*J. Mar. Biol. Ass. India*, **51** (1) : 107 - 110, January - June 2009

**Short Communication**

# †Carbon sequestration by a few marine algae: observation and projection

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**Abstract**

$CO_2$ sequestration by the marine planktonic microalgae *Nannochloropsis salina* and *Isochrysis galbana* as well as macroforms *Gracilaria corticata, Sargassum polycystum* and *Ulva lactuca* was estimated under laboratory conditions. The green seaweed *U. lactuca* registered 100% utilization of $CO_2$ towards carbon fixation from the ambient water up to 15 mg/l and beyond that it declined to 60%. The microalgae were able to utilize 27.7% of dissolved $CO_2$ at 15 mg/l, but did not show any effect either for carbon fixation or for emission at lower and higher levels. Gross primary productivity of these algae were also not affected by increase in the $CO_2$ levels. It is estimated that the seaweed biomass along the Indian coast is capable of utilizing 9052 $tCO_2$/d against emission of 365 $tCO_2$ /d indicating a net carbon credit of 8687 t/d.

**Keywords:** Carbon sequestration, microalgae, seaweeds, carbon credits

## Introduction

Increase of carbon dioxide besides methane and oxides of nitrogen in the atmosphere is leading to climate change. These greenhouse gases (GHGs) cause depletion of ozone layer protecting the atmosphere against UV radiation, thereby warming the atmosphere. The average concentration of $CO_2$ increased from 315 ppm in 1960 to 380 ppm in 2007 (IPCC, 2007). There has been a 35% increase in $CO_2$ emission worldwide since 1990.

Carbon fixation by photoautotrophic algae has the potential to diminish the release of $CO_2$ into the atmosphere and in helping to alleviate the trend toward global warming. Primary producers of coastal and marine ecosystems such as phytoplankton, seaweed and seagrass are excellent carbon sequestering agents than their terrestrial counterparts (Zou, 2005). In this communication, an attempt is made to assess the carbon fixing efficiency and respiratory emission rate of two marine planktonic algae and three seaweeds in varying levels of dissolved $CO_2$ in relation to the proposed rise in the level of dissolved $CO_2$ in coastal waters. We also attempt to project a quantitative estimate of carbon sequestering capacity of the seaweeds that are distributed along the Indian coast based on our observation of $CO_2$ assimilation ability of various marine algal species.

## Material and methods

***Marine algal samples***: Samples of *Gracilaria corticata* J. Agardh, *Sargassum polycystum* C. Agardh and *Ulva lactuca* Linn. were collected from the intertidal rocky beach adjoining Thotlakonda (17°49'18.75"N lat. and 83°24'58.06"E long.) near Visakhapatnam and brought to the laboratory. The samples were washed and the thallii were cleaned with excess water to free epiphytes, organisms and adhering sand particles. They were acclimatized overnight in large tanks containing filtered (0.45µ) seawater of 32 ppt. Samples of microalgae *Nannochloropsis salina* Hibberd and *Isochrysis galbana* Parke were taken from the stocks at their

*†Presented in the International Symposium "Marine Ecosystem- Challenges and Opportunities (MECOS 09)" organized by the Marine Biological Association of India during February 9-12, 2009 at Kochi.*

exponential growth phase, being maintained at the algal feed culture laboratory of Visakhapatnam Regional Centre of CMFRI for the last ten years. The concentration of cells during the experiment was 1.25 x $10^6$ /ml for *Nannochloropsis salina* and 2.0 x $10^6$ /ml for *Isochrysis galbana.*

***Enrichment of $CO_2$***: Seawater collected from the seaweed collection site was brought to the laboratory and filtered through 0.45µ GFC (Millipore) to remove plankton and algal spores. Prior to the experiment, the initial $CO_2$ concentration was determined. Later, $CO_2$ was dissolved into the seawater taken in separate glass containers at the rate of 5, 10, 15 and 25 mg/l from a $CO_2$ cylinder dispensed through a tabletop sodamaker. The initial level of dissolved $CO_2$ in each set of airtight container was ascertained titrimetrically according to Dye (1958) and maintained at the required level.

***Determination of $CO_2$ utilization, emission and primary production***: Cleaned thallii of seaweeds were weighed (0.5 g) accurately and incubated with 300 ml of $CO_2$ enriched seawater (5-25 mg/l) after determining the initial $O_2$ and $CO_2$ in airtight, thick and clear polythene bags in light and dark condition under a column of water (40-50 cm) for two hours. After the incubation in light/ dark, 100 ml water samples from each bag were drawn gently using a large hypodermic syringe into separate glass bottles (100 ml) and subjected to $CO_2$ determination (Dye, 1958) and another 100 ml for determining dissolved oxygen (Gaarder and Gran, 1927) using Winkler's reagent.

Similarly 10 ml each of stock cultures of *Nannochloropsis salina* and *Isochrysis galbana* were treated with 290 ml of $CO_2$ enriched (0-25 mg/l) seawater. $CO_2$ utilized for carbon fixation (light incubation), $CO_2$ emission (dark incubation) and their gross primary productivity (GPP) in various levels of dissolved $CO_2$ were determined. GPP was calculated for each species in different $CO_2$ concentrations from their oxygen production values multiplied with the factor 0.536/PQ, where PQ was 1.25 (Westlake, 1963). Triplicate polythene bags for each species and each $CO_2$ treatment and control (without seaweeds as well as 0 mg/l of $CO_2$) were maintained to get average values.

## Results

***Carbon utilization and emission***: Four levels of dissolved $CO_2$ in seawater were tested to assess the rate of carbon utilization in light and its emission in dark during respiration by the macro and microalgae and the results are presented in Table 1. *Gracilaria corticata* (red alga) and *Sargassum polycystum* (brown alga) utilized 100% of the dissolved $CO_2$ for photosynthesis when the ambient level was 5 mg/l and beyond that, the $CO_2$ utilization rate showed steep decline. The emission rate was nil when the ambient $CO_2$ levels were increased from 5 to 25 mg/l, except at 25 mg/l concentration, where 20% increase in emission over the control was observed in the case of *G. corticata*. However, the green alga *Ulva lactuca* registered 100% utilization of $CO_2$ for carbon fixation from the ambient water upto a level of 15 mg/l and beyond that level it declined to 60%. The microalgae were able to utilize 27.7% of dissolved $CO_2$ when the ambient level was 15 mg/l, but at lower and higher levels it did not show any effect either for carbon fixation or for emission.

As shown in Table 2 the effect of increasing levels of dissolved $CO_2$ on the GPP of *Sargassum polycystum* at elevated levels of $CO_2$ in ambient water gradually increased from 124% to 209% over

Table 1. $CO_2$ fixed (% over initial level) in light (photosynthesis) or emitted (% over initial level) in dark (respiration) by some marine algae observed under different levels of dissolved $CO_2$ in closed system

| Species | $CO_2$ level (mg/l) 0 | | 5 | | 10 | | 15 | | 25 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Light | Dark | Light | Dark | Light | Dark | Light | Dark | Light | Dark |
| *Gracilaria corticata* | 0 | 0 | 100 | 0 | 25 | 0 | 33.3 | 0 | 20 | 20 |
| *Sargassum polycystum* | 0 | 0 | 100 | 0 | 50 | 0 | 50.0 | 0 | 40 | 0 |
| *Ulva lactuca* | 0 | 0 | 100 | 0 | 100 | 0 | 100.0 | 0 | 60 | 0 |
| *Nannochloropsis salina* | 0 | 0 | 0 | 0 | 0 | 0 | 27.7 | 0 | 0 | 0 |
| *Isochrysis galbana* | 0 | 0 | 0 | 100 | 0 | 0 | 27.7 | 11.5 | 0 | 0 |
| No plants (control) | 0 | 0 | 0 | 0 | 0 | 0 | 16.6 | 0 | 0 | 0 |

the control (0 mg/l). *Gracilaria corticata* registered marginal decrease in GPP at 5 mg/l (9.0% less) and 10 mg/l (21.5% less) and an increase of 45% at 15 mg/l as well as 25 mg/l of ambient $CO_2$ levels over the control. However, *Ulva lactuca* did not show any marked difference. The planktonic algae registered higher GPP rates at 10 mg/l of $CO_2$ (111%) and at 15 mg/l $CO_2$ (84%). *Isochrysis galbana* showed 49% higher GPP only at 10 mg/l level and beyond this level registered considerable reduction in GPP (71% less at 15 mg/l and 89% less at 25 mg/l of $CO_2$) besides showing 84% less GPP at 5 mg/l concentration of $CO_2$ over the control.

Table 2. GPP (% over the control) of marine algae in different levels of dissolved $CO_2$

| Species | $CO_2$ level (mg/l ) | | | | |
|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | 25 |
| *Gracilaria corticata* | 100 | 91 | 78.5 | 145.2 | 146 |
| *Sargassum polycystum* | 100 | 224 | 0 | 252 | 309 |
| *Ulva lactuca* | 100 | 93 | 100.0 | 95 | 109 |
| *Nannochloropsis salina* | 100 | 89 | 211 | 184 | 89 |
| *Isochrysis galbana* | 100 | 16 | 149 | 29 | 11 |

The values presented in Table 1 were used to compute the $CO_2$ sequestering efficiency of the green, brown and red seaweeds along the Indian coasts as the standing stock of Indian seaweeds and their composition are known (Kaladharan and Reeta Jayasankar, 2003). The green seaweeds represented by *Ulva lactuca* are more efficient in carbon utilization than their brown and red counterparts (Table 3). The $CO_2$ emission rates of *Ulva* and *Sargassum* were observed as negligible and the net carbon utilisation of the Indian seaweed biomass is projected as 8687 t $CO_2$/ day.

## Discussion

Although seaweeds and phytoplankton are considered as excellent sequestering agents of GHGs, quantitative estimates were not available for the Indian seaweed biomass. Two culture systems are in use for $CO_2$ sequestration with planktonic algae- one is the open pond system and the other is the closed photobioreactor system and there is ongoing discussion regarding the merit of these two systems (Benemann, 1993; Pedroni *et al*., 2001). We used closed photobioreactor system employing airtight, thick and clear polythene bags. The results obtained by us, though preliminary, indicate the capacity of the marine algae to utilize the excess $CO_2$ dissolved in the ambient water at levels 5 mg/l higher than the *in situ* levels in general and *Ulva lactuca* in particular, the commonly occurring seaweed along the intertidal zones of Indian coast. The emission of $CO_2$ through their respiratory activity is also minimum (0 to 20%) as these algae are capable of reutilizing the respiratory release of $CO_2$ within their cellular interspace for subsequent photosynthesis (Kanwisher, 1966).

The merit in the present investigation is that both the planktonic algae and macroalgae employed were representing different taxa such as green, brown and red algae. The methodology used was very simple but effective in the sense that within the same experimental set up $CO_2$ emitted or utilized and primary productivity could be monitored simultaneously by drawing samples for estimation through a hypodermic syringe where chances of contamination of extraneous air is minimum. This study also provides ample chance for quantifying the carbon sequestering efficiency of seaweeds as well as phytoplankton species.

Atmospheric $CO_2$ levels play a major role in the rate of carbon assimilation in terrestrial plants, and lower concentration of $CO_2$ promote higher photosynthesis (Forrester *et al*., 1966). On the contrary, their marine counterparts, especially the

Table 3. Total estimated $CO_2$ absorbed (t/day) and emitted (t/day) by seaweed biomass along the Indian coasts

| Type of seaweeds | Standing crop(t)* | Efficiency to absorb (mg/g/h ) | $CO_2$ absorbed (t/day) | Efficiency emit to (mg/g/h ) | $CO_2$ emitted (t/day) |
|---|---|---|---|---|---|
| Red algae | 36523 | 1.60 | 584 | 1.0 | 365 |
| Brown algae | 41740 | 2.35 | 981 | 0 | 0 |
| Green algae | 182613 | 4.10 | 7487 | 0 | 0 |
| Total | 260876 | 8.05 | 9052 | 1.0 | 365 |

* Data from Kaladharan and Reeta Jayashanker (2003)

seaweeds registered higher rate of GPP (carbon assimilation) in increased levels of ambient $CO_2$ (Table 2) indicating the possibility of their unaltered carbon sequestering efficiency even in higher levels of dissolved $CO_2$.

It is estimated by Kaladharan and Reeta Jayasankar (2003) that the standing crop of seaweeds in the Indian waters was 2,60,876 tonnes, comprising 14% agar and carrageenan yielding seaweeds (Rhodophyceae), 16% algin yielding seaweeds (Phaeophyceae) and 70% green algae (Chlorophyceae). Taking these estimates into consideration, the $CO_2$ assimilation rate per day was computed for green algae represented by *Ulva lactuca*, brown algae represented by *Sargassum polycystum* and red algae represented by *Gracilaria corticata* (Table 3). As the green seaweeds are dominant, their carbon assimilation efficiency is high (Table 1). They are comparatively under-exploited as well as distributed throughout the intertidal zones to the euphotic zones of the neritic waters, and hence, sequester huge quantities of dissolved $CO_2$ from the coastal waters. Large scale mariculture of seaweeds especially of commercially important species can marginally reduce $CO_2$ concentration in the atmosphere as well as provide large harvestable biomass of raw material for phycocolloid industry.

## Acknowledgements

The authors are grateful to the Director, CMFRI for constant encouragement and for providing necessary facilities. Field and laboratory assistance rendered by Sri Ch. Moshe is appreciated.

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Received : 19/12/08
Accepted : 16/02/09