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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 9 (6): 1043-1046, 2006
ISSN 1028-8880

A Pilot-scale Unit for Suspended Cultivation of *Gracilaria gracilis* in Izmir Bay, Aegean Sea-Turkey

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Abstract: A metal frame with dimensions of 1×1×1 m for the suspended cultivation of *Gracilaria gracilis* (Stackhouse) Steentoft, Irvine and Farnham was settled in shallow water in Inciralti in Izmir Bay. The alga was tied by sixteen ropes just below the surface of the water (0.1-0.2 m), at mid depths (0.6-0.7 m) and near the bottom (1.1-1.2 m). The total of 16 plants were measured weekly from July 28th to October 20th 2002. Water temperature, dissolved oxygen, nitrate, nitrite, ammonia, orthophosphate and silica were also analysed. The healthy growth of algae was observed only at mid depth. The plants near to the surface died because of waves, water level fluctuations or direct sunlight. *Gracilaria* suspended near to bottom was lost, consumed by fish or bleached and died after two weeks. Relative growth rates varied from 8.2 to 0.96% day^{-1}. At the end of the experiment, mean individual weight of plants reached to 9.3 g.

Key words: *Gracilaria gracilis*, seaweed, cultivation, growth, Aegean Sea

INTRODUCTION

There is an increasing demand for *Gracilaria* species because of their importance for producing agar. Gracilarioid seaweeds contribute to more than half the world's agar production (Fletcher, 1995). *Gracilaria gracilis* is widely dispersed in areas in Argentina, Egypt, France, Indonesia, Italy, South and North Korea. This species is also reported on the Mediterranean, Aegean Sea and the Black Sea (Ketchum, 1983; Rotem *et al*., 1986). The biomass of *Gracilaria* was around 4 kg wet weight m^{-2} of the natural beds in Izmir Bay in the 1990's (Ercan, 1995). *Gracilaria* has been collected commercially and exported from Turkey for the agar industry. Because *Gracilaria* beds are subjected to increasing exploitive pressure, the harvesting of the plants has been prohibited between April and July 15th along the Turkish coast.

The natural biomass of agar-producing plants is declining and therefore there is a high demand for raw material and cultivation of agarophytes to supplement the harvest of natural plants may be a practical solution. Gracilarioids are cultivated in Chile, China, Taiwan, Namibia and South Africa (Critchley and Ohno, 1998; Wakibia *et al*., 2001). The cultivation of *G. gracilis* has been shown to be technically feasible using suspended rafts, ropes and netting lines in a bay at about 5 m depth in South Africa (Anderson *et al*., 1996).

Suspended cultivation has some advantages over bottom stocking, such as surface harvesting and easy control. In several studies, floating rafts were used and plants were attached on ropes hung on the rafts (Dawes, 1995; Anderson *et al*., 1996). In this study, we have adopted a new fixed type metal frame for hung the ropes with attached plants at different depths in shallow water column. This pilot-scale unit was settled to a natural *Gracilaria* bed. Therefore, the aim of this study was to evaluate the growth rates and biological feasibility of *G. gracilis* cultivation in the pilot-scale unit in a shallow bay.

MATERIALS AND METHODS

Because natural beds of *G. gracilis* are found in Inciralti in Izmir bay, it was selected as the planting area. The bay of Izmir is one of the largest bays of the Turkish Aegean coast. It extends about 24 km in the east-west direction and its average width is about 5 km. It is roughly L-shaped. From the standpoint of its topographical and hydrographical characteristics, the bay consists of three sections: the inner bay, the middle bay and the outer bay.

A metal frame of 1×1×1 m dimensions was constructed and settled underwater in an area of sandy bottom in inner bay around Inciralti (Fig. 1). Natural plants were collected and 10 cm lengths of 48 healthy plants

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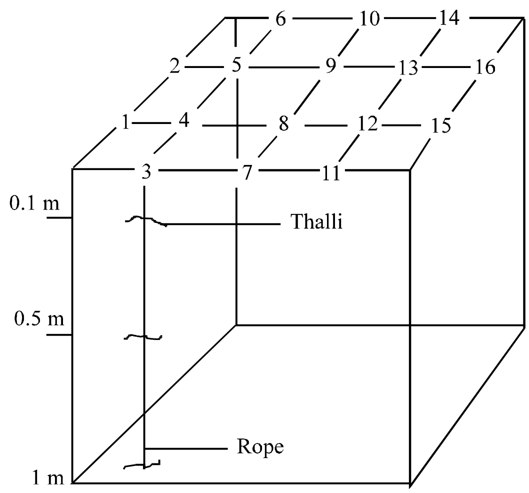

Fig. 1: The experimental design of metal frame, ropes and suspended plants

were tied to sixteen ropes under the surface of water (0.1-0.2 m), at mid depths (0.6-0.7 m) and in deep water (1.1-1.2 m). All healthy plants were examined every week from July 28th to October 20th. The plants were cleaned, washed thoroughly with sea water to remove epiphytes and sediments and weighed. Relative growth rate (RGR) was also calculated according to Anderson *et al*. (1999). The appearance of sporelings was recorded.

Measurements were made of water temperature (0.1°C sensitive electronic thermometer), dissolved oxygen (Winkler) and pH (pH paper) *in situ*. Salinity was determined by the Mohr-Knudsen method. Concentrations of nitrate, nitrite, ammonia, orthophosphate and silica were analysed by spectrophotometric methods using a Hach-DR2000 UVD model spectrophotometer (Strickland and Parsons, 1972). Statistical analysis was carried out by using Minitab for Windows.

RESULTS

In the study period, water temperatures were high with relatively small fluctuations. It slightly increased from July to October. Water temperature and wet weight of healthy plants had a significant correlation (r = 0.64). The values of dissolved oxygen showed monthly variations (Fig. 2). pH values did not vary dramatically and changed between 7.2 and 7.4.

The salinity varied between 39.7 and 40.3‰. Water depth showed recordable fluctuations (Fig. 2). The plants close to the surface (0.1-0.2 m) died as a result of waves, water level fluctuations or direct sun light. Also, the plants suspended at 1.1-1.2 m (near to the bottom) were subjected to epiphytism, consumed by fish, or affected by current and sedimentation. Opportunistic algae like *Ulva* spp., *Polysiphonia* spp. and filamentous blue-greens were observed on the ropes but they were collected regularly every week. The only healthy growing plants were the ones suspended at a depth of 0.6-0.7 m. These plants showed a detectable growth during the research period. There were cystocarpic plants in August-September and they reached maximum abundance in October.

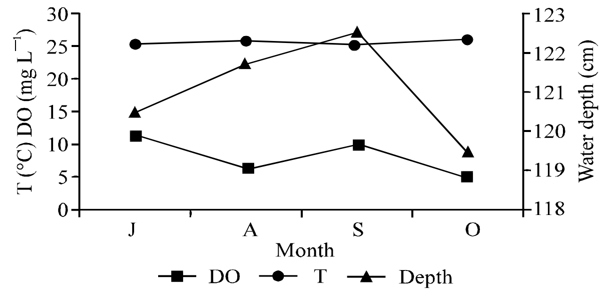

Fig. 2: Changes in water temperature, depth and dissolved oxygen

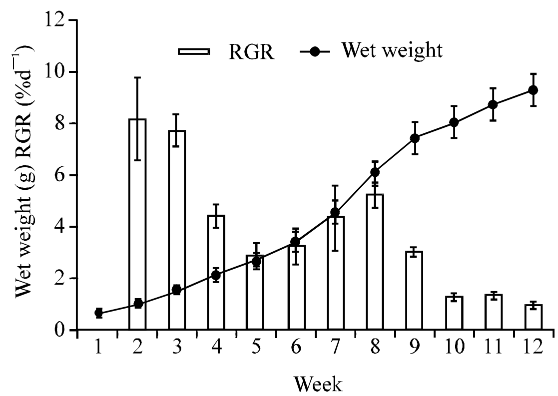

Fig. 3: Mean wet weight and relative growth rates (±standard error) of *Gracilaria gracilis* grown in suspended cultivation unit in Inciralti (Izmir bay), from July 28th to October 20th (n = 16)

The mean value of wet weight was measured as 0.65 g at the beginning of the experiment (Fig. 3). Wet weight varied significantly ($p<0.01$) by time, reaching a maximum of 16.33 g (9.31 g, mean value) in the 12th week. The maximum relative growth rate (RGR) was measured as 8.2% day^{-1} in the first week (Fig. 3). RGR decreased gradually, to a level that was very low (0.96% day^{-1}) in the 12th week, in October. ANOVA showed significant differences in RGR values by time ($p<0.01$). The water temperature was still high and nutrient levels were not low in October. The concentrations of orthophosphate,

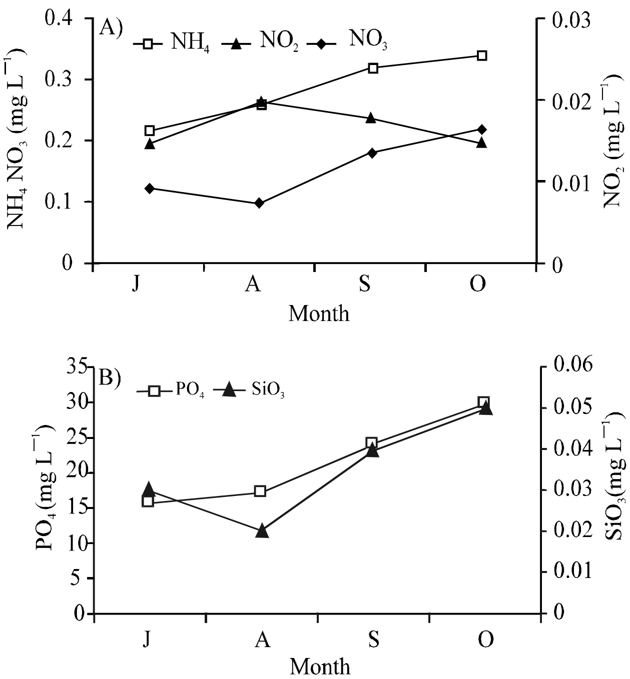

Fig. 4: (A) Changes in ammonia, nitrate and nitrite concentration (B). Changes in orthophosphate and silica, from July to October

nitrate, ammonium and silica increased during the research period (Fig. 4). The metal frame was settled in shallow water, no major difference was observed between surface and bottom water temperatures, an indication of a generally mixed water column. A reason for decreasing RGR might be decreasing transparency resulted from phytoplankton growth or increasing epiphytism in shallow areas.

DISCUSSION

The *Gracilaria* grew well in July-October, because water temperature was rather high and there was a significant correlation between wet weight of *Gracilaria* and water temperature. A direct relationship between the increase in water temperature and the biomass of *Gracilaria* became evident (Pizarro and Barrales, 1986). Growth of *Gracilaria* is generally highest in the summer when the water temperatures and daily irradiance are highest (Bird and Ryther, 1990). But RGR of *Gracilaria* decreased in October while the water temperature and nutrient levels were higher than those in July. However, it is unlikely that high temperature reduced growth because the optimum temperature for *Gracilaria gracilis* growth is 25°C as shown by Engledow and Bolton (1992). Rather, low growth was unlikely to be as a result of low nutrient levels, because of the mixed water column, there was no nutrient starvation. Low growth was typical for the autumn in the experiments carried out by Anderson *et al.* (1996) in a bay at 5 m depth and was ascribed to variable and weak winds, little water movement and low ambient nitrogen levels. In our study, because of the shallowness, there was a mixed water column and nitrogen and phosphate levels were still high in October. But we observed dense phytoplankton growth which causes low light intensity. The low growth in October was partly due to high epiphyte contamination as it was also reported by Wakibia *et al.* (2001).

The salinity values changed between 39.7 and 40.3‰ in the study. It was reported that the growth of strain-16 *G. gracilis* is generally highest in salinities of 25 to 33‰ with median temperatures ranging from 23 to 29°C (Daugherty and Bird, 1988). Salinities higher than 36‰ are reported to cause stress in *G. tikvahiae* McLachlan (Hanisak, 1987). In our study, higher salinity might be a growth limiting factor. However, there are natural beds of *G. gracilis* in the same area.

The best results were taken from the plants suspended at 0.6-0.7 m depth. The plants suspended near the water surface and near the bottom were died by sunlight, affected by waves or current, subjected to epiphytism or fish consumption. Ren *et al.* (1984) reported that strong sunlight had a detrimental effect on algae on floating rafts. It is hypothesized that epiphytes compete with *Gracilaria*, being involved in light decrease, nutrient and inorganic carbon consumption and tissue damage to their host (Friedlander and Levy, 1995).

We used a fixed pilot unit for suspended cultivation in shallow waters. The growth rates of *Gracilaria* in our study were comparable to those recorded under some aquaculture regimes (Penniman *et al.*, 1986; Anderson *et al.*, 1999; Wakibia *et al.*, 2001), but were less than others (Wang *et al.*, 1984; Nelson *et al.*, 2001). Growth rates of *Gracilaria* cultivated in Taiwan were highest between July and November (Yang and Wang, 1983). RGR varied from 8.8 to 1.8% day^{-1} of cultivated *Gracilaria* in shrimp pond effluents in Brazil (Marinho-Soriano *et al.*, 2002).

The mean biomass of plants reached to 9.31 g in October and they were harvested. According to our findings, the best time to harvest is when the RGR is low. The control and collection of the plants were relatively easy in pilot unit. The best harvest period for the alga was reported as summer when the biomass, agar content and gel strength are close to their maximum (Givernaud *et al.*, 1999). Growth of *G. multipartita* (Clemente) Harvey were maximum in spring and autumn and the seaweed partially decayed after its maximum fertility was reached in June and October along the Atlantic coast of Morocco (Givernaud *et al*., 1999).

The present study demonstrates that suspended cultivation of *G. gracilis* in shallow natural beds is feasible in Izmir Bay and that there is potential to improve yields by technical research for replenishment of natural stocks.

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