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# Raft culture of *Gracilaria edulis* in open sea along the south-eastern coast of India

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ABSTRACT

Culture of *Gracilaria edulis* was undertaken using a floating raft method to improve biomass production. Research on seasonality of growth, growth rate differences in different localities, subtidal (off-shore) and intertidal (near-shore) cultivation and seasonal occurrence of epiphytes was carried out. Lowest biomass ($1.5 \pm 0.1$ kg fresh wt $m^{-2}$) and daily growth rate (DGR) ($2.6 \pm 0.1$%/day) were obtained during January–February which were significantly different ($P<0.001$) from other maximum growth periods. The range of biomass (1.6–2.6 kg fresh wt $m^{-2}$) and DGR (3.6–5.9%/day) was higher at Ervadi than Thonithurai, but not significantly different ($P>0.05$). Cultivation in subtidal region gave significantly higher biomass ($12.5 \pm 0.9$ kg fresh wt $m-^{2}$) and DGR ($7.4 \pm 0.4$%/day) than those from intertidal region ($4.4 \pm 0.4$ kg fresh wt $m-^{2}$) and DGR ($5.1 \pm 0.1$%/day). Epiphytes are reported to cause severe problems for the growth of *Gracilaria*. A maximum of 15 epiphytic algae recorded in April and August and minimum of 7 in February. The findings presented here indicate that *G. edulis* can be cultivated successfully for 8 months each year with maximum growth rates during November–December. Cultivation in the subtidal region, harvest after 60 days of growth, periodical weeding of epiphytic algae improved the yield further.



## 1. Introduction

*Gracilaria* is one of the largest genera of the seaweeds with more than 150 species. The genera are distributed widely along the Atlantic, Pacific and Indian Ocean with majority of species observed in Indo-Pacific region (Tseng and Xia, 1999). Silva et al. (1996) listed 65 species of *Gracilaria* from the Indian Ocean alone. Commercial cultivation of *Gracilaria* is being practised in Indonesia and Chile and to a lesser degree in Malaysia and Thailand. Small quantities are also being cultivated in Namibia and South Africa (Bixler and Porse, 2010).

In India, 32 species of *Gracilaria* have been reported (Krishnamurthy, 1991). Among these, *Gracilaria edulis* is more abundant and utilised for more than two decades for agar production. The agar obtained from *G. edulis* has been reported to have gel strength of 490 g $cm^2$ with 8% alkali treatment (Meena et al., 2008). The commercial beds of *G. edulis* are mostly restricted to the Gulf of Mannar, south-east coast of India. In recent times, particularly due to emerging Indian biotechnology industries, the demand for seaweed products, especially for agar has increased steadily. Consequently, wild stocks of agarophytes, especially *Gracilaria* have been over-exploited to meet growing market demands. The annual data for harvested seaweeds from the Tamilnadu coast of India (1978–2004) reported 117–664 dry tonnes of *G. edulis* harvested from wild stocks (Kaliaperumal et al., 2004). Such unsustainable pressure led to a severe decline in standing stocks. Currently, many Indian seaweed-based industries are not producing agar to their full capacity due to raw material shortages (A.K.Bose, personal communication). Several attempts have been made to develop cultivation methods for *G. edulis* (Chennubhotla et al., 1978; Kaliaperumal et al., 1993, 2003; Raju and Thomas, 1971; Subbaramaiah and Thomas, 1990; Umamaheswara Rao, 1974) employing a long-line rope, net-culture, and single floating-rope techniques. However the major disadvantage of these methods is the loss of the crop due to breakage of the plants from the substrate particularly during rough weather. In the present study, a floating raft method has been employed to improve the biomass and particularly to eliminate loss of biomass through fragmentation. Furthermore, the present study was to optimise the culture conditions factors such as seasonality, suitable site selection, comparison of subtidal (off-shore) and intertidal (near shore) cultivation and negative impacts of epiphytes. Development of cultivation techniques for *G. edulis* will not only increase its scale of production but also conserve seaweed biodiversity by minimising the harvest pressure on natural resource.

## 2. Materials and methods

### 2.1. Study site

Field cultivation experiments of *G. edulis* were carried out at Thonithurai (09° 16.92′ N 079° 11.40′E) in the Gulf of Mannar, on the south-east coast of India. The intertidal and shallow sub-tidal regions of the coast of Thonithurai typically have muddy bottoms covered with seagrass (*Thalassia* sp.). Small pebbles and dead coral pieces are

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embedded in the muddy substrate. Typically *Gracilaria*, *Hypnea* and *Padina* are the dominant algae attached to this hard substrate. The intertidal region is exposed during lowest tides and submerged during high tides; the tidal range is 0.7 m.

### 2.2. The floating raft method of cultivation

Square frames (1.5 m × 1.5 m), constructed from bamboo poles (7.5–10.0 cm diameter) were used to provide the cultivation structure. The corners were braced diagonally by bamboos in order to keep the raft square and intact. Each raft held 20 parallel lines of polypropylene rope (3 mm diam., Garware Wall Ropes Ltd., Pune) which were spaced at 5 cm distance and to which vegetative fragments of thalli were attached. Apical, growing fragments of *G. edulis* (average 1.0 ± 0.25 g fresh wt and 3.0 ± 0.1 cm length) collected from natural substrate of Thonithurai coast, were inserted at 5 cm intervals between the twists of the rope. Each rope had 25 propagules with a total fresh weight of 25 g rope$^{-1}$. A raft with 20 ropes had an initial mass of propagules of 500 g fresh wt raft$^{-1}$ which was equivalent to 222 g fresh wt m$^{-2}$. Lower side of the raft, below the ropes was fully covered with fish exclusion net (1 mm diam., 1 cm mesh size) in order to prevent access by fish and minimise loss of any materials that might detach from the pp ropes (3 mm diam., Garware Wall Ropes Ltd., Pune) . (Figs. 1 and 2).The raft was anchored securely by stones (approx. 25 kg wt). The plants were harvested at 60 day intervals. Harvest was made by clipping method. The propagules hanging on the rope were cut uniformly at 3 cm from the rope leaving the propagules with approx. 3 cm length on the rope to grow further.

Daily growth rate DGR (%/day) was calculated using the formula of Dawes et al. (1993) as follows

$$\mathrm{DGR}(\%/\mathrm{day}) = In(W_f/W_o)/t \times 100$$

where $W_f$ is the final fresh weight after $t$ days of culture period and $W_o$ is the initial fresh weight.

Biomass was determined for harvested plants after washing the plants thoroughly in seawater. All attached algae and fauna were removed manually. Excess water was drained off by keeping the plants on a mat of fish net over wooden stand for 10 to 15 min and fresh weights were then measured using a simple bring balance with biomass in a suspended mesh bag.

Biomass ($Y$) expressed as mean kg fresh wt m$^{-2}$ was determined using the modified formula of Doty (1986) that included the initial weight of the propagules as follows:

$$Y = (W_f - W_i)/\mathrm{m}^2$$


**Fig. 1.** Raft with line and netting.


**Fig. 2.** *Gracilaria edulis* grown in rafts.

where $W_f$ is the final fresh weight, $W_i$ is the initial fresh weight, and m$^2$ is the area covered. Biomass and daily growth rate values are given with standard error.

### 2.3. Seasonal variation in growth

Thirty rafts were seeded during the first year (2006–2007) and 25 rafts were seeded during the second year (2007–2008) and third year (2008–2009). Each year, seeding was done in June and four consecutive harvests were made at 60 day intervals July–August, September–October, November–December and January–February.

### 2.4. Growth at different stations

Ten rafts each were anchored at the same time in the intertidal region of Thonithurai coast and the Ervadi coast (9° 12.49′N, 78° 43.59′E) in the Gulf of Mannar. The distance between the two stations is 70 km. The coast of Ervadi has a long, flat intertidal reef. The bottom substrate consists of coralline rocks with small interspersed patches of sand beds. The flat reef is always submerged at low tide, and the tidal range is between 0.3 and 1.0 m (lowest low tide and highest high tide). Three harvests were made from the rafts at 60 day intervals. This experiment was conducted in 2005.

### 2.5. Growth at intertidal (near-shore) and subtidal (off-shore) cultivation

Eleven rafts were placed in the subtidal region (i.e. off-shore) about 2 km from the shore where depth was approximately 6 m and these were used to compare to rafts which were stationed within the intertidal (i.e. near-shore) region. Four harvests were made from each site at 60 day intervals. Harvest in the off-shore region was done by dragging the raft into the boat and harvested rafts were placed again in their place. This experiment was conducted during 2008–2009.

### 2.6. Seasonal occurrence of epiphytic algae on G. edulis and on supporting rope

Epiphytic algae occurring on the *G. edulis* and the supporting rope were recorded at monthly intervals for 1 year (January–December 2007) during the cultivation period. Samples were preserved in 4% formalin. The algae were identified by the reference to Littler and Littler (2000) and verified against the checklist of Indian Algae (Oza and Zaidi, 2001).