

Photosynthetic efficiency of marine algae from Mandapam coast

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ABSTRACT

Photosynthetic efficiency of the marine macrophytes from different groups were studied and compared with their pigment constituents. The photosynthetic activity was found to be maximum in green algae except for some coenocytic and calcified species. Thick and rigidly branched thallus possessed lower photosynthetic activity than the delicate and leafy thalloid of less thickness. P max activity of *Gracilaria crassa* was found to be lowest in the red algae taken for this experiment. *Sargassum* being rigid and thickly branched species possessed lower P max activity. The photosynthetic activity did not show a significant positive correlation with the chlorophyll content.

Introduction

Macroalgae display a great variation in their morphology from unbranched uniseriate to thick differentiated thalli. The morphology and structural organization of the algae inherit the properties like surface area / volume ratio, pigment concentration / metabolic activity of tissue, which finally influence metabolism and growth (Littler, 1980; Littler and Arnold, 1982; Raven, 1986; Nielsen and Sand Jensen, 1990). The distribution of seaweed is mostly depending on the quality and quantity of light it receives and the efficiency of the plant to utilize it. Light provides the initial energy of photosynthesis and ultimately all biological process. Photosynthesis is by far the largest component of primary production (Littler *et al.*, 1979; Heine, 1983; Levitt and Bolton, 1990). Models of aquatic plant productivity typically estimate gross photosynthesis measured as a change of dissolved oxygen or change of inorganic carbon in the surrounding water or by the rate of ^{14}C incorporation by the plants (Kemp *et al.*, 1986). In the sea, light is attenuated due to absorption and scattering. As the solar energy penetrates the ocean, it 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 $400 - 700 \mu\text{E m}^{-2}\text{s}^{-1}$ of light, mid sublittoral species saturate with $150-250 \mu\text{E m}^{-2}\text{s}^{-1}$ and deep littoral species requires less than $100 \mu\text{E m}^{-2}\text{s}^{-1}$ light (Luning, 1981). The present work is aimed to

find out the photosynthetic efficiency of different species of marine algae of Mandapam coast based on their morphological variation.

Materials and Methods

Different species of marine macrophytes from the group Chlorophyta, Rhodophyta and Phaeophyta were collected from the intertidal area of Gulf of Mannar from Thonithurai to Pudumadam ($9^{\circ}17'\text{N}$ and 70° to 79° E) during low tide in the morning. The plants were transported to the laboratory in plastic bags. They were brushed off epiphytes and washed several times in sterilized seawater. The plants were taken to Madurai Kamaraj University in enriched seawater and kept in the growth chamber for 24 h to avoid the transportation stress. The chamber was maintained with a temperature of 28°C , light intensity of 1000 lux and the photoperiod of 18:6 h light and dark cycle. The plants were kept under complete darkness before subjecting them to the light treatment for analysing P max activity. Few healthy dark-adapted thalli were hung from the top inside the cylindrical chamber of the Hansatech oxygen electrode containing 2 ml of sterilized seawater. Saturated light of 100w.m^{-2} was provided from India Ltd Photophone slide projector. The light was allowed to pass through a 10 mm diameter water bath blue filter. A magnetic stirrer stirred the water inside the cylindrical tube continuously. The amount of oxygen evolved was monitored continuously at 25°C and recorded in a chart

recorder adjusted with 10 mv and 10 mm chart speed. The standard was drawn with sterilized seawater to avoid background photosynthesis. After taking three consecutive readings from each sample, the plants were weighed and the photosynthetic activity was expressed in μ mole O_2 /gfw/h. Known quantity of fresh thallus were taken and ground in a mortar and pestle and with 90% acetone. Chlorophyll-a was extracted and analyzed by the standard procedure of Jeffrey and Humphrey (1975).

Results

The photosynthetic activity of green algae was found to be more than the other groups except in some siphonaceous and calcified form. It ranged between 32.15 to 88.89 μ mole O_2 /gfw/h. Maximum photosynthetic activity was found in *Cladophora glomerata* (88.89 μ mole O_2 /fgw/h) coinciding with the high chlorophyll content (0.6127 mg/gfw). There is no significant positive correlation between these two parameters in green algae. *Halimeda gracilis* possessed the lowest Pmax activity (6.14 μ mole O_2 /gfw/h) followed by *Caulerpa racemosa* (7.67 μ mole O_2 /gfw/h) and *C.fergusonii* (17.13 μ mole O_2 /gfw/h). It was observed that the chlorophyll content of these algae were also comparatively less than the other species. In

the same genus, the species of *H. macroloba* possessed higher P max activity (68.84 μ mole O_2 /gfw/h) with high chlorophyll content (0.6607 mg/gfw). Similarly in *C.scalpelliformis*, the P max activity was 32.15 μ mole O_2 /gfw/h) and the chlorophyll content was 0.4893 mg/gfw. P max activity of *Enteromorpha compressa* was found to be 34.20 μ mole O_2 /gfw/h even when chlorophyll content was less than *Halimeda gracilis*. The P max activity of *Ulva lactuca* and *U.reticulata* were also found to be different ranging from 52.37 to 93.74 μ mole O_2 /gfw/h. Thus it can be mentioned here that there was a wide variation in the P max activity within different species and among different genera. Chlorophyll content alone may not influence the photosynthetic activity. The thallus thickness and rigidity and cell volume are the other parameters, which affect the P max activity (Fig. 1).

In brown algae six different species were taken to find out the photosynthetic efficiency. It was observed that there was a wide variation in the P max activity and the chlorophyll content existed among the species. It ranged between 8.04 to 44.59 μ mole O_2 /gfw/h. Lowest was found in *Sargassum ilicifolium* (8.04 μ mole O_2 /gfw/h), where the chlorophyll content was found to be highest (1.0671 mg/gfw). The

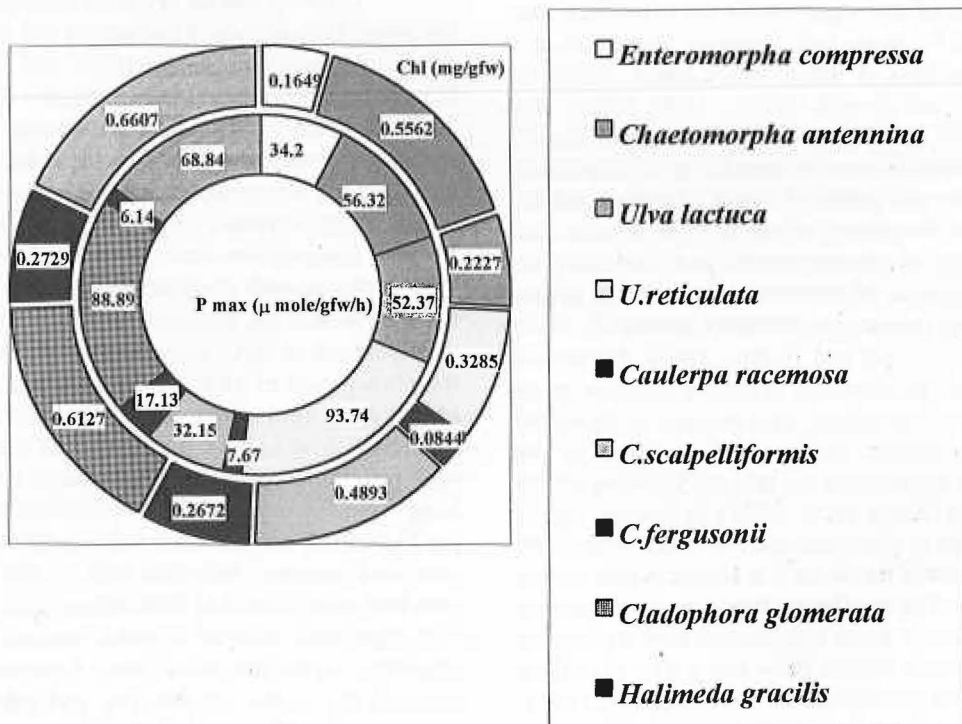


Fig. 1. P max activity and the chlorophyll content of green algae

young plants of *S.wightii* also exhibited a low photosynthetic activity ($9.61 \mu \text{ mole O}_2/\text{gfw/h}$) although the chlorophyll content was much lower than *S.ilicifolium* (0.2477 mg/gfw) followed by *Hydroclathrus clathratus* having the P max activity of $12.60 \mu \text{ mole O}_2/\text{gfw/h}$ and chlorophyll content much lower than *S.wightii* (0.1540 mg/gfw). The photosynthetic activity was found to be highest in *Padina boergesenii* ($44.59 \mu \text{ mole O}_2/\text{gfw/h}$) with a reasonably good quantity of chlorophyll-a (0.9980 mg/gfw) followed by *Stoechospermum marginatum* ($29.33 \mu \text{ mole O}_2/\text{gfw/h}$.) and *Dictyota dichotoma* ($21.09 \mu \text{ mole O}_2/\text{gfw/h}$.) The P max activity of *Padina boergesnii* and *Stoechospermum marginatum* were proportional to their chlorophyll content (Fig. 2).

Twelve species of red algae constituting six species of *Gracilaria* were taken for the estimation of P max activity. The P max activity of *Gracilaria* species ranged between 5.36 to $29.18 \mu \text{ mole O}_2/\text{gfw/h}$ whereas the chlorophyll content was between 0.037 to 0.1394 mg/gfw . Lowest photosynthetic activity was observed in *Gracilaria crassa* and highest in *Gracilaria corticata* var. *cylindrica*. The chlorophyll concentration was found to be least in highly photosynthesizing species *G. corticata* var. *cylindrica*

(0.0372 mg/gfw). Except for *G. corticata* var. *pudumadamensis*, all the species were having both reproductive and the vegetative stage. P max activity was taken separately for both the stages. There was a marginal variation in the P max activity of vegetative and reproductive thallus. In general, the photosynthetic activity of reproductive thallus was comparatively less than the vegetative one. But in *G. corticata* var. *corticata* the P max activity of the reproductive thallus ($17.15 \mu \text{ mole O}_2/\text{gfw/h}$) was twice to that of the vegetative thallus ($9.68 \mu \text{ mole O}_2/\text{gfw/h}$) although there was no variation in the chlorophyll content between these two varieties (Fig. 3).

In other six species of red algae, the P max activity ranged between 13.56 to $29.18 \mu \text{ mole O}_2/\text{gfw/h}$ (Fig. 4). The reproductive thallus of *Sarconema* showed a similar result like *G. corticata* var. *corticata* but the chlorophyll content of the cystocarpic thallus was found to be comparatively higher than the vegetative thallus. In *Hypnea valentiae*, there was marginal variation in the P max activity between vegetative ($23.10 \mu \text{ mole O}_2/\text{gfw/h}$) and the cystocarpic thallus ($27.72 \mu \text{ mole O}_2/\text{gfw/h}$). They coincided with the variation of their chlorophyll contents. P max activity was found to be highest in *Ceramium* sp.

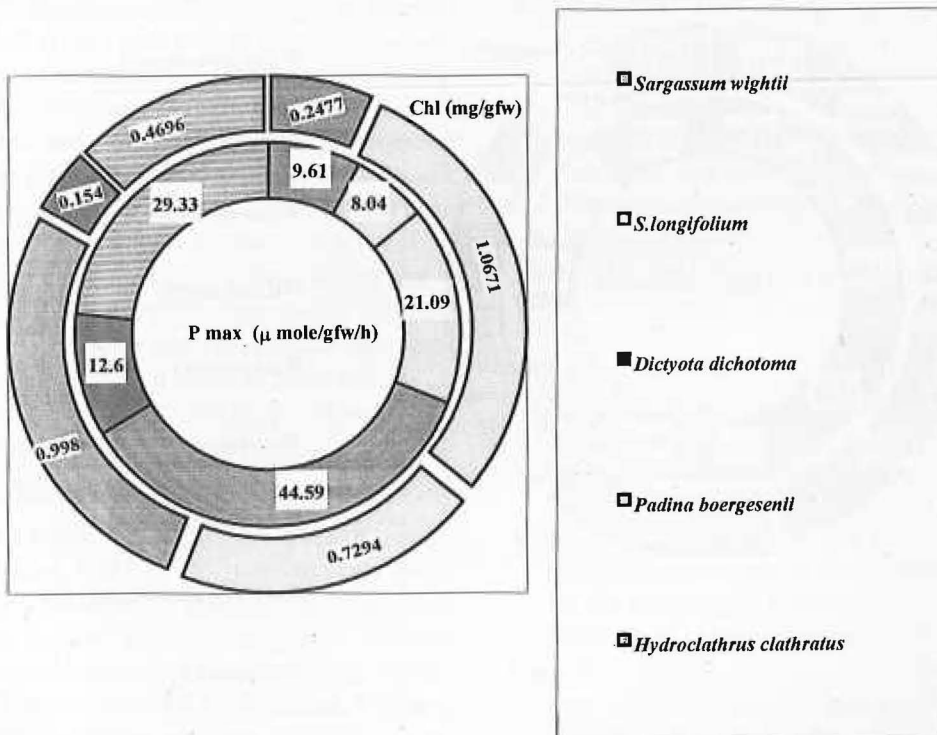


Fig. 2. P max activity and the chlorophyll content of brown algae

(29.18 μ mole O_2 /gfw/h) followed by *Jania rubens* (26.75 μ mole O_2 /gfw/h.) coinciding with the highest chlorophyll concentration (0.3381 mg/gfw). The P max activity of *Acanthophora spicifera* (17.55 μ mole O_2 /gfw/h) and *Laurencia poiteaui* (16.11 μ mole O_2 /gfw/h) were proportional to their chlorophyll contents. It was very clear from the experiment that the P max activity of delicate thinly branched thallus was more than the coarse and rigidly branched thallus (Fig. 4).

Discussion

The photosynthetic efficiency of marine macrophytes are influenced by multiple factors such as their distribution, thallus structure, thickness of the thallus, cell volume, cell sap content and the pigment constituent of the thallus. In the present experiment, it was observed that the coenocytic thallus of *Caulerpa racemosa* and calcified thallus of *Halimeda gracilis* exhibited lowest photosynthetic activity. The chlorophyll concentration was also found to be lower in these species. *Halimeda macroloba* being another calcified species had high photosynthetic activity due to its leafy thallus. The calcification, which was found on the basal part of the thallus, did not affect photosynthetic activity. The chlorophyll concentration was also found to be higher in these species. Similarly

another coenocytic species *C. scalpelliformis* showing a flattened leafy structure possessed higher P max than *C. racemosa* and *C. fergusonii*. It may be explained here that the cell volume and the cell sap of these coenocytic algae varied from species to species. Fleshier the structure, less was P max activity as observed in *Caulerpa racemosa*.

In brown algae, photosynthetic activity was found to be least in the species of *Sargassum* and maximum in *Padina boergesenii*. The thallus structure of *Padina* is flattened and thin. The chlorophyll content was also found to be more in *Padina*, which might have helped to enhance the photosynthetic activity. Similarly *Stoechospermum marginatum* also possessed high photosynthetic activity with relation to chlorophyll content. Thus it was observed that the rigidity of the thallus in *Sargassum* and *Hydroclathrus clathratus* reduced the P max activity to a greater extent. *G. crassa* being a bulbous fleshy structure with more cell sap showed a drastic reduction in the photosynthetic activity. Thus flattened, leafy and delicate thallus possessed higher photosynthetic activity than rigid, coarsely branched and voluminous species. Similar results were obtained by different workers (King and Schramm, 1970; Littler,

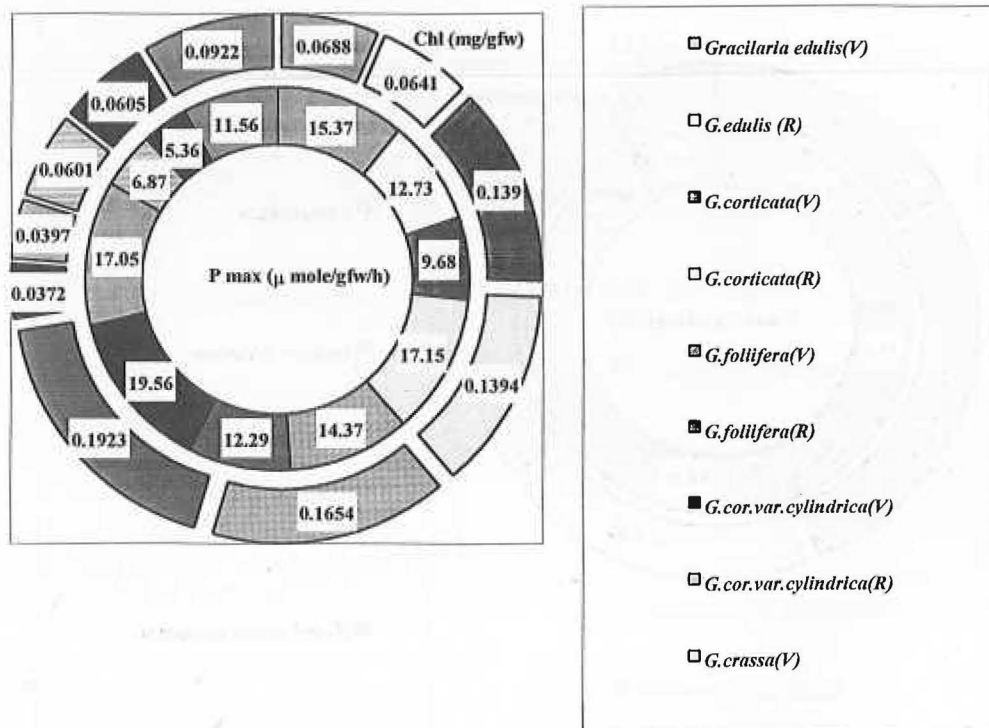


Fig. 3. P max activity and the chlorophyll content of *Gracilaria* species

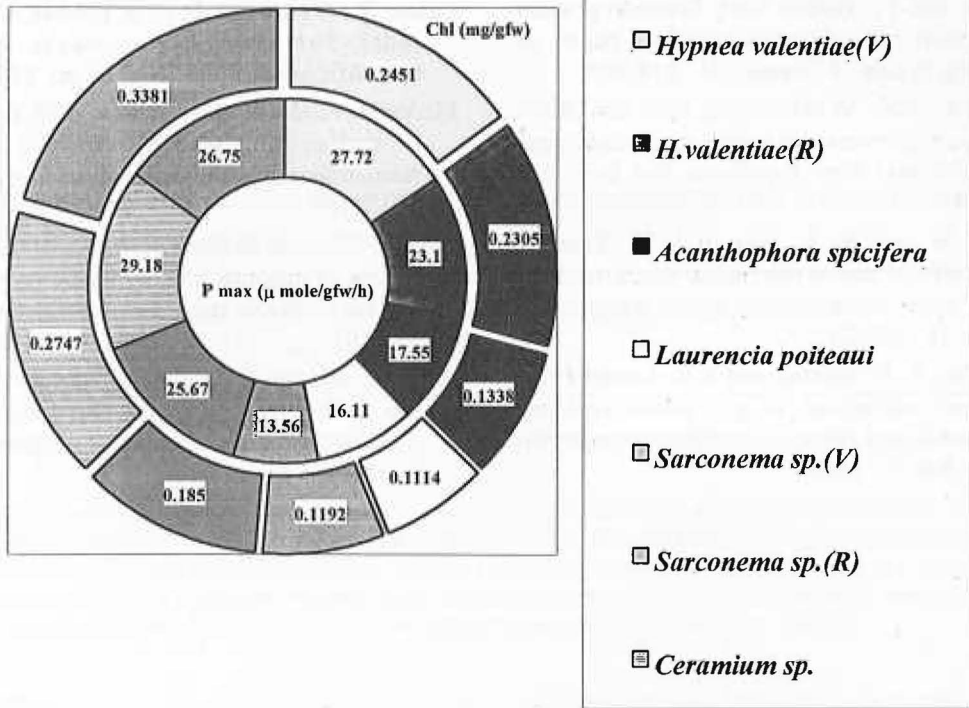


Fig. 4. *P max* activity and the chlorophyll content of other red algae

1980; Littler and Arnold, 1982; Nielsen and Sand Jensen, 1990 and Enriquez *et al.*, 1995). Nielson and Sand - Jensen (1990) used surface area / volume ratio to scale metabolic parameters. Enriquez *et al.* (1995) showed the relationship between light limited photosynthesis and the thallus thickness. Markager and Sand-Jensen (1996) explained maximum growth rate in the field experiments increased from 19 to 350 m mole $\text{Cmol}^{-1} \text{Cd}^{-1}$ as thallus thickness declined in 30 species. Allometric equations of the type $\log \text{rate} = a + b \times \log(\text{size parameters})$ are often used to relate the rate of photosynthesis or respiration to size dependant parameters such as cell volume (Banse, 1982), thickness (Enriquez *et al.*, 1995) or surface area to volume (Nielsen and Sand Jensen, 1990).

Acknowledgements

The author is thankful to Dr. P.S.B.R. James, former Director, CMFRI for granting study leave and Dr. V.N. Pillai for his constant encouragement. The author is also thankful to Indian Council of Agricultural Research for providing Senior Research Fellowship and to Madurai Kamaraj University for providing necessary facilities to carry out this work.

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