B-5.1 Potential of carbon fixation by marine phytoplankton

Contact Person Masataka Watanabe
Division of Water and Soil Environment,
National Institute for Environmental Studies
16-2 Onogawa, Tsukuba, Ibaraki 305, Japan
Tel +81-298-51-6111(Ext. 330)
Fax +81-298-56-4680

Total Budget for FY1990-FY1992 34,055,000 Yen

Abstract

A large scale axenic culture tank was used in order to understand the causative relationship between the growth of phytoplankton and the variation of CO_2 concentration in atmosphere. Variations of Organic carbon and inorganic carbon in sea water and absorption of atmospheric CO_2 into sea water had been measured in the tank in detail. About 17% of assimilated inorganic carbon was excreted from the cells as dissolved organic carbon, which is very important for the production of DOC in the surface layer of the ocean. It was found that the growth of C. antiqua was limited by available [$H_2CO_3^*$] instead of [HCO_3^-].

Key Words Marine microcosm, Ocean carbon cycle, Marine phytoplankton, carbon fixation

1. Introduction

Fossil fuel burning and changing in land use have been attributed as the major cause of changing the natural global carbon cycle. Increasing amounts of carbon dioxide in the atmosphere may cause a detectable change in the global climate. The role of ocean and marine ecosystem on the absorption of CO_2 is the key issue for the accurate prediction of the global carbon cycle (Sarmiento & Toggweiler, 1984; Toggweiler & Sarmiento, 1985), yet the mechanism of carbon cycle in the ocean has been unclear. In order to understand the carbon cycle in the ocean, it is necessary to understand the carbon flow between atmospher-ocean and ocean-phytoplankton. A large scale culture tank was used to measure the carbon cycle in air-sea-phytoplankton system. The concentration of carbon dioxide in air, cell number and the concentration of total carbonate in water were measured.

2. Material and Method

A large axenic culture tank (Watanabe et al., 1988, 1991) was used to grow the clonal axenic culture strain of Chattonella antiqua (Hada) Ono (NIES-1, Microbial Culture Collection of the National Institute for Environmental Studies). The tank was 2m high by 1m internal diameter (working volume of the tank was $1m^3$), in addition to an air space of $0.4m^3$, connected with $2m^3$ air tank(Fig. 1). Illumination was from a 5KW xenon lamp operated at $530\mu Einst \cdot m^{-2} \cdot s^{-1}$ (average at the water surface) with a 12 : 12 h LD regime (L : 0600-1800 hours). Temperature was kept at 25±1°C. Sterilized

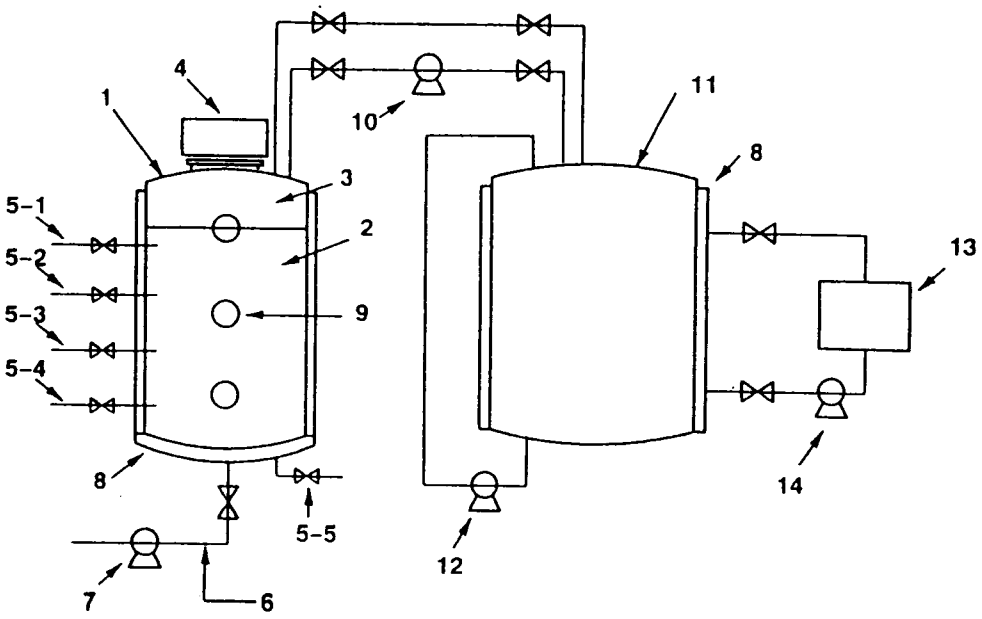

Fig. 1 Schematic view of a large axenic culture tank

air was introduced from the bottom of the tank to maintain a fully mixed condition until the cells reached to stationary phase. The tank was inoculated with 1 liter of C. antiqua culture at an initial concentration of 7 cells·ml^{-1}. When cells reached to stationary phase, mixed gas of 95% air and 5% CO_2 was introduced in air space of the tank and aeration was stopped in order to maintain completely closed condition and therefore there was no inflow-outflow of air. At 1300 hours, cell number, pH, total carbonate, temperature, particulate organic carbon were measured. Cells were counted with a Coulter TA-II counter and pH was measured with pH meter (TDA, HM-60V) installed in a plastic cell (diameter = 80mm, heigh = 150mm). Total carbonate was measured with Coulometer (UIC Inc. Model 5012) based on the method of Dickson & Goyet (1991). DOC was measured with TOC analyzer (Shimazu TOC-5000) based on the method of Mackinnon (1981). For particulate carbon and nitrogen measurements, samples of water were filtered through precombusted (400°C for 4 h) Whatman GF/F 47-mm glass-fiber filters. Particulate C and N were measured with a CHN analyzer (MT-3, Yanaco, Japan). The PO_4^{3-} concentration was analyzed by the method of Murphy and Riley (1962) with a Technicon Auto Analyzer. The concentration of CO_2 in air space of the tank was continuously measured by NDIR (Fuji Electric Inc. ZRC).

3. Results

The initial cell concentration was 7 cell·ml^{-1} and the initial nutrient concentrations were 31.1μM of DIP and 846.1μM of DIN. The specific growth rate was μ = 0.68 d^{-1} until the 8th day and μ = 0.11 d^{-1} after the 9th day (Fig. 2).

The initial concentration of total carbonate (C_T) was 1985μM and C_T decreased from 1808μM to 1550μM from the 6th day to the 9th day according to the growth of the cells (Fig. 3). The value of pH increased from the initial value of 8.202 to 9.0 in the 11th day. The initial concentration of DOC was 175.7μM and the concentration of DOC from 235.3μM (6th day) to

294.2μM (9th day).

The concentration of CO_2 in air space of the tank decreased from 514.7ppm (6th day) to 189.6ppm (9th day) (Fig. 4). According to the growth

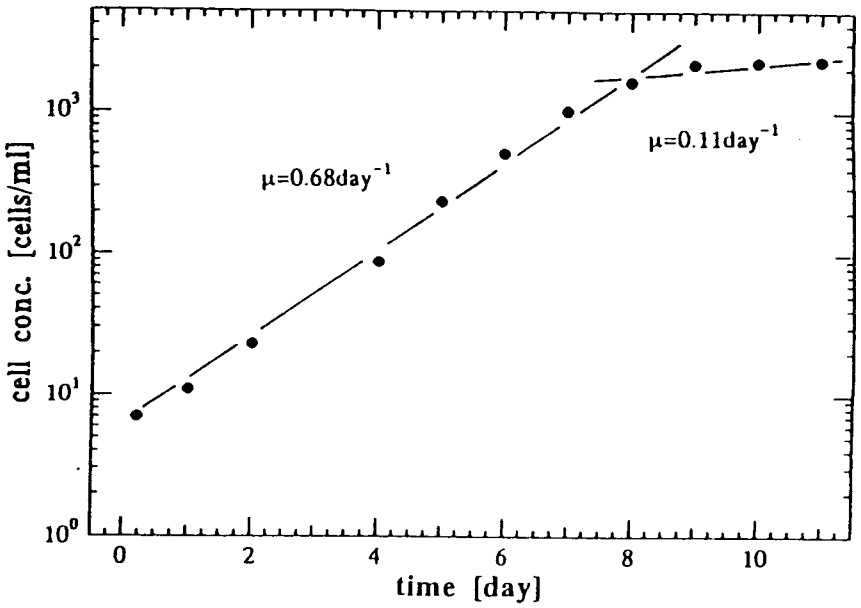

Fig. 2 The growth of C. antiqua

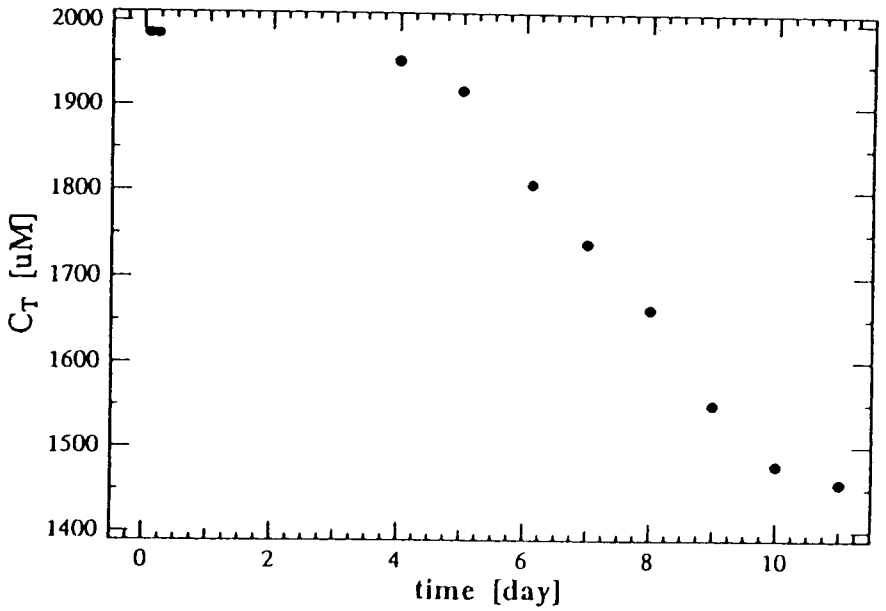

Fig. 3 Variation of CT during the growth of C. antiqua

of the cells, CT was assimilated as organic carbon and DOC was excreated from the cells. Proportions of CT, DOC and POC in the tank (in which mass of total carbon was conserved) were shown in Fig. 5. Percentage of CT was 84.3% in 6th day and 70.3% in 9th day. The amount of decrease in CT is equal to the amount of increase in DOC + POC and percentage of DOC and

POC increased from 11.0% and 4.7% to 13.4% and 16.3%, respectively. Therefore, from 6th day to 9th day 83% of assimilated C_T was fixed within the cells and 17% of assimilated C_T was changed to DOC.

4. Discussion

The process of the assimilation of C_T by phytoplankton and absorption of CO_2 from air space to sea water in the tank was measured in detail,

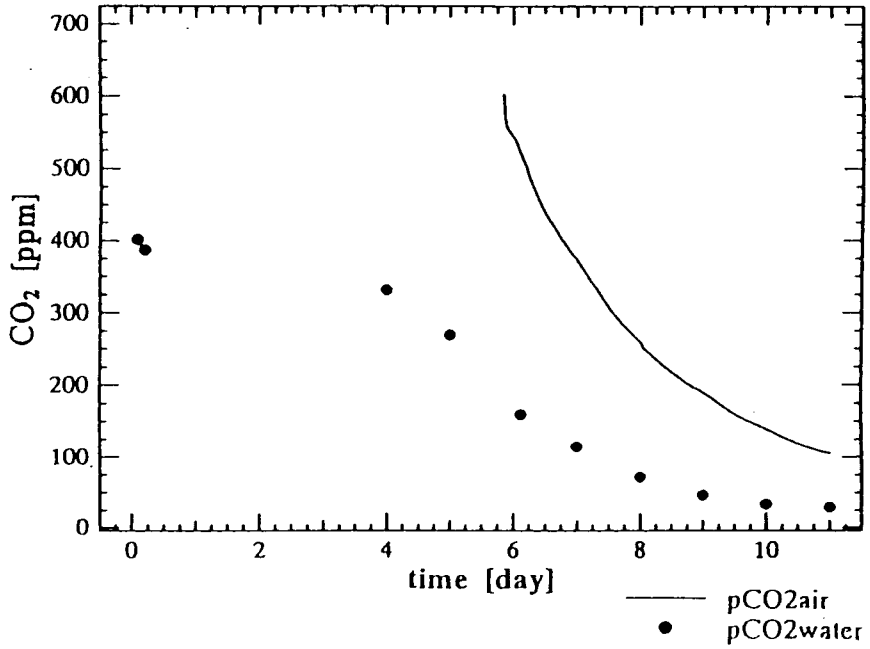

Fig. 4 Variation of pCO_2 air and pCO_2 water

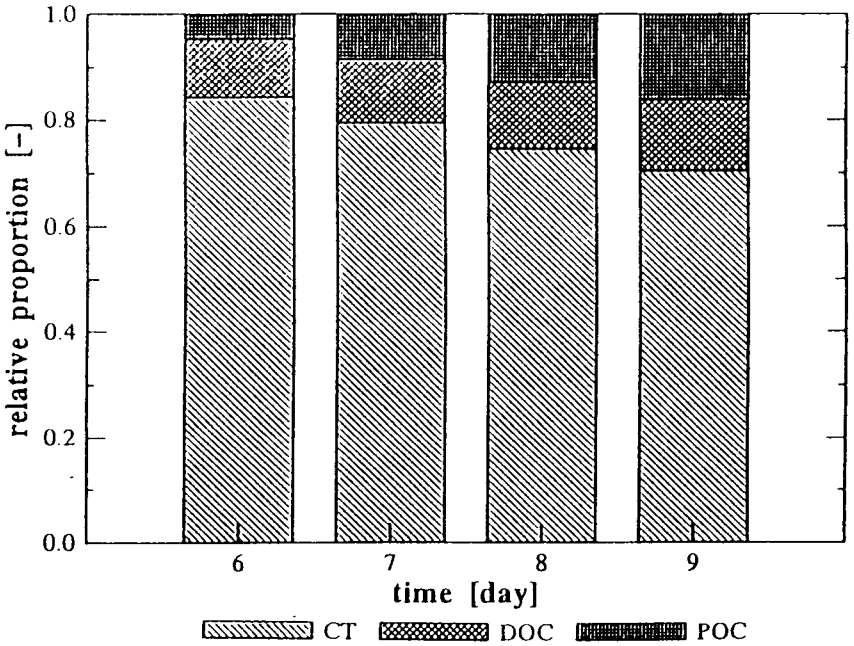

Fig. 5 Relative proportion of C_T, DOC, POC

according to the growth of C. antiqua. It was found that 17% of assimilated C_T was excreated into the sea water from the cells, and this is very important in order to understand the process of DOC production in the surface layer of the ocean.

The growth rate decreased from μ = 0.68 d^{-1} to μ = 0.11 d^{-1} in 9th day (Fig. 1). The concentrations of [$H_2CO_3^*$] and [HCO_3^-] in 9th day were > 1 μM and ca. 900 μM in 9th day, respectively, and therefore, it was suggested that the cells of C. antiqua utilized [$H_2CO_3^*$] as carbon source. The utilization of [$H_2CO_3^*$] or [HCO_3^-] is highly phytoplankton species dependent and therefore ocean carbon cycle is controlled by phytoplankton succession. The large axenic culture tank is useful to understand the ocean carbon cycle which is controlled by marine ecosystem.

Reference

Dickson, A. G. and Goyet, C. (1991) : Handbook of methods for the analysis of the various parameter of the carbon dioxide system in sea water. Version 1.0, U. S. Department of energy, Special Research Grant Program 89-7A.

Mackinnon, M. D. (1981) : The measurement of organic carbon in sea water. In E. K. Duursma & R. Dawson (eds.) Marine organic chemistry. El sevier Scientific Publishing Company, Amsterdam, Netherlands, 415-443.

Murphy, J., and J. P. Riley, 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chem. Acta 27 : 31-36.

Sarmiento, J. I. & Toggweiler, J. R. (1984) : A new model for the role of the oceans in determining atmospheric PCO_2. Nature, 308, 621-624.

Toggweiler, J. R. & Sarmiento, J. L. (1985) : Glacial to interglacial change in atmospheric carbon dioxide : the critical role of ocean surface water in high latitudes. In : Geophysical Monograph 32. American Geophysical Union, 163-184.

Watanabe, M., Kohata, K. & Kimura, T. (1991) : Diel vertical migration and nocturnal uptake of nutrients by Chattonella antiqua (Raphidophyceae) under stable stratification. Limnol. Oceanogr. 36, 593-602.

Watanabe, M., Kohata, K. & Kunugi, M. (1988) : Phosphate accumulation and metabolism by Heterosigma akashiwo (Raphidophyceae) during diel vertical migration in a stratified microcosm. J. Phycol. 24 : 22-28.

Publication

Watanabe, M. (1992) : Experimental Marine Ecosystem in the Ocean. Nikkei Science vol.22, (5) : 20-25.

Watanabe, M., Kohata, K. & Kimura, T. (1991) : Diel vertical migration and nocturnal uptake of nutrients by Chattonella antiqua under stable stratification. Limnol. Oceanogr. 36 : 593-602.

Fujimori, Watanabe, Kohata, Sato and Ishikawa (1992) : Modeling of Chattonella bloom (I). Proceedings. Oceanogr. Soc. Japan.

Ito, Higasi, Kunugi and Watanabe (1992) : Measurement of DMS in phytoplankton cells and medium in large scale culture. Proceedings. Oceanogr. Soc. Japan.