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High photosynthetic activity in a continuous culture system of filamentous diatom caused by continuous harvest

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ABSTRACT: A high net production of filamentous diatom (*Melosira varians*) was maintained by continuous harvest. In the culture box, a part of the algal mat on the bottom floated by the formation of oxygen bubbles within the algal mat due to photosynthetic activity. Two types of culture boxes: harvest boxes of floating algal mat and: non-harvest boxes were used to determine the effect of a continuous culture system. There was a slow downwards current with water of the culture system. The production rate was checked by the oxygen production rate in the culture systems of filamentous diatom. Oxygen production rate per unit area was measured by the current rate and the difference of dissolved oxygen in the inflow water and the outflow water. In the daytime, a high production rate of oxygen was observed in the harvest boxes in comparison with the non-harvest boxes. However, the respiration rate in both boxes in the nighttime was shown to have a similar value. The difference in the oxygen production rate was caused by the continuous harvest. This treatment allowed much more solar radiation to reach the young diatom cells on the bottom.

Key Words: High net production, Continuous harvest, Filamentous diatom, Oxygen production rate.

Introduction

A model of a continuous culture system of filamentous diatom, *Melosira varians*, was made which was based on an area of the dry riverbed of the River Chikuma. In the riverbed, clean sub-surface water seeps out. In the resulting pool, a filamentous diatom of *M. varians* is commonly observed. This diatom is the food most favored by fishes and insect larvae.

The following is an outline of a culture system for filamentous diatom. The surface water is pumped up from an irrigation channel. A sedimentation trap and roughing filters trap suspended matter in the water. Filtered water was introduced to the culture boxes. Filamentous diatom of *M. varians* grew in these boxes. It formed an algal mat on the floors of the boxes. Bubbles were produced in the mat by photosynthesis. Thus, floating algal mats were observed.

It is then easy to harvest this floating algal mat. This harvested algae is the real net production in this system and it is possible to use this algae as good food for fishes. This system is one of the best production systems for fish populations.

It would be possible to harvest floating algae every day during the experiment. By measuring the daily harvest, the net production may be obtained. It is necessary to make clear that the reason of the possibility of continuous harvest in the culture system. We made two types of culture systems: daily harvest system and non-harvest system. The production mechanisms in both systems were considered. The production rate of chlorophyll in comparison with the oxygen production rate in culture systems of filamentous diatom was discussed.

Apparatus and Method

The culture experiment was done during 35 days from September 20th, 2001 to October 25th, 2001. The surface water was pumped up from an irrigation channel in Ueda city, Japan. The irrigation channel was connected to the river Chikuma (the longest river in Japan). A sedimentation trap, made using a bucket and a roughing filter, trapped suspended matter in the water. The filtered water was introduced into the culture boxes. The boxes were plastic containers (30 cm width, 45 cm length and 26 cm height) in which there was gravel on the bottom. The water from the roughing filter entered the culture boxes and the water flow in the boxes was downwards. The water depth was about 10 cm and the water current speed was kept at about 20 cm per hour. Filamentous diatom of *M.varians* grew in these boxes and formed an algal mat on the bottom. Bubbles were generated in the mat by photosynthesis, and thus floating algal mat was observed. Six culture boxes were used. In all of the boxes, floating algal mat was observed. In 3 of the boxes, floating algal mat was harvested (Harvest Box), and in the other boxes, floating algal mat was not harvested (Non-harvest Box). In the harvest boxes, floating algae was harvested every day. In contrast, the floating algal mat was not harvested in the non-harvest boxes.

Sampling: Samples and harvests were taken every morning at 9:00. The biomass of the samples was measured every other day. An algal mat sampler was use for quantitative sampling of the algal mat in the box (Nakamoto 1993). Random points were chosen in each box and samples ware extracted. The extracted sample was brought back to the laboratory. The amount of chlorophyll and the number of cells in the extracted sample was measured. Part of the sample was filtered through glass fiber filter paper (Whatman GF/C). The amount of chl.*a* per unit area was measured as an index of the biomass. The chl.*a* was dissolved in acetone to allow the amount of chl.*a* to the measured. A part of the sample was use to count the number of cells. In the harvest boxes, all of the floating algal mats were collected everyday using a tea strainer. The harvested sample matter was weighted (wet and dry) and cell number and chl.a content were measured.

Oxygen production rate: The difference of photosynthetic activity between the two types of culture boxes was compared to show the effects of harvesting. The production rate of chlorophyll was compared with the oxygen production rate in culture systems of filamentous diatom. The concentration of oxygen dissolved in water was measured by the Winkler method on the 11^{th} day after the start of harvesting (the 25^{th} day of the run days). From 5:00 a.m. to 7:00 p.m. the next day, dissolved oxygen concentration was measured every 2 hours. Oxygen production rate per unit area was measured by the speed of the water current and the difference in the concentration dissolved oxygen in the inflow water and in the outflow water.

Oxygen production rate ($g \cdot m^{-2} \cdot h^{-1}$) = (DO out($g \cdot m^{-3}$) − DO in ($g \cdot m^{-3}$)) × V ($m \cdot h^{-1}$)

Results

Environmental conditions

The environmental conditions were same for each box. The average temperature of inflow water was 14.7°C and the average radiation was 9.35 MJ m^{-2} d^{-1}. The concentration of nutrient in the inflow water was NO_3-N 2.12 mg l^{-1} and PO_4-P 0.05 mg l^{-1}.

Biomass

The biomass of both culture types was almost the same amount per unit area. Exponential growth of algae was observed during the initial 2 weeks. Then, drastic changes of the growth rates were observed in both systems. An remarkable of algal mat was observed after 10 days.

The floating algal mat was checked in all of the culture boxes from the 14th day of the run days (Fig.1). In the harvest boxes, the floating algal mat was completely harvested everyday after the 14^{th} day. The floating algal mats in the other boxes were not harvested. The biomass in each box became almost constant. The average daily harvest was 48 mg chlorophyll a per m2. This amount was the real daily net production. However, there was no significant difference in the biomass of either system (excluding the biomass of the harvested algae). This means that the net production in the Non-harvest box was zero (Fig.2).

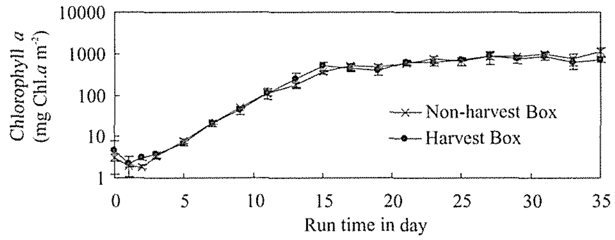

Fig. 1. Change of amount of chlorophyll *a* per unit area in the two culture types of filamentous diatom.

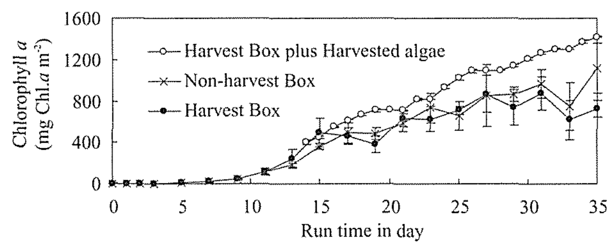

Fig. 2. Change of amount of chlorophyll *a* in the culture systems of filamentous diatom and the integrated mass of harvested algae.

Photosynthetic activity

The photosynthetic activity was checked by measuring the oxygen production rate during the 11^{th} to 12^{th} day after the start of harvesting. Sunrise was at about 5:00, and sunset was at 18:00. The photosynthetic activity in the daytime in the harvest boxes is higher than that in the non-harvest boxes. However, the respiration rates at nighttime in both systems were the same (Fig.3).

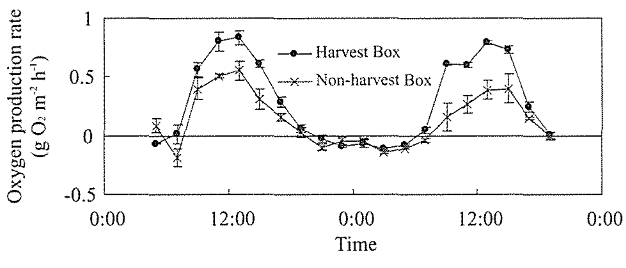

Fig. 3. Change of the oxygen production rate on the 11^{th} and 12^{th} day after the start of harvesting (25^{th} and 26^{th} days of the run days).

Discussion

The high net production was maintained by the daily harvest of the floating algal mat in the harvest boxes. This harvest matter was the real net production. However, there was no net production in the non-harvest boxes. This positive net production in the harvest boxes was induced by the daily harvest. We have confirmed that net production is the respiration value subtracted from the gross production value.

[Net production = Gross production − Respiration]

The purpose of this experiment was to clarify the significance of the harvest treatment. There was photosynthetic activity in the both systems. We considered the production rate of chlorophyll in comparison with the oxygen production rate in culture systems of filamentous diatom. There was same amount of solar radiation in both systems. In order to get small net production, two hypothesis of the daily change in oxygen production were considered. Hypothesis 1: There might be the same photosynthetic activity in both systems. The gross production rate in the Non-harvest Boxes is the same value as that of the Harvest Boxes. The size of the fluctuation of the gross production is the same. However, the respiration rate in the Non-harvest Boxes is larger than that in the Harvest Boxes. Hypothesis 2: Photosynthetic activity in the daytime in the Harvest Boxes is higher than that in the Non-harvest Boxes, but the respiration rates at nighttime in both systems were the same.

We checked the photosynthetic activity by the oxygen production rate during the 11^{th} to 12^{th} day after the start of harvesting. We confirmed that there was a difference in the amount of photosynthesis in the daytime, and the respiration rate at nighttime is almost the same in both systems. Because the gross production rate in the non-harvest boxes is not the same value as that of the harvest boxes, hypothesis 1 is incorrect. However, hypothesis 2 is correct because photosynthetic activity in the daytime in the harvest boxes is higher than that in the non-harvest boxes, but there were the same respiration rates at nighttime in both systems. We infer that the high photosynthetic activity was maintained by the continuous harvest of floating algae in the culture system of filamentous diatom. Harvesting treatment gives good light conditions to the young cells in the box. In the non-harvest boxes, solar radiation is not fully utilized as the floating algal mat on the surface reflects some of the solar radiation. Thus the floating algal mat shades the young cells in the box.

Higher net production resulted from the higher photosynthetic activity in the harvest box. Due to the daily harvest, the net production became a higher portion of the gross production.

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