* var. *liui* and *Gracilaria chilensis*. The plastid genome analysis will help in the understanding of *Gracilaria* evolution.

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Gracilaria edulis; plastid genome; Gracilariaceae; phylogenetic analysis

Gracilaria edulis (S.G.Gmelin) P.C.Silva is a marine red alga belonging to the family Gracilariaceae (<http://www.algaebase.org/>). *Fucus edulis* S.G.Gmelin is the basionym of *G. edulis*. The species first came to attention because this previous edible alga contained a toxin causing fatal human poisoning (Yotsu-Yamashita et al. 2004). The following studies were about the physicochemical properties, nutritional composition, mineral and trace metals concentrations of *G. edulis* (Sakthivel and Pandima Devi 2015; Thodhal Yoganandham et al. 2018). In addition, Most of the research focused on its bioactivities such as antitumour activity (Patra and Muthuraman 2013; Priyadharshini et al. 2014; Sakthivel et al. 2016) and cholinesterase inhibitory activity which can be used in Alzheimer's disease treatment (Suganthi et al. 2010). Some studies explored its usage in withanolides production (Sivanandhan et al. 2013, 2015) and biodiesel production (Bharathiraja et al. 2016). However, no genomic studies on *G. edulis* have been reported.

In this study, we report the determination of the complete *G. edulis* plastid genome sequence by next-generation sequencing methods. The genomic DNA collected from one *G. edulis* individual in a population in south China (Yinggehai, Hainan Province, 18°30'36" N, 108°42'15" E) was sequenced. The specimen was stored at the Culture Collection of Seaweed at the Ocean University of China (sample accession number: 2017060064). Paired-end reads (150 bp) were sequenced by using Illumina HiSeq system (Illumina, San Diego, CA, USA), obtaining 27 Gb of sequence data. The tRNA genes were identified by using tRNAscan-SE Search Server (Schattner et al. 2005). Other plastid genomic regions were

annotated from the *Gracilaria chilensis* (NC_029860) plastid genome by using Geneious R10 (Biomatters Ltd., Auckland, New Zealand).

The complete *G. edulis* plastid genome is a circular DNA molecule measuring 179,410 bp in length, and the overall G + C content of the complete plastid genome was 30.0% (GenBank accession number MN053318). The plastid genome contained 235 genes, including 201 protein-coding genes, 1 ribonuclease gene (*rnpB*), 3 rRNA genes, 30 tRNA genes, and 1 intron interrupting the *trnM* gene. The length of the coding region was 143,982 bp, corresponding to 80.3% of the total length. The plastid genome of *G. edulis* was compact, with 10 pairs of overlapping genes found with overlap lengths of 2–95 bp (*rps18–rpl33*, *atpF–atpD*, *trnR–chlI*, *carA–ycf53*, *psbD–psbC*, *ycf40–rps1*, *trnT–ilvB*, *rpl14–rps17*, *rps17–rpl29*, and *rpl23–rpl4*). The gene numbers and structures were largely similar among Gracilariaceae species published in the NCBI sequence database.

Phylogenetic analysis was conducted using MrBayes 3.1.2 software (Ronquist and Huelsenbeck 2003) based on 81 shared plastid protein sequences from 17 red algal plastid genomes and *Cyanidioschyzon merolae* (NC_004799) served as the outgroup. Concatenated alignments were generated and poorly aligned regions were removed by using the Gblocks server (Castresana 2000). All red algal taxa were clearly separated according to their original class (Figure 1). Florideophyceae species formed a large branch, in which The *Gracilaria* species formed a sub-branch including *G. edulis*. This analysis of complete plastid genome is conducive to understand the evolution of *Gracilaria*.

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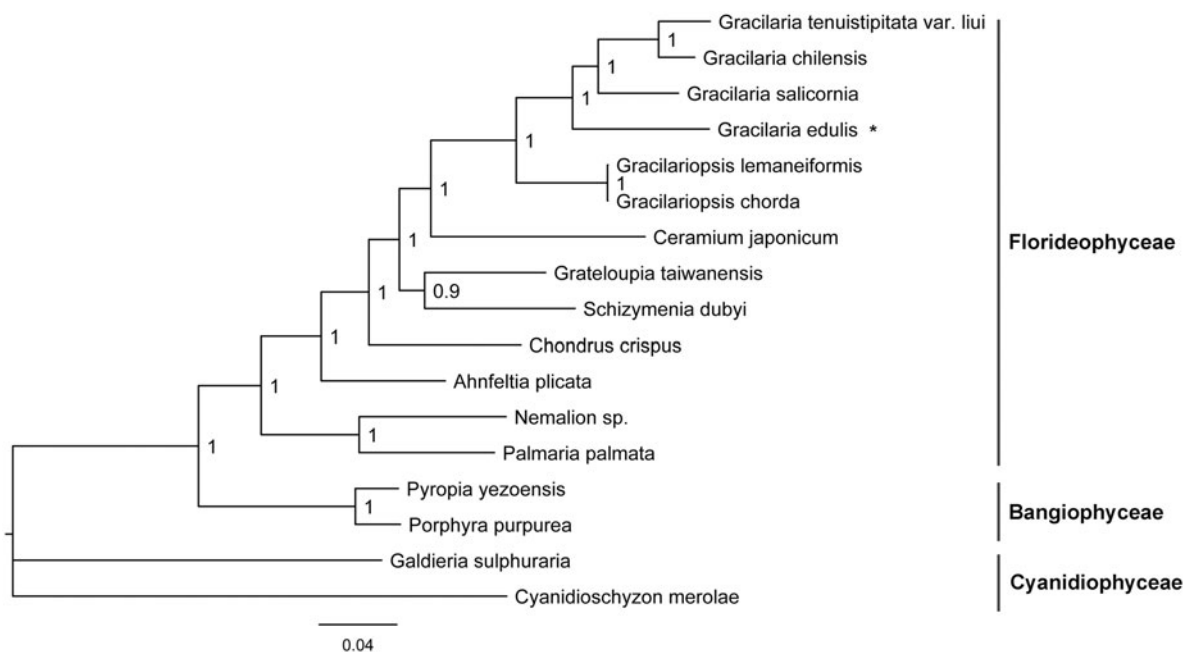


Figure 1. Phylogenetic tree (Bayesian method) based on the complete plastid genome sequence of red algae as shown below: *Gracilaria edulis* (MN053318), *Gracilaria salicornia* (NC_023785), *Gracilaria tenuistipitata* var. *liui* (AY673996), *Gracilaria chilensis* (NC_029860), *Gracilariopsis chorda* (NC_031149), *Gracilariopsis lemneiformis* (KP330491), *Grateloupia taiwanensis* (KC894740), *Schizymenia dubyi* (NC_031169), *Chondrus crispus* (NC_020795), *Ceramium japonicum* (NC_031174), *Nemalion* sp. (LT622871), *Ahnfeltia plicata* (NC_031145), *Palmaria palmata* (NC_031147), *Pyropia yezoensis* (KC517072), *Porphyra purpurea* (U38804), *Galdieria sulphuraria* (KJ700459), and *Cyanidioschyzon merolae* (NC_004799). The asterisks after species names indicate newly determined plastid genomes.

Disclosure statement

No conflict of interest for all the authors including the implementation of research experiments and writing of this article was reported.

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References

- Bharathiraja B, Ranjith Kumar R, PraveenKumar R, Chakravarthy M, Yogendran D, Jayamuthunagai J. 2016. Biodiesel production from different algal oil using immobilized pure lipase and tailor made rPichia pastoris with Cal A and Cal B genes. *Bioresour Technol.* 213:69–78.
- Castresana J. 2000. Selection of conserved blocks from multiple alignments for their use in phylogenetic analysis. *Mol Biol Evol.* 17: 540–552.
- Patra S, Muthuraman MS. 2013. *Gracilaria edulis* extract induces apoptosis and inhibits tumor in Ehrlich ascites tumor cells in vivo. *BMC Complement Altern Med.* 13:331.
- Priyadharshini RI, Prasannaraj G, Geetha N, Venkatachalam P. 2014. Microwave-mediated extracellular synthesis of metallic silver and zinc oxide nanoparticles using macro-algae (*Gracilaria edulis*) extracts and its anticancer activity against human PC3 cell lines. *Appl Biochem Biotechnol.* 174:2777–2790.
- Ronquist F, Huelsenbeck JP. 2003. MrBayes 3: Bayesian phylogenetic inference under mixed models. *Bioinformatics.* 19:1572–1574.
- Sakthivel R, Muniasamy S, Archunan G, Devi KP. 2016. *Gracilaria edulis* exhibit antiproliferative activity against human lung adenocarcinoma cell line A549 without causing adverse toxic effect in vitro and in vivo. *Food Funct.* 7:1155–1165.
- Sakthivel R, Pandima Devi K. 2015. Evaluation of physicochemical properties, proximate and nutritional composition of *Gracilaria edulis* collected from Palk Bay. *Food Chem.* 174:68–74.
- Schattner P, Brooks AN, Lowe TM. 2005. The tRNAscan-SE, snoscan and snoGPS web servers for the detection of tRNAs and snoRNAs. *Nucleic Acids Res.* 33:W686–W689.
- Sivanandhan G, Arunachalam C, Selvaraj N, Sulaiman AA, Lim YP, Ganapathi A. 2015. Expression of important pathway genes involved in withanolides biosynthesis in hairy root culture of *Withania somnifera* upon treatment with *Gracilaria edulis* and *Sargassum wightii*. *Plant Physiol Biochem.* 91:61–64.
- Sivanandhan G, Kapil Dev G, Jeyaraj M, Rajesh M, Muthuselvam M, Selvaraj N, Manickavasagam M, Ganapathi A. 2013. A promising approach on biomass accumulation and withanolides production in cell suspension culture of *Withania somnifera* (L.) Dunal. *Protoplasma.* 250:885–898.
- Suganthi N, Karutha Pandian S, Pandima Devi K. 2010. Neuroprotective effect of seaweeds inhabiting South Indian coastal area (Hare Island, Gulf of Mannar Marine Biosphere Reserve): cholinesterase inhibitory effect of *Hypnea valentiae* and *Ulva reticulata*. *Neurosci Lett.* 468: 216–219.
- Thodhal Yoganandham S, Raguraman V, Muniswamy G, Sathyamoorthy G, Rajan Renuka R, Chidambaram J, Rajendran T, Chandrasekaran K, Santha Ravindranath RR. 2018. Mineral and trace metal concentrations in seaweeds by microwave-assisted digestion method followed by quadrupole inductively coupled plasma mass spectrometry. *Biol Trace Elem Res.* 187:570–585.
- Yotsu-Yamashita M, Yasumoto T, Yamada S, Bajarias FF, Formeloza MA, Romero ML, Fukuyo Y. 2004. Identification of polycavernoside A as the causative agent of the fatal food poisoning resulting from ingestion of the red Alga *Gracilaria edulis* in the Philippines. *Chem Res Toxicol.* 17:1265–1271.