A preliminary study of raft cultivation of *Gracilaria verrucosa* and *Gracilaria sjoestedtii*

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Introduction

The ever-increasing demand for *Gracilaria* as a source of agar has attracted wide interest in this genus and has prompted research efforts directed at finding feasible means of artificial cultivation. Efficient, economically feasible cultivation of *Gracilaria* in shallow ponds has already been achieved in Taiwan (Shang 1976). Now, on the coast of northern China, long famous for its large-scale cultivation of seaweeds such as *Laminaria* and *Porphyra*, experiments are in progress to estimate the potential productivity of *Gracilaria* in raft cultivation.

Materials and methods

The species investigated were *Graciliara verrucosa* and *G. sjoestedtii*. Experimental raft cultivation was patterned on that used locally for *Laminaria* (Tseng 1981). Fragments of *Gracilaria* 10–15 cm long and weighing less than 1 g were affixed to cultivation ropes 1.2 m long. Initially, inocula were spaced at 20-cm intervals, 7 per rope, and ropes were suspended on the rafts at a density of 3 per m. Later, intervals of 5 and 10 cm for inocula were tried. Fragments were outplanted on the rafts at about 2-wk intervals, from March 23 to May 6. Temperature was monitored during the experimental period until harvest in July, when plants were weighed or measured, and differences due to depth or transplant density were noted.

Results and discussion

Growth in nature vs. cultivation. Gracilaria verrucosa and *G. sjoestedtii* of various sizes and developmental stages can be collected on the seashore of Qingdao year-round, whereas *Gracilaria* cultivated on the raft had a shorter growing season. Only under temperature conducive to a considerable growth rate could outplanted fragments of *Gracilaria* be cultivated successfully. At lower growth rates, the fronds would be covered by contaminants such as epiphytic diatoms and macrophytes, further inhibiting the growth of *Gracilaria* and ultimately causing disconnection from the rope. In the suitable season, however, the growth rate of *Gracilaria* on the floating raft was apparently higher than on the shore. Generally, a fragment after two months of cultivation would be about 50 cm long and weigh 55 g, with possible maxima of 1.4 m length and 170 g weight, which *Gracilaria* has never been found to achieve in the intertidal zone in Qingdao.

Growing season of G. verrucosa and G. sjoestedtii. Gracilaria verrucosa grew at a temperature range of 8–21 °C, the optimum range being 12–20 °C which at Qingdao occurs from the beginning of May to the middle of June (Fig. 1). The average growth rate was 29 g fresh wt m^{-1} d^{-1} with a maximum of 49 g m^{-1} d^{-1}. For *G. sjoestedtii*, the growing season was divided into spring and autumn phases, with respective temperature ranges of 14–24 °C and 24–8 °C. The corresponding optimum temperature ranges were 16–23 °C and 24–14 °C, or, from the end of May to mid-July and from late September to late November. The average growth rate of this

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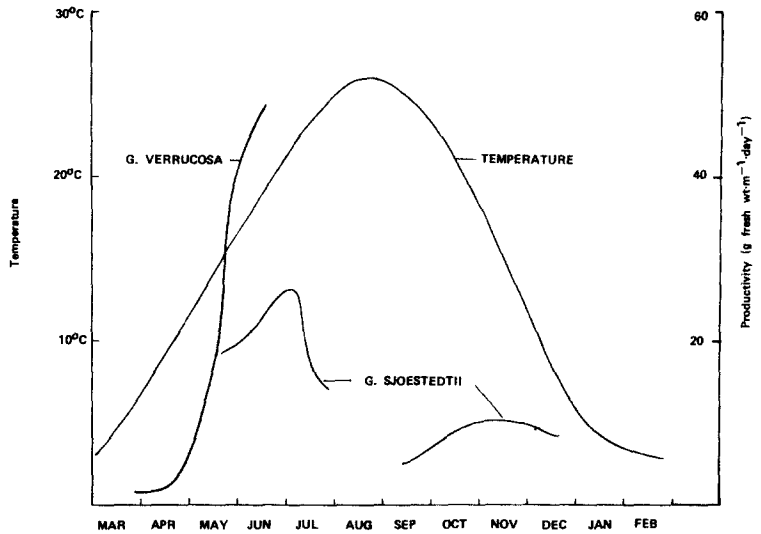

Fig. 1. Growth of *Gracilaria verrucosa* and *G. sjoestedtii* relative to season and sea temperature.

species was 19.5 g m^{-1} d^{-1} in spring and 10.4 g m^{-1} d^{-1} in autumn, with a maximum of 27 g m^{-1} d^{-1}.

Effects of transplanting time on overall growth. As shown in Figure 1, the growth rates of *G. verrucosa* and *G. sjoestedtii* varied with temperature. To establish the most favorable time for transplanting sporelings, *G. verrucosa* fragments transplanted at different times but harvested at the same time can be compared (Table 1). Even in the season of active growth, it was not true that early transplanting and a longer growth period would ensure a good harvest. On the contrary, of three sets of plants harvested on the same day, the thalli transplanted on April 21 were heavier than those transplanted on March 23 and April 9. The growth rate of the fourth set, which was transplanted in early May and harvested on June 16, was markedly higher than any other group, which indicated that this period is the most favorable for cultivating *G. verrucosa*. The reason for inferior overall growth in earlier transplants was not only suboptimal temperature at the time of transplanting, but also the tendency of epiphytic species to attach to the thalli during this initial period of slow growth. Plants thus contaminated were unable to grow well even when the temperature later became optimal for growth. Therefore, it is advisable to transplant inocula only when temperature is conducive to rapid growth, to ensure comparatively higher production in a shorter period.

The growth rate of G. sjoestedtii *at different depths.* Because of the suspended cultivation method being used, it was necessary to examine the growth rate at different depths. From the mean thallus weight of *G. sjoestedtii* on the culture ropes (Table 2), it was evident that no significant difference in growth with depth occurred from 0.2 to 1.2 m. Except for a slight increase in the growth of plants at the surface,

Table 1. Comparisons of growth of *G. verrucosa* sporelings transplanted at different times.

Transplant		Harvest			Increase/day
Date	Temperature (°C)	Date	Temperature (°C)	Mean fresh weight (g) of plants	
23.iii	6	3.vi	17	15.4	0.20
9.iv	8	3.vi	17	19.0	0.33
21.iv	10	3.vi	17	21.1	0.47
6.v	12.5	16.vi	19	59	1.47

Table 2. The growth of *G. sjoestedtii* at different depths, as mean fresh weight (g) of plants.

Experiment period	Depth (cm)						
	Surface	20	40	60	80	100	120
10.iv–14.vii	78	37	55	50	57	93	85
24.v –14.vii	115	40	75	48	45	47	47
10.vi–14.vii	38	45	32	55	31	33	21
Average	76.8	53.3	54.0	51.0	46.0	64.7	51.0

Table 3. Comparison of length (cm) of *G. verrucosa* plants cultivated at different densities.

Observation date*	Interval		
	20 cm	10 cm	5 cm
26.iv	18.0	19.4	13.6
11.v	27.7	32.9	25.6
30.v	40.4	47.7	36.1

* Experiment started on 10.iv, inocula 10 cm long.

this experiment showed that light intensity was not a limiting factor at depths to 1.2 m.

Growth of G. verrucosa *at different densities.* Effects of density and depth are still subjects to be studied further. In Table 3, the thallus lengths obtained by *G. verrucosa* at different densities are compared, viz., 7 fragments of *G. verrucosa* attached to each growing rope at 20-cm intervals, 13 fragments at 10-cm intervals, and 25 fragments at 5-cm intervals. The interval of 10 cm produced the best growth, 20 cm the next, and 5 cm the worst. The weakness of this experiment was that only the length of frond and not the weight was measured. Nevertheless, it was confirmed that the pre-assigned interval distance of 20 cm was not the most desirable one and the closer planting was sure to increase production. It was also seen that the closer planting can prevent epiphytic algae from attaching.

After over one year of experiments, the average production of *Gracilaria* at suitable temperatures is as follows: 20 g of inoculum of *G. verrucosa* applied to each meter of floating raft will produce up to 1239 g in 1.5–2 months; the same amount of *G. sjoestedtii* will yield 1176 g in the spring growth period, 861 g in the autumn growth period. If the two species are cultured in sequence for 5–6 months, a total annual production of 3.3 kg fresh wt m^{-1} can be obtained from an original inoculum of only 60 g. This productivity is somewhat similar to that of *G. edulis* in India (Raju & Thomas 1971), although the cultivation periods are different. The harvest of 3.3 kg m^{-1} of *G. verrucosa* and *G. sjoestedtii* is produced in about six months, whereas the yield of 3.5 kg m^{-1} of *G. edulis* required about eleven months in India. The advantage of this is that it is possible to obtain higher production in a shorter period without the need for special management and elimination of weeds, therefore saving both time and labor.

Algae farmers can either cultivate these two species of *Gracilaria* sequentially according to growing season or interplant with other seaweeds. In Qingdao, taking the growing seasons into consideration, raft culture of *Laminaria* can alternate with that of *G. sjoestedtii.* The growing season for *Laminaria* extends from December to harvest in May, which is about the time for planting *G. sjoestedtii* for harvesting first in late July and again in November. After *G. sjoestedtii* has been harvested, it is about time to plant *Laminaria* again. In China we have a sound base for *Laminaria* culture. If *Laminaria* can be cultivated alternately with *Gracilaria*, production efficiency will be enhanced and cultivation will be economically profitable.

References

Raju, P. V. & P. C. Thomas, 1971. Experimental field cultivation of *Gracilaria edulis* (Gmel.) Silva. Bot. mar. 16: 71–75.

Shang Y. C., 1976. Economic aspects of *Gracilaria* culture in Taiwan. Aquaculture 8: 1–7.

Tseng C. K., 1981. Marine phycoculture in China. Proc. int. Seaweed Symp. 10: 123–152.

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