

Effect of light intensity on the saturation of photosynthesis in *Gracilaria* species (Rhodophyta)

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ABSTRACT

Effect of light intensity on the saturated photosynthesis was studied in three different species of *Gracilaria*. Photosynthetic oxygen evolution reached saturation in the range of 15 to 30 $\mu\text{E}/\text{m}^2/\text{sec}$. However, the saturation in *G. crassa* was observed at low intensity than *G. edulis* and *G. corticata*. The photosynthetic activity was found to be maximum in *G. corticata*. $^{14}\text{CO}_2$ uptake also showed maximum carbon fixed per unit fresh weight in *G. corticata* i.e., 21.3 m mole / g. Fw / h as compared to 18.1 m mole / g. Fw / h in *G. edulis* and 17.9 m mole / g. Fw / h in *G. corticata*.

Introduction

Seaweeds grow in an exceptionally diverse light environment and light provides the initial energy of photosynthesis and ultimately for all biological processes. In the sea, light is attenuated due to absorption of light and scattering. Solar energy that penetrates the ocean is altered in both quality and quantity. The level of irradiance needed to saturate a species shows some correlation with its habitat. Intertidal species require 400 - 700 $\mu\text{E m}^{-2} \text{s}^{-1}$. Upper and mid littoral species saturate with 150-250 $\mu\text{E m}^{-2} \text{s}^{-1}$ and deep littoral species require less than 100 $\mu\text{E m}^{-2} \text{s}^{-1}$ (Luning, 1981). For red seaweed, little is known of long term spectral effects on growth performance or metabolism. Leukart and Luning (1994) demonstrated that green light at very low intensity (0.5 $\mu\text{m m}^{-2} \text{s}^{-1}$) was

more effective than the red or blue light for germling growth in several red algae cultivated for 15 weeks. The better growth rate in red than blue light of *Porphyra umbilicalis* was probably due to high photosynthetic efficiency and quantum yield in red light (Figueroa *et. al.*, 1995). Keeping this in mind this experiment was set up for observing the light saturation curve for three important species of *Gracilaria* and the effect of saturated light under laboratory condition.

Materials and Methods

Considering the location specificity of seaweeds in their distribution, two centres namely Thonithurai and Pudumadam were selected for the collection of samples in the Gulf of Mannar. All these area are limited to 20 km distance but exhibit wide difference in sea conditions. Pudumadam lies between 9° 17' N and 79° E and has rocky coast and sandy

bottom. Species like *Gracilaria corticata* var. *corticata* grow abundantly in the intertidal area. The plants are attached to rocks and exposed to direct sunlight during low tide and strong wave action during high tide. The plants are flattened and rigid, dichotomously branched and dark brown in color. Thonithurai, which lies between 9° 17' N and 79° 11' E has sparsely rocky coast with muddy sea bottom covered by seagrasses. Sea off Thonithurai is relatively calm due to the presence of chain of islands protecting the strong wave action of the sea. *Gracilaria edulis* and *G. crassa* grow well in this area attached to either small pebbles or dead gastropod shells. *G. crassa* also prefers to grow in the rock crevices.

The samples were collected from the respective sites during low tide in the morning and transported to the laboratory in plastic bags containing seawater. They were cleaned thoroughly in sterilized seawater and transported to Madurai Kamaraj University in enriched seawater. The plants were kept in growth chamber at 25° C and 16 L : 8 D photo-period for a day to overcome the transportation stress. A few healthy plants were selected and exposed to complete darkness before exposing the plants to different light intensities.

Apical portion of the plant was hung from the top inside the cylindrical oxygen electrode (Hansatech, UK) containing 2ml of filtered seawater. Saturated white light was passed through a round bottom flask (10 cm diameter water bath) from the slide projector (Photophone Ltd., India) before illuminating the chamber. The water inside the cylindrical tube was stirred continuously by a magnetic stirrer. The amount of oxygen evolved was monitored continuously at 25°C. Mean of three consecutive readings was taken for calculation. Rate of photosynthesis was expressed as micro mole of oxygen evolved

per gram fresh weight per hour. The light source was adjusted to different intensities ranging from 0.6 to 60 $\mu\text{E. m}^{-2} \text{s}^{-1}$ using calibrated Schott neutral density filter.

The photosynthetic activity of three species of *Gracilaria* was also monitored by $^{14}\text{CO}_2$ uptake, by using radioactive carbon (Kulandaivelu and Nedunchezian, 1993). 100 mg of thalli were cut into small pieces and put in small glass vials containing 5 ml of filtered seawater. The samples were kept in a water-bath, maintained at 30°C and exposed to white saturated light to facilitate steady photosynthesis. At the end of incubation 50 μl of H^{14}CO_3 (0.5 m Bq) was added. The reaction was allowed to continue for 15 minutes. The algal samples were taken out, washed thoroughly, ground and centrifuged at 5000 g. From the supernatant, 10 μl of sample was taken in a screw capped glass scintillation vial containing 5 ml of scintillation liquid (Scinto-0, United Technology, Packard). Counts were taken with the help of a liquid scintillating counter (Packard model - 4000).

The absorption spectra of three species of *Gracilaria* were drawn within wavelength of 400-700 nm at room temperature using a Hitachi 557 spectrophotometer. The ground glass sides of matched cuvettes were kept in the light path so that reference and sample beams were scattered to the same extent. The slit width of the measuring beam was narrowed down to 2 nm.

Photosynthetic pigment estimation of *Gracilaria* spp. was carried out by the standard method of Jeffrey and Humphrey (1975).

Results and Discussion

G. edulis, *G. crassa* and *G. corticata* exhibit a wide variation in their morphology

and habitat. The physiological status of the plants depends on these factors. Light saturation curves for *Gracilaria* spp shown in Fig. 1 exhibit that all the species reached the saturated photosynthesis from 15 to 30 $\mu\text{E} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ of light intensity.

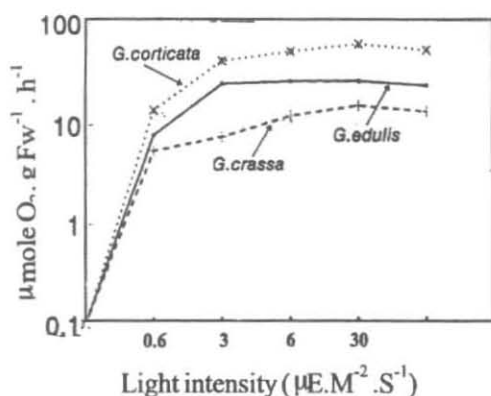


Fig. 1. Light saturation curve for *Gracilaria* spp.

G. crassa did not show a wide variation in the photosynthetic oxygen evolution under different light intensities but it reached the peak at 6 $\mu\text{E} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$. $^{14}\text{CO}_2$ uptake showed that Po activity in terms of ^{14}C uptake was maximum in *G. corticata* than *G. edulis* and *G. crassa* (Fig. 2)

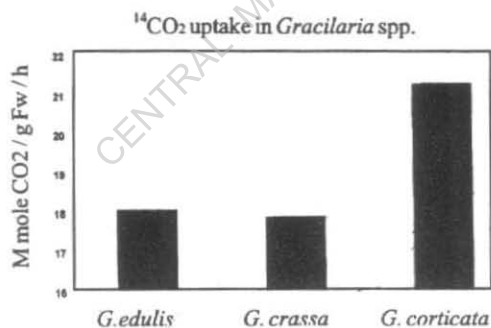


Fig. 2. $^{14}\text{CO}_2$ uptake in *Gracilaria* spp.

It reached to 21 millimole of CO_2 uptake / g Fw / h compared to 18.1 in *G. edulis* and 17.9 in *G. crassa*. While comparing the photosynthetic activity by oxygen evolution per unit fresh weight, showed a similar trend.

However, oxygen evolution was very less in *G. crassa* than *G. edulis* and *G. corticata*. It was also observed that the rate of respiration was more, compared to the rate of photosynthesis, after a brief exposure to low light intensity ($0.6 \mu\text{E} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$). In *G. edulis* an equilibrium was established when the light intensity increased from 0.6 to $6.0 \mu\text{E} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$. The saturation of photosynthesis was taken after comparing the O_2 evolution under light and O_2 uptake under darkness (Figs. 3 and 4). The photosynthetic saturation was obtained between 6-30 $\mu\text{E} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$. In *G. crassa* although the O_2 uptake was less than the O_2 evolution under all light intensities, it remained to be constant after exposing the plant to 6 $\mu\text{E} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$. In *G. corticata* the dissolved oxygen content was found to be constant after exposing the plant to 30 $\mu\text{E} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$.

Room temperature absorption spectra of the thallus of *Gracilaria* species showed absorption maxima at 676, 621, 565, 495 and 433 nm representing the photosynthetic pigments chlorophyll, phycoerythrin, phycocyanin, allophycocyanin and carotenoid respectively (Fig. 5). All the absorption peaks were high in *G. corticata* confirming higher photosynthetic pigments as shown in Table 1. *G. crassa* represented the least. Statistical analysis showed a significant positive correlation on the photosynthetic activity and the pigment constituents.

Although there is very little report on light saturation curve on red algae, intertidal macroalgae by definition alternate between exposure to air with rise and fall of tide. There is growing evidence that many intertidal macroalgae are photosynthetically active during exposure to air. In some cases the photosynthetic activity in air surpass those in water at the same temperature and light (Johnson *et al.*, 1974;

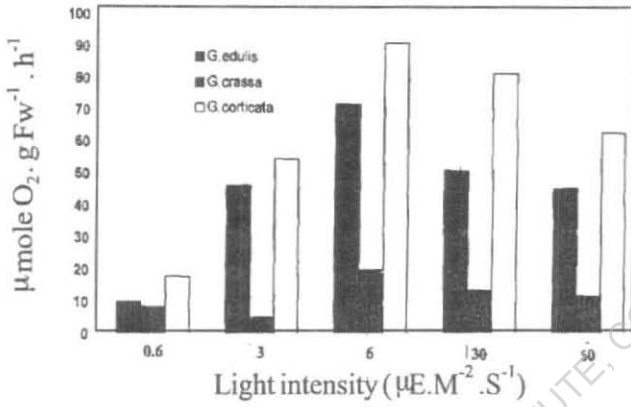


Fig. 3. Rate of Photosynthesis in Gracilaria spp.

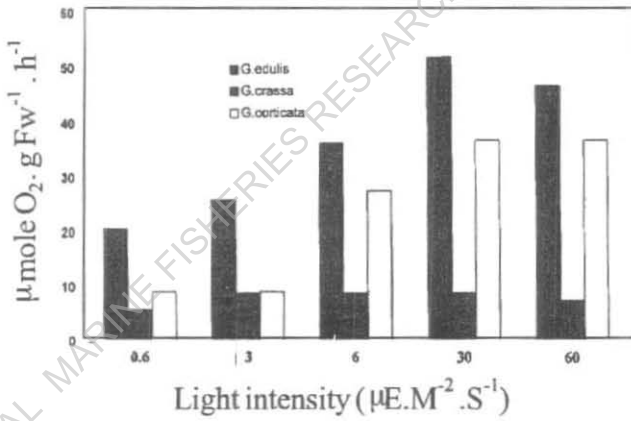


Fig. 4. Rate of Respiration in Gracilaria spp.

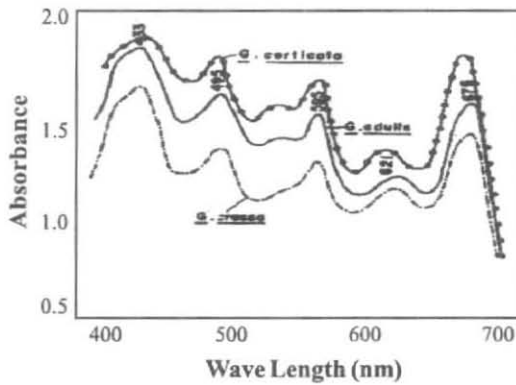


Fig. 5. Absorption spectra of the thallus of Gracilaria spp.

Table 1. Photosynthetic pigment constituent of *Gracilaria* spp (mg/g Fwt.)

Species	Chlorophyll	Phycoerythrin	Phycocyanin	Allophycocyanin
<i>G. edulis</i>	0.0982	0.1278	0.0501	0.0473
<i>G. crassa</i>	0.0333	0.1265	0.0600	0.0404
<i>G. corticata</i>	0.1161	0.3122	0.1932	0.1300

Bidwell and MacLachlan, 1985; Madsen and Maberly, 1990). In the present experiment, it was observed that *G. corticata*, which is constantly exposed to air during low tide, showed maximum photosynthetic activity even under laboratory condition.

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