SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

PRESENT STATUS OF GRACILARIA CULTURE

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ABSTRACT

Species selection for high agar yield and culture site evaluation arc the most crucial factors in seaweed farming for agar production. Seeds can be made available from either vegetative propagules or natural spore recruitment or induced spore-shedding in hatcheries. Gracilaria verrucosa, with high production rates and good gel quality, is preferred in pond culture due to its ability to adapt to a wide range of ecological conditions. Given optimum conditions, harvest of pond cultured *Gracilaria* may take place two to three months after seeding. Long line. raft method and substrate improvement are some of the methods applied in field cultivation.

1. Introduction

The increasing demand for agar, agarose and agaropectin is primarily due to the development of new applications of these seaweed products in the food industry, in specialized laboratory methods such as immunodiffusion, diffusion and chromatography techniques, bio-engineering, microbiology and biochemistry. A stable source of raw materials for the manufacture of these seaweed products is essential to meet this increasing demand.

At present, there are two major sources of tropical species of agar-producing seaweeds, namely from gathering natural stocks and from farming/culturing of these species. Production through gathering of natural stocks depends on the availability of harvestable stocks; this is greatly influenced by seasonal changes in the weather (monsoons) which in turn make supply seasonal. In addition, production is highly influenced by the harvest pressure of the previous season. These factors lead to a tendency for production from natural stocks to be unreliable. Production through culturing is more predictable and stable, and targeted outputs are easily attained. Cultivation entails man's intervention in the process of production. It involves a wide range of techniques, from the simple management of natural stocks to the complex propagation of selected clones and genetically bred hatchery seedstocks in capital intensive situations (Neisch 1978).

2. Considerations in the selection of species and sites for culture

The following points are important when considering the selection of species to be used and sites for culture:

a) The species targeted for culture must be fast growing and capable of being propagated utilizing vegetative propagules (cuttings) or spores. Species with large and robust thalli are preferred because they can produce a large amount of biomass within relatively short cropping periods.

b) It must have a high content of good quality agar. These considerations require that the available species be screened. Comparative studies on their productivity should therefore be conducted to determine the species to be selected. Because the properties of agar (gel strength. gelling and melting temperatures, amount of sulfate groups) differ among species, it is essential that the correct name be applied. Thus the taxonomy of the species should be clarified. The names are indices to the type and quality of agar that the Gracilaria contain and are used as the basis for determining prices.

c) The selection of sites is a very important factor to consider in both pond and field culture, because this will ultimately determine the success or failure of the farming venture. In general, sites which support natural stocks of the species to be cultured are good sites. If culture is planned in an area where no stock of the chosen species exists, then one should select sites which have ecological conditions comparable to the site where the stocks are found. This requires the gathering of data on parameters such as salinity ranges, nutrient (i.e. nitrate and phosphate} levels, turbidity, and type of substrate. Other ecological parameters such as degree of exposure to waves, depth of the water and accessibility should also be included in the evaluation of sites.

Natural Gracilaria stocks are generally found in areas which are characterized by calm water. high nutrient levels and shallow areas with sandy-muddy substrates. Sites for field culture should be located in areas which are protected from waves since Gracilaria have fleshy and fragile thalli and are therefore easily removed or broken by wave action. Species which are found in commercial quantities generally grow quite well in slightly brackish and highly fertilized waters, thus protected bays and lagoons are preferred. In tropical areas, *Gracilaria* species with a high potential for culturing are also found on reef, sandy flats, sandy, rocky and wave-exposed areas.

3. Production of Seeds

The term “seeds” as used here refers to both the vegetative propagules (cuttings) and spores which can he utilized as planting materials. The importance of the availability of a local source of seed materials is emphasized. These seedstocks may come from natural stocks or from cultivation. Gracilaria exhibits triphasic alternation of generations consisting of the gametophyte, sporophyte and carposporophyte. The latter, however, is microscopic and is parasitic on the female gametophyte. Thus, the large somatic stage consists of the gametophyte and the sporophyte. The results of studies on the populations of these two generations have shown that the sporophytes are generally more dominant than the gametophytes, i.e. they are usually larger in size and the population makes up the bulk of the biomass. It has also been shown that under pond culture conditions the alga may not develop reproductive stages. These factors are relevant in the selection of the type of “seeds” to be used in culture.

1. *Vegetative propagules (cuttings)*

Healthy stocks are selected for this purpose. They should have thalli which are fleshy and elastic in texture, dark reddish brown in colour, and are robust, well-branched with smooth and shiny surfaces. In addition, they must be clean, i.e. free from dirt and epiphytes. The preparation of the “seeds” varies according to the type of culture used, and these are described in appropriate sections of this paper.

2. *Spores us seeding material*

Two methods are presently used in the production of sporelings from spores: natural spore-recruitment and induced spore-seeding in hatcheries.

2.1 Natural spore recruitment

The use of spores as seeding materials for the production of sporelings for culture requires the availability of natural stocks. In the natural spare recruitment method artificial substrates such as ropes, rocks and netting are used. Ropes and netting are generally preferred because of their ease of handling during both the process of recruitment and cultivation. The use of ropes is a proven technique in the West Indies. The ropes are anchored or tied to wooden stakes among dense populations of Gracilaria. They are left in the area for about two weeks to allow the naturally shed spores to settle on them. The sporelings developing from the spores become visible after three to four weeks, and the seeded ropes are then transferred to the culture sites for outgrowing.

2.2 Hatchery production of sporelings from spores

The production of sporelings from spores requires skill in recognizing fertile materials, and selecting them from available stocks. Recognition of the fertile female materials is quite easy because of the highly recognizeable presence of cystocraps. These fertile structures appear as elevated mammilate “bumps” with dark coloured contents on the surface of the thalli. Cystocarps which have already shed their spores are pale in colour. In contrast the recognition of fertile sporophytic thalli is quite difficult because the tetrasporangia are microscopic and do not form apparent recognizeable structures. The use of a stereomicroscope is quite indispensable. Under low magnification, the tetrasporangia appear as dark purplish microscopic spots on the surface of the thalli. The presence of these structures has, however, to be counter-checked by examining sections of the suspected thalli under a compound microscope. The tetrasporangia are of the cruciate type and are embedded in the cortex of the thallis.

The hatchery production of sporelings requires a land-based set-up which may be sited some distance away from the outgrowing area. The set-up was first used in Penang, Malaysia. It is quite similar to those used in the seeding facilities for *Porphyra* and *Laminaria* although less sophisticated. It consists of a seeding tank with provision for control of water depth and an adjustable seeding material support structure. This structure consists of a wooden frame strung with monofilament netting material which fits into the seeding tank. It is provided with a mechanism that allows its height from the bottom of the tank to be adjusted.

Various types of substrates, e.g., pieces of gravel, shells or lines can be seeded. These materials are placed at the bottom of the seeding tank. The use of lines as a setting substrate requires an additional structure, i.e. a frame which fits the tank when laid flat on the bottom. The line may be monofilament nylon (90 lbs test as used in Malaysia), nylon braided ropes (ca. 3mm dia) or plastic tying materials. The line is wound evenly around the seeding frame, which is then placed at the bottom of the tank.

Fertile *Gracilaria* material collected from natural stocks is brought to the seeding facility. The moist materials are placed in containers, such as Styrofoam boxes provided with aeration holes, to avoid stressing which can affect the shedding and/or viability of the spores.

The fertile *Gracilaria* are then placed on the seeding support structure submerged in water in the seeding tank. The distance of the seeding materials from the seeding substrates (rocks, stones or lines in frames) should be adjusted to ensure the uniform distribution and density of the spores. The seeding materials are left in the tanks for two to three days to allow shedding of spores.

The seeded materials may be left in the tank for another one to three days to allow the spores to germinate and become completely attached to the substrates. The seeded rope is transferred to a holding tank or to a nursery area while waiting for the spores to develop into sporelings.

3. Production and selection of highly productive seedstocks

The utilization of highly productive species/strains with high quality natural product is essential for the successful farming of *Gracilaria*, or any crop for that matter. In species where it is easy to manipulate the individuals to be improved, hybridization utilizing the gametes may be the normal and logical way of improving the seedstocks. However, in *Gracilaria* and other species, where the techniques for manipulating the sexual process to produce hybrids are not well known, different methods of selection may be used.

One of these methods is species/strain selection. Different species/strains present in a natural population e.g., different species, various coloured strains, morphologically different thalli are selected. These different species/strains are then multiplied through cloning. Comparative eco-physiological studies are then conducted using these stocks. In *situ* studies on seasonality and production capacities of the various species/strains relative to changes in ecological factors such as salinity, temperature, nutrients and water movement are important in defining the field conditions which determine the productivity of the various strains, as well as the seasonal aspects of reproductive states and capacities of the various forms.

Physiological studies to determine the range in tolerance of the various species/strains to changes in ecological factors can be determined by manometric techniques using a respirometer, where the various factors can be accurately controlled. The photosynthetic/respiratory responses can be monitored under varying conditions of stress.

Analysis of the content and quality of agar in the various strains is also an indispensable tool for determining the qualities of the various strains or species as a basis for the selection of seed-stocks.

4. Methods of culture

1. Pond culture

Although several species of agarophytes belonging to the genera Gelidium, Pterocladia and Gracilaria have been reported to he produced commercially through some form of farming in several countries (such as Japan, China, Republic of Korea, Vietnam, India and the Philippines), it is in Taiwan where the production of Gracilaria through pond culture has achieved a high degree of success. Here, an annual average of 12,000 tonnes of dried Gracilaria has been produced in recent years (Chiang 1981).

As stated earlier, the genus Gracilaria is characterized by the alternation of three somatic generations. Of these, it is the macroscopic, gametophytic and sporophytic stages which are used as planting materials in pond culture. Although the reproductive potential of Gracilaria through spores is high, vegetative propagation by cuttings is used in pond culture at present because of the very high regenerative capacity of the plant and the simplicity of the method. However, hatchery-produced seedlings from spores have been demonstrated to be superior in the open field culture of Gracilaria (Doty 1986).

Of the several species of Grucilaria presently used (e.g. chordu, G. tenuistipitutu, G. edulis, G. verrucosa, G. lichenoides, G. compressa and G. giga), G. verrucosa is the most popular due to its ability to adapt to a wide range of ecological conditions in ponds, its higher production rates and better gel quality. The culture of Gracilaria started in 1962 in southwestern Taiwan. Production in ponds is primarily influenced by three ecological factors, namely salinity, light and temperature. High production is recorded during the warmer months and growth is slow during winter. High light intensity adversely affects growth, and light conditions are controlled by adjusting the water depth in the ponds. Salinity of 15 to 24 ppt appears to be optimal for growth. The increase in salinity during the summer months is controlled by the addition of freshwater, thus farms need to be located near freshwater resources.

1.1 Site selection

Successful pond culture of Gracilaria depends greatly on the selection of appropriate sites. The following criteria are recommended for the selection of pond culture sites.

- the site should be located near seawater and freshwater resources;
- the area should be protected from strong winds;
- the pond bottom should be at or near the zero tide level and have a sandy-muddy substrate;
- the pH of the water should be slightly alkaline (i.e. 8.2 to 8.7).

Gracilaria are euryhaline and can grow in brackishwater under a wide range of salinity, although 15 to 24 ppt has been found to be optimal. Rises in salinity during the sunny months due to evaporation losses (reaching values as high as 35 ppt), or falls (to as low as 8 ppt) during the rainy season are detrimental to the crop. The maintenance of optimal salinity in the ponds requires a readily available supply of freshwater and seawater. The ponds should be located in areas protected from strong winds because there is a tendency for Gracilaria to accumulate on the leeward side of the pond. The formation of thick heaps of Gracilaria in one side of the pond causes shading, which has adverse effects on growth.

Water management is greatly influenced by the tidal changes in relation to the elevation of the pond bottom. Ponds located in areas where the bottom is at, or a little above, the zero tide level are easily managed as water exchange is easy.

1.2 Culture ponds

The average size of ponds for the culture of Gracilaria is about one hectare or smaller. Smaller ponds are easier to manage than larger ones because they are less susceptible to the influence of winds. Pond management is also easier when Gracilaria is polycultured with shrimp and/or crab. Provision of entrance and exit gates facilitate proper water management.

The depth of the ponds vary from 50 to 80 cm. The bottom is generally of clayish loam, silty loam or sandy loam. It has been observed that in ponds with a sandy bottom, *Gracilaria* easily gets buried due to the effect of wind. This problem, however, could be resolved by increasing the depth of the water during windy periods. In larger ponds, wind-breaks consisting of bamboo slots are installed perpendicular to the direction of the wind to prevent the seaweed being transported to one side of the pond.

1.3 Culture method

The following method is generally followed in the pond culture of *Gracilaria*. The ponds are dried for several days, and then water is introduced. Healthy stocks (see earlier criteria) are selected as planting materials. The planting material is transported from its source to the pond site early in the morning to prevent its exposure to the sun. During long-distance transport it is frequently sprinkled with seawater, and perforated bamboo or plastic pipes are inserted into the bottom of the heap to provide aeration. The plants must be placed in the water of the pond immediately upon arrival. The planting material is then cut into pieces and is broadcast uniformly on the bottom of the pond. In Taiwan, stocking is usually carried out in April at a density of 5,000 to 6,000 kg of chopped *Gracilaria* per hectare.

1.4 Pond management

The water is maintained at a depth of approximately 30 to 40 cm above the algae. However, the depth is increased to 60 to 80 cm during the warm summer months to prevent a significant rise in the water temperature. Water depth is also increased during the cold winter months to avoid temperature drops below 8°C which are lethal to *Gracilaria*.

Frequent exchange of water is necessary to maintain the optimum temperature in the ponds. The water is changed every two to three days, when about 50 to 75% of it is drained and replaced with fresh seawater. The growth of *Gracilaria* is enhanced by adding either organic or inorganic fertilizers. In Taiwan, weekly application of urea at 3 kg per hectare was found sufficient. Fermented pig manure may be applied at 160 to 180 kg per hectare two to three days after changing the water.

1.5 Harvest and post-harvest activities

Under optimum conditions, the crop may be harvested two to three months after seeding. Cropping may be done every 10 to 40 days, either manually or by using scoop nets. The frequency of harvests is dictated primarily by the market price and the season. Approximately 30 to 40% of the biomass is harvested during each cropping. The crop is thoroughly washed in pond water to remove the silt, sand, pieces of shells and other extraneous materials such as snails and other algae. The clean *Gracilaria* is spread uniformly on bamboo screens or plastic sheets for drying. An average wet to dry ratio of 7:1 is generally attained.

Standards set by the Bureau of Standards in Taiwan for the export of dried *Gracilaria* require that the product should not contain more than 1% of mud and sand, not more than 1% shells and not more than 18% other seaweed species. Moisture content should not exceed 20%.

Dried *Gracilaria* is then packed into sacks of 100 kg weight which are either exported or sold to local processing plants. Ten to twelve metric tonnes of dried *Gracilaria* are produced in a hectare of pond.

1.6 Polyculture with shrimp and/or crab

Polyculture with shrimp (*Penaeus monodon*) and/or crab (*Scylla serrata*) is carried out mainly in Ping-tung prefecture in southwestern Taiwan. Stocking material for a hectare of farm consists of 4,000 to 5,000 kg of *Gracilaria*, 5,000 to 10,000 crabs and 10,000 to 20,000 shrimps. Crushed trash fish and snails are generally used as feed for crab. Crabs are harvested after three months, and the shrimp after four to seven months. Survival rates as high as 80% for crabs and 80 to 90% for shrimp have been documented, making this polyculture one of the most profitable aquaculture methods in Taiwan. The net income from polyculture has been shown to be three times that from monoculture.

In the Philippines a group of 40 fish farmers in Iloilo are producing *Gracilaria* in their multi-crop fish farms, using cuttings as seedstocks. Unlike Taiwan, they do not use fertilizer; instead, they allow daily water exchange by tidal flow to ensure adequate nutrient supply for the seaweed. The ease of water management is enhanced by siting the bottom of the ponds at, or slightly above, the zero tide level. Problems with water management are encountered when ponds are located away from both fresh water and sea water sources, and where the level of the bottom of the ponds is way above the zero tide level making water changes a major problem. In such ponds water changes can only be facilitated during extreme high tides, and maintenance of adequate nutrient levels and control of water temperature are difficult. Large size ponds are subject to problems caused by wind generated waves referred to earlier. Provision of wind breakers such as "bamboo blocks" and "net blocks" in the ponds perpendicular to the direction of the prevailing winds (as practiced in Taiwan) has proved effective and led to increased production compared to ponds without them.

The development of blooms of other algae such as filamentous blue greens and greens is a major problem in the Philippines. These algae may totally displace *Gracilaria,* or else they become so mixed with *Gracilaria* that it is impossible to remove them, resulting in dried materials of very low quality. The problems of blooms of epiphytes and other weeds are being controlled by the introduction of grazers such as Tilapia and milkfish. However, the size and number of these grazers must be controlled otherwise these may consume the *Gracilaria.*

Pond culture of Gracilaria is also being carried out in Vietnam, Thailand, Indonesia, Hainan and Hawaii.

2. Field culture

Several methods are currently being utilized in the field culture of *Gracilaria.* The "seeds" used in these various methods are cuttings or sporelings produced from spores.

2.1 Fixed bottom type of culture

2.1.1 Long line method

In this method, three-strand polyethylene ropes 5-8 mm thick and five metres long are generally used. Other materials such as coir or abaca ropes may also be used. In the West Indies, where the mariculture of sea moss (Gracilaria) is most successful, both sporelings produced from spores and cuttings are utilized as "seeds" in the fixed long line method as well as in the raft method.

The seeding of long lines using cuttings consists of untwisting the rope and inserting bunches of cuttings between the strands of the rope, the seedlings passing twice or three times through the rope. This method ensures that the cuttings are securely held in place. The seeding of the ropes is done in the shade, where the seedlings are placed in basins of sea water to prevent them becoming dehydrated.

The support system for the long lines consists of rows of wooden stakes driven into the ground. The distance between stakes in the row is about one metre, while the distance between rows varies between 4-5 metres or longer. The seeded rope is tied to a stake, stretched tightly and rhe other end tied to the opposite stake in the next row. In the West Indies, two seeded ropes are usually tied to a pair of stakes.

The same technique is supplied for ropes seeded with spores. In Malaysia, unbraided plastic rafia seeded with hatchery produced sporelings was used as long lines. In India, longer ropes are used and additional stakes are provided to prevent the ropes from sagging to the ground. The distance of the seeded ropes from the ground varies depending on the depth and clarity of the water as affected by tidal changes. This'method of field culture is presently being utilized in the West Indies, Myanmar, India, Brazil and Sri Lanka.

2.1.2 Chilean method

The field culture method presently used in Chile is quite simple but has proved very successful. The anchoring system for the seedstocks (cuttings) consists of plastic bags one metre long, 0.1 mm thick and 4 cm in diameter. The plastic bag is filled with sand and the two ends are knotted. Five bunches of seedstock are fixed to the same side of the sand-filled bags by rubber bands.

The seeded bags are arranged in rows on the substrate and are positioned in such a way that the bag serves as an anchoring weight. The middle of the cuttings are weighted by the bag against the surface of the substrate and their tips freed.

The use of rocks as anchoring units for the cuttings is effective. However the use of both sand-filled bag and rocks as anchoring materials for cuttings was only efficient in sites which are not exposed to strong surges or waves. Evaluation of the efficacy of this system showed that more than 60% of the biomass could be lost due to removal of thalli by strong surges, and rocks were observed to be more easily dislodged from the substrate than the sand filled bags.

2. 1 .3 Improvement of substrates

This method can only be utilized in areas where natural beds are found. The introduction of artificial substrates such as rocks, shells, bamboo or wooden stakes, etc. in the site provides additional favourable substrates for the spores to settle or fragments of thalli to attach. Most of the beds of commercially important species of Gracilaria are found in shallow bays and coveswhere the substrate is generally particulate (sand-muddy). The survival and growth of spores is greatly enhanced by the availability of solid substrates. Studies of the influence of solid substrates on biomass production have shown that production more than doubled in portions of the beds where solid substrates had been introduced.

2.2 Raft method

The raft method is popularly used in West Indies in areas where bamboos are available. The raft generally measures 2 x 4 metres in size. Seeded long lines are tied to the shorter bamboo frame, stretched tightly and fixed to the opposite side of the raft. The distance between ropes varies, but about 12 to 14 lines may be planted to one raft.

In India, coir ropes fabricated into network of 7 cm mesh size was used on a 2 x 2 metre raft. The same method of seeding was utilized.

A variation on this method has been developed in the People's Republic of China. Pieces of rope about 70 cm long seeded with Gracilaria cuttings are hung horizontally on the low fixed raft or vertically along a long line floating raft.

References

ARMISEN, R. AND GALATAS. F. (1987). Production. properties and uses of Agar. In McHugh. D.J. (Ed.) Production and utilization of products from commercial seaweeds. FAO Fish. Tech. Pop. 288: 1-57.

BARRALES. H. AND PIZARRO. A. (1988). Field assessment of two methods for planting th e agar-containing seaweed. Gracilaria,. in Northern Chile. Aquaculture 59: 31-43.

BIRD. K.T. (1987) *Gracilaria* cultivation in the Caribbean. Paper presented at the 1987 Caribbean Aquaculture Trade Expo. in Puerto Rico. 8 pp.

BIRD. K.T. (1988) Agar production and quality from Gracilaria sP. strain G-16. Effects of environmental factors. Botanica Marina 31: 33-39.

BIRD, K.T.. HANISAK, M.D. AND RYTHER. J. (1981). Ch emical quality and production of agars from Gracilaria *likvahiae* grown in different nitrogen enrichment conditions. Botanica Marina 24: 441-444.

CHIANG. Y.M. (1981). Cultivation of Gracilaria (Rhodophycophyta, Gigartinales) in Taiwan. Proc. 10th Intl. Seaweed Symp.: 569-574.

DAUGHERTY. B. AND BIRD. K.T. (1988). Salinity and temperature effects on agar production for Gracilaria verrucosa Strain G-16. Aquaculture 74: 1-Y.

DOTY. M.S. (1986) Estimating farmer returns from producing Gracilaria and Eucheuma on line farms. Monografias Biologicas. 4: 45-62.

GUERIN. J.M AND BIRD. K.T. (1987). Effects of aeration period on the productivity and agar quality of Gracilaria sp. Aquaculture 64: 105-109.

GUERRERO,R.D (1989). Producing Gulaman in ponds for export. Fishbites. Agribusiness Weekly. July 14-20: 12.

LIN, M.N.. LIN. G.Y. AND HUANG.T.L. (1979). Preliminary report on the improvement of Gracilaria farming. Agriculture 2(3): 22-31

RAJU. P.V. AND THOMAS. P.C. (1071). Experimental field cultivation of *Gracilaria* edulis (Gmel.) Silva. Botanica Marina. 14: 71-75

NEISCH. A.C. (1978). Developments in the culture of algae and seaweeds. pp. 395-402. In T.V.R. Pillay and W.A. Dill (Eds.). Advances in Aquaculture. Fishing News Books Ltd.. Farnhein. Surrey. England.

SIJIAN. I.. (1986). Experiments of picking spore and raising seedling of Gracilaria renuistipitata. Jour. Zhanjiang Fish. Coll. 1: 31-34.

SIJIAN. L.. BENSONG. L.B.. SHUFANG. Z., BINGSIN. L. AND ZHENYING. J. (1986). The experiment of Gracilaria tenuistipitata fixed to sporeling rope with float raft in tidal zone. Jour. Zhanjiang Fish. Coll. 1: 35-38.

SMITH. A.H.. NICHOLS, K. AND MCLACHLAN. J. (1984). The cultivation of seamoss Gracilaria in St. Lucia. West Indies. Hydrobiologia 1 16-1 17: 249-251.

TACHANAVARONG. S. (1988) Gracilaria culture in Thailand. In Report on Training Course on Seaweed Farming. ASEAN/SF/88/GEN/6: pp. 136-141. FAO Publication.

TRONO, G.C. JR (1981). The present status of production and utilization of seaweeds in Asia. In Trono. G.C. Jr and Fortes. E.T.G., (Eds.). Report on the training course on Gracilariu Algae. SCS/GEN/81/29: 44-44. FAO Publication. Manila.

TRONO, G.C. JR.. (1981). Field culture of Gracilaria and other species. In Trano, G.C. Jr. and Fortes, E.T.G., (Eds.). Report on the training course on Gracilaria Algae. SCS/GEN/81/29 : 51-56.

TRONO. G.C.. JR (1986). Seaweed culture in the Asia-Pacific Region RAPA Publication 1987/8. Regional Office for Asia and the Pacific. FAO of the United Nations, Bangkok. Thailand. 41 pp.

TRONO. G.C.. JR. (1988). Production of economically important seaweeds through culture and harvesting of natural stocks. In Report on the Training Course on Seaweed Farming. ASEAN/SF/88/GEN/6 : 59-70. FAO Publication.

SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

GRACILARIA CULTURE IN CHINA

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ABSTRACT

Gracilaria verrucosa is the most common species in China and one of the main raw materials for agar production. Experiments showed that spore release is maximum between 8 a.m and 10 a.m, after short desiccation of the mature plant and in seawater with a temperature of 20-25ºC and a salinity of 19-27 ppt.

The spores will grow well above 15ºC, in strong light intensity within 3000 Lux and in salinity range of 23-27 ppt. The *Gracilaria* thalli are tolerant to wide salinity ranges. Outdoor as well as indoor collection of spores are the methods used in rearing of seedlings. Farming is done by means of mud flat or intertidal culture, floating culture or pond culture.

I. Introduction

A number of agarophytes, including *Grarilaria*, *Gelidium* and others, have been used in China as marine vegetables or traditional medicinal herbs for over 1,000 years. However, these seaweeds became an industrially important raw material for processing agar only some decades ago.

Agarophytes in China are mainly represented in three genera of Rhodophyta, *Gracilaria*, *Porphyra* and *Gelidium*. Among more than 30 species of agarophytes, *Gracilaria verrucosa*, *G. tenuistipitata*, *Gelidium amansil* and *Porphyra haitanensis* are the major ones. In addition, other red seaweeds, such as *Pterocladiu* sp., *Gelidiella* sp. and *Ceraminum* sp. are often collected and mixed with the main agarophytes mentioned above and used for producing agar.

China is a major world producer of cultured seaweeds. The total annual production of cultured seaweeds is about 300.000 dry tonnes** Of these, *Laminaria* and *Porphyra* account for 200,000-250,000 tonnes and 20,000 tonnes respectively. *Gracilaria* production is about 5,000 tonnes per annum (Shang, 1976; Chiang, 1981, Yang et al., 1981; Chueh and Chen, 1982; Zheng, 1987). In China, *Laminaria* is a main marine vegetable and raw material for extracting iodine, mannitol and alginate. *Porphyra* is also a popular marine vegetable. But in recent years some phycologists have observed that a considerable quantity of *Porphyra* thalli obtained from the later harvests during the season can be used for processing agar. These later croppings have less edible value.

At present *Gracilaria* and *Porphyra* are the most important raw materials for producing agar. Although *Gelidium* has long been considered as the best raw material for processing agar,it **is** not the ideal cultured species because of its slow growth and low yield. On the other hand, *Gracilaria* is easier to farm. It is expected that a higher output can be obtained in farming conditions. Shang (1976) reported that the average productivity of dry *Gracilariu* in Taiwan ponds was 7-12 t/ha/year. A few years later Chiang (1981, P. 573) observed that 16-43 t/ha/year could be expected. So it is believed that there will be a substantial development of *Gracilaria* culture in China to meet the increasing demand of the agar market.

In the present review I shall first discuss some genera1 ecological characteristics of *Gracilaria* which are especially important to its commercial production, and subsequently review the farming practices developed for the species.

** Weights of seaweed production provided refer to dry weight only

2. Biology of *Gracilaria*

Gracilaria verrucosa is the most common species in China. It grows fast and has a high agar content. Following is a discussion on the influence of the various environmental factors on the release and germination of spores and the growth of thalli of the spores.

2.1 Influence of environmental factors on spore release

Both carpospores and tetraspores are released naturally into seawater after their maturation. Experiments showed that the maximum quantity of spores is released from 8 a.m. to 10 a.m., gradually decreasing thereafter. The minimum quantity is released between 10 p.m. and 6 a.m., after which the next maximum will take place. Besides the diurnal changes in release rhythm, the quantity of spores released also depends on ambient environmental factors. (Zheng, 1987).

2.1.1 Deciccarion

In general, when a mature *Gracilaria* is taken out of seawater and kept in a shady spot for two to four hours (air temperature 15-25ºC), the tetraspores or the carpospores will be released if the plant is dipped in seawater again.

2.1.2 Seawater temperature

Experiments have shown that the highest number of spores are released at 20-25°C. According to field surveys, the reproductive season of *Gracilaria* is between June and August in northern coastal provinces or between March and May in southern China. During these seasons, the natural seawater temperature is 20-25°C. The experimental results coincided with natural reproductive seasons (Zheng, 1987).

2.1.3 Specific gravity of seawater

When mature plants were kept in seawater of different specific gravities, those in seawater of lower specific gravity would release spores earlier than those kept in water of higher specific gravity. If the plants are put in seawater with an obviously low specific gravity(<1.005), the released spores will swell and even break up due to osmosis caused by the low salinity and most of them will not complete normal germination. In order to obtain good results in the collection of spores, the optimum specific gravity range of 1.015 (19.0-20.2 ppt) to 1.020 (25.5-26.9 ppt) should be observed (Zheng, 1987).

2.2 Influence of environmental factors on germination and growth of the spores

Gracilaria spores just released into seawater measure around 30 um in diameter but this varies with species. Tetraspores are slightly bigger than carpospores. For example, the tetraspores of *G. tenuistipiruta* have a diameter of 24-55 um, and the carpospores 23-40 um. Soon after release, the spores will attach to substrates and start first cleavage of cells. The germination and growth of spores are also influenced by amhiect environmental conditions such as seawater temperature, light intensity and salinity (Zheng, 1987).

2.2.1 Seawater temperature

To examine the germination and the growth of the spores, specimens attached to slides for 12 hours were placed in sterilized seawater enriched with 1 ml of 1 M KNO, and 1 ml of 0.1 M KH_2PO_4 per litre of seawater medium, and incubated with a light intensity of 400 Lux, photoperiod of 10:14 for different periods of time (Zheng, 1989).

The results showed that both tetraspore discs and carpospore discs need a seawater temperature higher than 15°C. Even if all other environmental conditions are suitable for their growth, they would survive but grow very slowly (Zheng, 1987).

2.2.2 Light intensity

Light intensity is one of the most important factors that influence the germination and growth of spores. When the light intensity is stronger, the rate of germination and growth of spores are higher within 3,000 Lux. If the spores attached to slides are kept in a dark place they will die in 20 days.

2.2.3 Specific gravity of seawater

Although Graciluria plants prefer to inhabit estuarine areas, their spores are unable to withstand seawater with low salinity. If the spores attached to substrate are put in seawater with a specific gravity below 1.010, (12.5-13.7 ppt) their cells swell up due to the absorption of water into the cells. The colour of the pigments in the cells becomes pale, and the spores eventually die. Experiments proved that the optimum specific gravity of seawater for germination and growth of spores ranges from 1.018 (23.0-24.2 ppt) to 1.025 (25.5-26.9 ppt) (Zheng, 1987).

2.3 The effect of environmental factors on growth of Gracilaria thalli

The effects of environmental factors on Graciluria thalli are similar to those on their spores, but not entirely the same. For instance, as mentioned above, spores kept in seawater with a specific gravity below 1.010, will break up and die, but the thalli can grow very well in the same conditions. In view of this, ambient environmental factors required by Gracilaria thalli must be studied.

2.3.1 Specific gravity of seawater

Gracilaria are euryhaline seaweeds. Under natural conditions, the specific gravity in which the plant can grow out ranges from 1.005 to 1.026 (5.2-38.1 ppt), Experiments and field surveys have shown that the optimum specific gravity is 1.010-l .020 (11.3-30.1 ppt) where freshwater regularly flows in (Zheng, 1987).

2.3.2 Seawater temperature

Gracilaria are eurythermal plants which can grow at 5-30°C. Optimum temperature varies with species. For example, the optimum temperature for G. verrucosa is 15-25°C. They can be found in northern China during May to August, but in south China only in winter and spring. In summer, the growth of Gracilaria is almost completely stopped in the south until late autumn when the water temperature drops below 25°C and the seaweeds resuscitate.

Field surveys have shown that the optimum seawater tzmperature for G. tenuistipitata, a species mainly distributed in Guangdong and Hainan Island, is identical with G. verrucosa. When the water temperature is 30° C, its diurnal growth rate measures 0.1-0.2 cm/day but as the temperature continues to fall to 28°C, the growth rate increases to 0.4-4.5 cm/day. When the temperature is from 15-25°C, growth rate can be higher than 1 cm/day.

2.3.3 Light intensity

The growth of Gracilaria requires a high light intensity. It has been shown that growth rates of seaweeds vary when they are planted at different depths of water (Zheng, 1987).

The study showed that the Gracilaria can grow well in water less than 1 m deep where the seawater transparency is around three metres. If the seaweeds are planted in seawater deeper than three metres, they not only stop growing but start rotting as well.

Dissolved oxygen was measured in seawater collected from different water depths where Gracilaria is located. The results showed that Graciluria exposed to the maximum light intensity also has more intense photosynthetic activity. As the plants are located beneath 3 metres depth, their respiratory intensity exceeds the photosynthetic intensity. This explains the finding that the amount of dissolved oxygen in the seawater of the experimental groups was less than that of the control group in which no Gracilaria were present.

3. Farming

China has **more** than 30 years' history of Gracilaria farming. According to the specific biological characteristics of the seaweeds, different methods of collecting spores and farming thalli have been studied and practised. This includes collecting natural spores, artificial outdoor collection of spores, indoor spore collection, mud flat culture, floating raft culture and pond culture.

3.1 Rearing of seedlings

3.1.1 Outdoor collection of spores

The procedure involves four steps: selection of site. preparation of substrate. collection of parent plants (tetrosporophyte and/or carposporophyte) and collection of spores.

1) Site selection: A suitable site for collection of spores should be an intertidal flat area with a hard bottom and clear seawater with a specific gravity range of 1.010-1.025 (12.5-33.4 ppt). A large spherical dwarf dam 20-30 cm high is made at the selected site to store seawater after ebb tide.

2) Preparation of substrate: Cheap substrates like stones, shells or broken corals can be used. These substrates have a clean surface for easy attachment of spores. If the substrate is stone, each block should weigh about 0.5 kg, the total amount is about 600 tonne stones per ha. For shell, 120 tonnes per ha is sufficient. The substrate is spread on the selected site. In recent years, artificial fibre (e.g. nylon, polyethylene) ropes or nets have been used to collect spores. The texture of these materials is good but the cost is higher. Used or worn fishing nets can be used as cheaper substrates.

3) Collection of parent plants: The parent plants must be fully mature with a dull red-brown colour and without rotted spots. In fully mature plants, the sporangia are easily seen on the entire surface of the plant body.

4) Treatment of parent plants: Parent plants are washed with clean seawater to get rid of mud or other matter and allowed to air dry on bamboo curtains for two to four hours until irregular corrugations appear on the plant surface. At this time, the seaweeds can be spread in a selected site with substrate. The quantity of parent plant required is about 300 kg per ha.

As soon as the parent Gracilaria are planted in seawater, they release a great quantity of spores into the seawater. The spores will settle down on the substrate in one day. Under natural conditions, the germination of spores is very fast. They will turn into dish-shaped thalli in five days.

Another method is to put the desiccated seaweeds into a vat and stir them vigorously with a stick to stimulate release of spores into seawater. About two hours later, the seawater containing a huge quantity of spores can he sprayed into a selected site.

3.1.2 Indoor collection of spores

The main steps followed in indoor collection of spores are similar to those in outdoor collection. The only difference is that the spores attached to the substrate will be kept in indoor tanks for rearing until they grow into young plants.

3.2 Culture methods

3.2.1 Mud flat or intertidal culture

The main feature of this culture method is that the spore collection and farm sites are usually the same. In southern China, in late autumn or early winter, young Gracilaria can grow up to S-6 cm long as they enter a period of faster growth rate. At this stage, the substrate to which young Gracilaria are attached are kept in lines on the bottom, which serve as a walkway, at an interval of 30-40 cm. Routine management practice involves removal of miscellaneous seaweeds, collection of herbivorous gastropods and so on. Women and children often do this. In a normal season, 1,500 kg (dry) of Gracilaria can be harvested.

3.2.2 Floating culture

The method has been adapted from kelp farming. In a suitable season, such as January in southern China or May in the northern part, young seaweeds collected from other fields or reared in indoor tanks are pulled up from the substrate and inserted into “seedling ropes”, which are made of palm thread or artificial fibre. In each 20 metre rope, 200 pieces of seaweed can be inserted at 10 cm intervals. The seedling ropes are then fixed to a floating raft. Three months later, the seaweeds will **reach** a length of over one metre and can be harvested giving yields as high as 3000 kg (dry) per ha.

3.2.3 Pond culture

Pond culture of seaweeds has been adopted by Taiwan's phycologists and farmers since the 1960s. Before 1962 agarophtyes were very scarce in Taiwan, and had to be imported. Phycologists and farmers tried to rear Gracilaria in ponds with milkfish. Unexpectedly good results were obtained and many farms began to change the main cash crop from milkfish to Gracilaria. At present, Taiwan produces 12,000 tonnes fresh weight of Gracilaria annually from 300 ha of ponds (Chiang, 1981).

The stock seaweeds are cut into pieces and spread in the fish pond at a density of 5-6 tonnes of fresh thalli per ha. Chemical fertilizer or pig manure is applied regularly. Every 30-45 days, most parts of the seaweeds can be harvested leaving the rest of the body in the ponds as stock. The harvesting period lasts six months from June to November in the northern region.

This method is also being used in the southeast region where the lesser inputs and higher production make it an attractive proposition.

4. General Comments

Although satisfactory results have been obtained by several Gracilaria culture facilities, there have not been the great advances in production to match those achieved in Laminaria or Porphyra farming. The main reason for this is a lack of balance between production cost and market price. Indeed the lower market price is inhibiting the development of Gracilaria farming.

In recent years, Gracilaria farming has become popular because of the increasing demand from the agar processing industry. A main production zone of Gruciluria has grown up in Southern China (including Guangdong, Guangxi and Fujian provinces) where seawater is warmer and rich in nutrients suitable for growing Gracilaria plants. Liu (1987) reported that there are four species (G. verrucosa, G. tenuistipitata, G. gigas and G. bursa-postoris) which are suitable for farming. His experiments and investigations have shown that it is possible to obtain an average yield of two to three tonnes per ha. He suggested that the acreage under farming of Gracilaria can be expanded to 6700 ha in Guangdong Province to produce 15,000 tonnes (dry) of high quality Gracilaria. Technical progress and advances in Gracilaria farming will further reduce the production cost and improve product quality. The following suggestions are made to improve the culture, production and utilization of this agarophyte:

(1) High priority should be given to selecting species with faster growth rates and higher contents of good quality agar.

(2) Adequate measures should be taken to protect natural stocks of Gracilaria to prevent over-exploitation of natural stock.

(3) Polyculture of finfish and shellfish with Gracilaria offers several advantages. For example, the autophyte seaweeds can improve the quality of water contaminated by cultured animals; Gracilaria is a superior fodder for abalone which has a higher price in the world market. Gracilaria farming can supply feed to abalone farms, while abalone farming would also help to promote agarophyte farming.

References

CHIANG. Y.M.. (1981). Cultivation of Gracilaria (Rhodophycophyta. Gigartinales) in Taiwan. Proc. Int. Seaweed Symp. 10: 569-574

CHUEH, C.T., AND CHEN, C.C., (1982). Seaweed economics. In Tsuda R.T., and Chiang. Y.M. (Eds.), Proceedings of Republic of China United States Cooperation Science Seminar on cultivation and utilization of economic algae. Univ. of Guam Marine Laboratory, Mangilao. Guam, pp. 9-16.

LIU, S.J.. (1987). Distribution. present production, status and future of Gracilaria in Guangdong Province. Sci. and Tech. of Fisheries, 1: 14-15.

SHANG. Y.C.. (1986). Economic aspects of Gracilaria culture in Taiwan. Aquaculture 8: 1-7.

YANG. S.S.. EANG, C.Y.. AND WANG, H.H. Seasonal variation of agar produced in Taiwan area. Proc. Int. Seaweed Symp.. IO: 737-742.

ZHENG,C.K., WANG. S.J.. AND LIU, S.J. (1987). Phyccoculture. Shanghai House of Science and Technology Publication. pp. 225-254.

SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

EUCHEUMA AND *GRACILARIA LICHENOIDES* : A CO-FARMING POSSIBILITY

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ABSTRACT

Gracilaria lichenoides was observed to be growing well among Eucheuma on farms in Bali, Indonesia, without adversely affecting its growth or that of the Eucheuma. This observation led to the conclusion that co-farming of Eucheuma and G. lichenoides can benefit the Eucheuma farmer through additional income from the sale of Gracilaria. However, more studies should be done on the ways and means of co-farming Eucheuma and Gracilaria lichenoides, and also on establishing G. lichenoides as an important member of the agarophyte family.

Introduction

Studies on the biology and agronomy of Eucheuma were conducted at Geger Beach, Nusa Dua, Bali, Indonesia from June, 1986 to October, 1989. The experimental site is also the farm of about 50 families who are cultivating Eucheuma coftonii and Eucheuma spinosum. During the experimental period, Gracilaria lichenoides was observed growing among the Eucheuma plants on stakes, ropes, lines and rafts.

Since we were not interested in the culture of G. lichenoides, these seaweeds were considered as pests and were usually removed from near or around the Eucheuma during farm maintenance operations.

Recently (September-October, 1989), we became interested in the G. lichenoides because we observed that the farmers were also gathering these plants and selling them to the local traders who, in turn, wash the dried Gracilaria in fresh water and after re-drying sell them at the market at Denpasar, Bali.

Preliminary cultivation studies on G. lichenoides

Wild G. lichenoides were collected from the stakes, ropes, and rafts where they were growing. They were divided into uniform fifty gram cuttings and then tied with nylon nettings. The propagules (cuttings) were cultured in the same way as Eucheuma, by tying them to the lines attached to a raft (floating culture system) at intervals of 20,25, and 30 cm. along the line. The plants were harvested six weeks after planting just like the Eucheuma.

The fresh harvest weight of G. lichenoides six weeks after planting is given in Table 1.

Table 1 Distance of Planting (cm.)

Propagule No	20	25	30
1	200	205	150
2	210	210	190
3	220	150	220
4	220	240	250
5	17.5	255	240
6	245	230	245
7	200	250	250
8	230	300	270
9	210	225	260
MEAN	212	229	230

The growth ratio (harvest weight/propagule weight, H/P) was computed by dividing the mean harvest weight by 50 grams which was the weight of the initial propagule. The results are given in Table 2.

Table 2

Distance of Planting	H/P ratio
20	212/50 = 4.24
25	229/50 = 4.58
30	230/50 = 4.60

The data show that the *Gracilaria* can tolerate closer planting, and suggest that they can be planted alternately between *Eucheuma* plants.

The percent dry matter yield (% DMY) was determined by drying 2070 grams of fresh G. *lichen-oides;* this produced a commercially dry weight of 180 grams. Hence, the percent dry matter yield (% DMY) = 180/2070 x 100 = 8.69%.

The wet-to-dry ratio was therefore:

100/8.69 = 11.5

The result of this preliminary study showed that there is a potential for growing the *Eucheuma* and *G. lichenoides* together. The potential yield for a one-hectare farm of *Eucheuma* and *G. lichenoides* is shown in Table 3.

Table 3

Species	Weight of Propagules	H/P ratio	Net fresh Harvest	% DMY	Dry-Yield per ha per Ha (MT)	Sq. M (KG)
E.cottonii	16	5.0	60	12	7.0	0.70
G. lichenoides	8	4.0	32	8	2.8	0.25

The potential annual income (US $), assuming eight harvests per year has been calculated and is shown in Table 4.

Table 4

Species	Dry Yield/Ha/Yr (Tonnes)	Farm Gate Price (Per tonne)	Gross Income
E. cottonii	56	$350	$19,600
G.lichenoides	20	$450	$ 9,000
TOTAL	76		$28,600

Conclusion

The above data show that there is potential for farming *G. lichenoides* together with the *Eucheuma.* This can be done by planting the *Gracilaria* between the Eucheuma propagules. By doing this, the farmers could increase their incomes by an amount equivalent to about 50% of the yield and value of the *Eucheuma.*

There are possibly many other ways of co-farming *Eucheuma* and G. *lichenoides.* Studies on this aspect should be done by interested researchers.

SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

THE CULTURE OF *GRACILARIA VERRUCOSA* IN TAM GIANG LAGOON, THUA THIEN HUE PROVINCE, S.R. VIETNAM

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ABSTRACT

Gracilaria verrucosa is one of the aquatic plants which have been widely researched in the fisheries sector of Vietnam. Because of its wide distribution, fast growth, long annual culture time and capacity for harvesting several times a year, it was chosen as a species for culture in brackishwater coastal areas. Further, its culture is labour-intensive and generates substantial economic benefits.

1. Resource Survey, Biological Characteristics And Experimental Culture Of *Gracilaria Verrucosa* In Vietnam

Since 1963 Vietnamese scientists, and experts from the German Democratic Republic led by Prof. Dr. W. Brucker, have carried out surveys to determine the genus, species and distribution of seaweeds along the coast from Mong Cai district (Quang Ninh province) to Vinh Linh district (Quang Tri province). Surveys carried out by the Research Institute of Marine Products, Nha Trang Institute of Oceanography, Nha Trang Fisheries University and University of Hue gave additional information for all brackishwater areas along the coast of Vietnam. The results showed that there are 16 species of seaweed along the coast of Vietnam, of which *Gracilaria verrucosa* is predominant in terms of its distribution area, biomass and agar content and quality.

Research on biological characteristics, seed production techniques and intensive cultivation of *G. verrucosa* has been carried out continuously since 1963. In 1977, the Ministry of Fisheries approved a method for the bottom culture of *Gracilaria verrucosa* with a productivity of 10 tonnes/ha/year.

Between 1979 and 1988, some localities applied this method effectively, getting productivity-of 10 tonnes/ha/year, but the technology has yet to become stabilized and applied on a large-scale. However, in small ponds (200-1000 m^2) at the Research Institute of Marine Products at Qui Kim, Hai Phong, productivity averaged 35 tonnes/ha/year.

The overall results showed that *G. verrucosa* is distributed widely in brackishwater lagoons in Vietnam, where the bottom is sandy mud, muddy sand or muddy. If the bottom is sandy, the growth is low; if the bottom is muddy the individual size of the organisms is reduced. In general, seaweeds can tolerate salinity from 5 to 35 ppt, and a water temperature of 38°C to 40°C. For G. *verrucosa,* salinity from 10 to 22 ppt, temperature from 20°C to 25°C, pH from 7.5 to 8.5 and water depth from 40 to 80 cm are the ideal conditions. Experiments on pulse fertilization showed that a compound of fertilizers consisting of 3 mg/l $(NH_4)_2SO_4$ + 3 mg/l $NaNO_3$ + 0.6 mg/l $Na_2H_2PO_4$ was the most effective.

Pulse seed fertilization should last for only 4 hours, and be carried out in light rather than dark conditions. To limit the influence of foreign seaweeds on *Gracilaria verrucosa,* we should:

- improve pond conditions by ploughing the bottom and adding lime and organic fertilizer (0.2-0.5 kg/m^2);
- culture seaweed at an initial density of 500 g/m^2;
- intensify water supply/drainage for culture ponds.

Though the potential is great, the production of cultured seaweed in Vietnam is still low. Even in the best year to date (1987), production was only around 700 tonnes (dry weight), one third of which was harvested in natural habitats. The area available for seaweed culture in the whole country in the next decade will be about 2000 ha of which Thua Thien Hue province nas the largest area upto 770 ha in the Tam Giang lagoon system.

2. Topographical and ecological conditions at Thuan An seaweed farm in the Tam Giang lagoon system

The Tam Giang lagoon in Thua Thien Hue province is a continuous system of large bodies of water. Outside, the lagoon is surrounded by a long line of sand stretching from the mouth of the Tu Hien river to the estuary of the O Lau river, connected with the sea by the two estuaries of Thuan An and Tu Hien in the East. Inside the lagoon is the mainland of Phu Loc, Huong Phu and Huong Dien districts and Hue City. The total lagoon system is over 60 km in length. Due to the gently sloping bank the inshore part of the lagoon is shallow. In the dry season, the average water level is less than one metre. The depth in the middle of the lagoon is about 2 m but in some places up to 4-5 metres. The'speed of the river current is about 4.5 km/hr in the dry season, but in the rainy season it can reach 20 km/hr. The bottom structure is different: along the coast it is often sandy or muddy sand, in the middle of the lagoon it is often muddy or sandy mud. At the mouths of rivers one finds crude sand and hard terrain. The tide is semi-solar and irregular, and its amplitude is low (about 0.5-0.8 metres).

Thuan An seaweed culture lagoon is 2 km west of Thuan An estuary and is surrounded by dykes with gates and canals for regulating water.

In,1977-78, 10 ha of experimental ponds comprising eight small 0.5 ha ponds and one large (6 ha) pond were constructed.

In 1983-84, three additional ponds of 11 ha, 22 ha and 17 ha were constructed.

Another 50 ha were added in 1985-86, of which 20 ha were transferred to Phu Tan agricultural cooperative (Hue city). The remaining 30 ha were divided into 2 ponds of 15 ha each. The system of seaweed culture ponds in the Chuong lagoon (total area more than 300 ha) belong to Huong Phu and Hue City territory.

There are two kinds of pond bottom, which are present in roughly equal proportions. Shallow bottoms are sandy or muddy sand while deep bottoms are muddy or sandy mud. In shallow bottom areas Halidube tridentata grow densely and in the deep bottom areas Chara zeylanica and Najas indica grow fast, especially when salinity is low. Depending on the season, there are about 25 species of seaweeds detrimental to Gracilaria verrucosa, mainly blue and green algae (Cyanophyta and Chlorophyta).

The lowest mean water temperature is in January (20.9°C) and the highest is in July (30.6°C). In the temperate months from February to April, the mean temperatures are 21.5°C, 24°C, and 26°C respectively.

Salinity varies with the seasons. In the rainy season from September/October to December/January, the salinity drops to below 5 ppt. In February, salinity begins to increase, and reaches its maximum of 32-35 ppt in July and August.

Mineral content (N and P) in the ponds varies depending on the time of fertilization and the level of development of the seaweed in the ponds. The highest concentration is usually in November and the lowest in April and August. In general, the Tam Giang brackishwater lagoon has average low mineral content.

Surveys on other climatic factors in the region show that average annual rainfall is about 1900-3200 mm and distributed unequally, falling mainly in the period from September to November.

The sun shines about 1700-1900 hours in a year. This is favourable for harvesting and drying seaweed, but seaweed grows slowly in the shallow ponds (under 30 cm deep) during the hot months.

3. Seaweed Culture Techniques

The main crop is grown in spring/summer (January to May), and a sub-crop is grown in summer/ autumn (July to September). Seedstock preservation is carried out during winter (October to

December). The condition of the pond bottom is improved by submerged ploughing using a ploughing machine or a buffalo-drawn plough.

Seeding — using transplant seed from seedstock preserved during the winter or seed collected from natural habitats during the same period — is usually carried out in January/February. However, seeding may be carried out one month earlier or later depending on the arrival of warmer weather. Seeding is carried out a density of 200-500g/m^2

Additional manure is added only to the shallow bottom areas at about 2-5 tonnes/ha. Before planting, seedlings whether removed to a new place or gathered from nature are treated by pulse fertilization with inorganic fertilizers (N and P at a ratio N:P = 2:1) at 3-5 kg/tonne of seed.

All water gates are closed in the rainy season to prevent a sudden drop in salinity. In the hot season, the gates are opened and closed daily (depending on the tide level) to allow more circulation of water in the ponds. During monthly periods of low tide, it is necessary to open inlet gates. During this period water should be drained only at night. Whenever foreign seaweeds develop and fully cover the G. verrucosa, harvesting should be combined with removing them so that G. verrucosa growth is not restricted.

Harvesting starts about 1.5-2 months after seeding and continues everywhere in the region up to the beginning of the rainy season. Time of harvest is also decided by the results of laboratory determinations of agar content and quality confirmed by field technicians. The amount of seaweed left after each harvest is 300-400 g/m^2. Seaweed is harvested by scoop net or by hand, then washed in the field and dried on dike embankments. It is transported to a freshwater area for washing and drying for a second time. Finally, it is pressed, packed and transported to the market.

4. Results

1. ***Productionof Gracilaria Verrucosa cultured at Thuan An farm during 1985-1988***

Table 1: Yield and productivity of Gracilaria *Verrucosa, 1985-88*

Area (HA) and Yield (tonnes)								
Pond	1985		1986		1987		1988	
	Area	Yield	Area	Yield	Area	Yield	Area	Yield
P1	10	138.58	10	272.15	10	92.15	10	231.00
P2	14	64.38	11	155.52	11	116.64	11	238.00
P3	22	101.52	22	324.00	22	125.72	22	420.00
P4	2	29.28	17	84.24	17	116.64	17	238.00
P5					10	180.00	15	266.00
P6							15	231.00
TOTAL	45	333.76	60	835.91	70	631.15	90	1624.00
Productivity (t/ha)		7.41		13.93		9.02		18.04

In 1985 productivity was low (7.41 tonnes/ha) because the summer-autumn weather persisted for a long time and there was an extended period of high salinity. After June, seaweed production was only 5-10% of that in the same period in previous years. In October, seaweed biomass in the whole lagoon reached 700-800g/m^2. After just two days of harvest which yielded 9.9 tonnes, a big storm blew away all the seaweed. After the storm 98 tonne (wet weight) were harvested from outside the lagoon and this was kept as seedstock for the following year.

Productivity in 1986 was much higher than in 1987. The reason was that the weather was temperate and Binh Tri Thien province had a bumper crop of seaweed. In contrast, hot weather came early in 1987 and lasted until the end of summer (salinity in July 1987 was over 35 ppt). The flood also came early. In August salinity dropped to 124 ppt, then to 5 ppt from September until the following January. Although seaweed was harvested in September and October 1987 during the period of April to September of that year seaweed density was low and the quantity harvested was smaller in comparison to the same period in previous years (though it was higher than in 1985).

The 1988 spring-summer crop achieved record productivity. Although harvesting ended in September, the annual average production was over 18 tonnes/ha, thanks to improvements in production management which encouraged the workers and helped increase yield of G. verrucosa to a much higher level than in the years before.

2. Monthly Production Of Gracilaria Verrucosa, 1985-88

Table 2: Monthlv seaweed harvest (Tonnes. Wet Weight): 1985-88

Month	1985	1986	1987	1988
2	14.00	28.00	51.00	165.30
3	46.30	79.70	107.80	260.50
4	146.40	127.20	110.70	203.80
5	68.00	110.20	103.70	328.30
6	16.60	74. 10	35.90	195.40
7	4.10	203.80	97.70	270.40
8	14.40	123.80	39.50	154.30
9	13.00	88.50	57.30	46.00
10	9.90		27.7	
	333.70	835.90	631.30	1624.00

It can be seen from Table 2 that the seaweed yield reached peaks every year; first in April-May and then in July-August.

In the rainy season (October to January) G. verrucosa grew in the lagoon, but its quality was often low. Because it was affected by the bad weather, it was not harvested but kept as seedstock for the following year.

3. Results of Gracilariu Verrucosa cultured at Thuan An Farm

In order to decide the time and location for harvesting, laboratory technicians at the seaweed centre collect samples from all areas every 10-15 days and test the content and quality of the agar.

Results gathered over several years show that the samples collected in December have a very low agar content'and some samples yielded no agar at all. In samples collected in January, the agar content increases to 15.2-17.2% with a gel strength of 120-125 g/cm^2 (determined at 1.5% concentration and normal temperature). From the middle of February, the agar content reaches 18-23.2%, after which it stabilizes in all areas at between 19.8 and 25.6% with a gel strength of over 200 g/cm^2.

These results coincide with those achieved at the Product Quality Control Branch of Da Nang City, and are now highly trusted by importers.

Several conclusions can be drawn from these investigations. Ponds in the range 5-10 ha are most suitable for management and operation, and give very stable productivity. Ponds with a deep, sandy mud, or muddy sand bottom often give higher yield and better agar quality. However, ponds with a sandy or muddy sand bottom may have dense growths of Halodube tridentuta. If the bottom of the ponds is ploughed and manured every year, productivity could reach over 10 tonnes/ha/year. Regular harvesting plus removal of foreign seaweeds can increase the productivity of G. verrucosa.

In suitable ecological and environmental conditions, G. verrucosa grows fast and can increase its biomass 5 to 10 times within 30-35 days without additional manure. This happens in Thuan An seaweed culture lagoon from March to May, so we have concentrated investment for the material and technical base during that period with the aim of increasing seaweed yield. Annual productivity and yield depend greatly on the quantity and quality of seedlings at the beginning of the crop. Nowadays, all the seedlings required for 90 ha production are supplied by preserving seedstock in the culture ponds during winter. However, if natural seedstock appears at the beginning of the Spring-Summer crop, it should be collected for the purpose of providing additional initial seeding for the culture ponds.

5. Economic effkiency of *Gracilaria Verrucosa* culture

a. The intial investment:

- Gates	VND	1,800,000
- Drying yard-storehouse		170,000
- Accommodation and office		500,000
- Transport vehicles		530.000
	TOTAL	3,000,000

b. Production costs of raw material
(with productivity of 1 ton/ha/year)
(VND/ton; VND/ha)

- Ploughing the ponds	VND	50,000
- Fertilizers (all kinds)		50,000
- Labour for seeding and controlling foreign seaweed		40,000
- Labour for harvesting and packing		250,000
- Guarding and direct management		250,000
- Indirect management		97,200
- Fuel		100,000
- Depreciation of real assets		300,000
- Tax		200.000

c. Income

- Main product (dried seaweed)	VND	2,000,000
- By product (Shrimp)		80.000
	TOTAL	2,080,000

d. Profit

e. Ratio of profit and initial investment:

$$\frac{743,000}{3,000,000} = 24.7\%$$

f. Ratio of profit and operating cost:

$$\frac{743,000}{1,337,000} = 55.6\%$$

The initial investment will be virtually paid back after four years of operation. The annual profit rate of the input is 55.6% (a good average standard for production enterprises in Vietnam).

***6.* Prospects for *Gracilaria Verrucosa* culture in Tam Giang Laggon, Thua Thien Hue province, S.R. Vietnam**

The total area of lagoon (about 20,000 ha) in the province means that natural seaweed resources are abundant. The experience gained in the last ten years has led to a high economic efficiency being achieved, even though semi-intensive cultivation is still being used.

Gracilaria culture in Thua Thien Hue province has attracted the attention of both local and central government authorities. The inhabitants living around the lagoon want to participate and are keen to adapt to this new kind of activity. Therefore, the seaweed culture area of this region will be further expanded, and with proper investment about 770 ha of the lagoon can be used for intensive culture.

Culturing, combined with the exploitation and protection of natural seaweed resources in this area, can help achieve the target of 1,000 tonnes of dried Gracilaria ***verrucosa*** in Thua Thien Hue province without any special difficulties.

SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

FUNDAMENTALS OF AGAROPHYTE CULTURE IN THAILAND

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ABSTRACT

Gracilaria sp. and Polycavernosa were cultured experimentally using four different methods: (a) field monoculture with insertion line technique (b) monoculture in pond (c) polyculture with seafish in sea cages and (d) polyculture with grouper fish in cages.

The best results were obtained from field monoculture with insertion lines and seaweed monoculture in ponds. Insertion lines increased from 1 kg to 20 kg in one month, while pond monoculture grew from 10 kg to 60 kg in 3 months.

Introduction

Before farming of agarophyte seaweeds can be undertaken on a commercial scale, it is necessary to establish the ecological parameters necessary for optimum production. This paper reports a study undertaken to determine these parameters for conditions prevailing in Thailand..

There are two genera of agarophytes with potential for commercial exploitation in Thailand. These are Gracilaria and the closely related Polycavernosa. Abbott (1987) has reported four species from each genus being present in Thailand. These are Gracilaria tenuistipitata, G. firma, G. irregularis, G. salicornia, Polycavernosa fisherii, P. changii, P. fasfigiata and P. percurrens.

Ecology of natural habitats

A study of the natural habitats of the agarophytes in Songkhla lake and Pattani lagoon was undertaken. The water temperature ranged from 20-35°C, with the optimum being 30°C. Salinity ranged from 10-35 ppt with an optimum of 25 ppt. The pH of the water ranged from 6-8, with the optimum being 7 (i.e. neutral). Agarophytes grow best in brackishwater. l-1.5 metres deep over a sandy/muddy bottom. Ideally conditions should be calm with little wind to generate waves which may lead to the seaweed aggregating on the leeward side of the lake.

Farming trials

Experiments have been carried out to assess four potential methods of culturing agarophyte seaweeds. At Ko Yo Island in Songkhla province, seaweed was monocultured using the insertion line technique. The seaweed cuttings were inserted into 50 metre lengths of 3.5 mm rope, and left to grow for one month.

At Da To village in Pattani province, the seaweed was monocultured in a 7 x 10 metre pond under 1 metre of water above a sandy/muddy bottom and left to grow for three months.

The other two experiments involved polyculture with fish in sea-cages. At Ko Yo Island in Songkhla province, the seaweed was placed in a 4 x 6 x 2 metre cage containing 300-350 sea fish and left to grow for one month. At Kantang in Trang province, the seaweed was placed in a 5 x 6 x 2 metre cage containing 300-350 grouper fish and left to grow for one month.

At the end of the growing period, the seaweed was harvested, cleaned with seawater and set out in the sun to dry (this usually took 2-3 days). Wet and dry yields were determined, and drying ratios calculated.

Results

Successful growth was achieved in all four experiments. The seaweed monocultured in insertion lines grew from an initial 1 kg to 20 kg after one month. The seaweed monocultured in a pond grew from an initial 10 kg to 60 kg after three months, i.e. an average growth rate of 20 kg/month.

The seaweed polycultured with sea fish increased its weight from 10 kg to 20 kg in one month, and that polycultured with grouper fish increased its weight by 1620 kg in one month.

The drying ratios calculated were 7: 1 for Gracilaria and 10:1 for Polycavernosa.

Quality and price

To obtain the maximum price, dried seaweed should meet certain quality characteristics. It should be black in colour, be free of impurities such as shells, rocks and mud and have a moisture content of about 20 per cent. Dry seaweed meeting these standards should fetch a price of US $800 per tonne.

Reference

ABBOTT, I.A. (1987). Some species of Gracilaria and Polycavernosa from Thailand. Unpublished manuscript.

SOME ASPECTS OF THE GROWTH OF *GRACILARIA TENUZSTZPZTATA IN POND* CULTURE

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ABSTRACT

The effect of temperature, salinity, nitrogen, culture density and depth on the growth of *Gracilaria tenuistipitata* were investigated between April 1985 and March 1986 in outdoor ponds in Guangxi Province, South China. The mean annual growth rate was 2.4% per day. Under favourable temperatures of 20-30°C, daily growth rate may reach as high as 3.3%. Salinity had an obvious effect on growth and photosynthesis, and growth peaked at 21 ppt, with a broad plateau between 7-27 ppt. Growth experiments showed that a total nitrogen (NH,- N plus NO,- N) concentration of 4 µm is sufficient to enable the plant to maintain a daily growth rate of 2.7%. The best growth of the plant was obtained at a culture density of 0.5-l kg/m^2 and a culture depth of 30 cm in the pond.

Introduction

Studies on *Gracifaria* are of special interest because of its increasing market value as a source of agar (ADB-FAO 1983), its importance in diet (Cordero 1984) and its significance as food in the cultivation of abalone (Chiang 1981). Recently, the demand for agar has steadily increased, while the supply of *Gracifaria* from natural populations has not. Consequently, cultivation of *Gracilaria* has begun to supplement harvests from natural populations (Mathieson 1975). The commercial beds of *Gracilaria* in China are so limited that the supply is unstable and cannot meet the ever-increasing demands (Tseng 1980). There are two varieties of *Gracilaria tenuistipitata* found along the coast of South China, *G.* tenuistipitata and *G. tenuistipitata* var. liui. Of these, the latter is mainly distributed in the north coast of Hainan Island and is far better than the former, because it grows faster and is adaptable to brackish seawater. *G. tenuistipitata* var. liui is, therefore, one of the most common species under pond cultivation in Guangxi and Hainan Provinces. The cultivation area once reached 1500 hectares, producing some 2000 tonnes dry weight and played an important role in agarophyte cultivation in China. Unfortunately, the growth rate sometimes fluctuated greatly. In serious cases, most of the plants in the ponds died for no obvious reason within a few days. The purpose of the work reported below was to determine the relationship between the main environmental factors and the growth rate and to find ways of overcoming the unusual deaths in order to stabilize and increase production.

Materials and methods

The effect of temperature, salinity, culture, density, depth and total nitrogen content of the ambient seawater on the growth of *G. tenuistipitata* var. liui were studied concurrently in outdoor ponds (l-1.5 m deep) in Guangxi Province, South China and in the laboratory in Qingdao from April 1985 to March 1986. Vegetative fragments of *G. tenuistipitata* var. liui were collected from the outskirts of Haikou city, Hainan Island. Pond culture experiments were carried out at Baihutou station near Beihai City, Guangxi Province, South China as follows:

1. *Temperature:* Triplicate samples of *Gracilaria* fragments 5-10 cm long weighing 500 g were cultured in a rectangular net cage in a depth of 0.5-1 metre. Measurements of weight were taken

every 15 days. growth rates were calculated and temperature monitored throughout the experimental period.

2. Salinity: Gracilaria were cultured in two ponds with different salinities using net cages similar to those used in the temperature experiments. The salinity of pond A was 30-34 ppt, and that of pond B was 24 ppt. Total nitrogen content of the two ponds was maintained at the same level by adding nitrogen fertilizer to pond A. Outdoor tank culture experiments and measurement of the effect of salinity on photosynthetic rate were conducted concurrently at Baihutou station and Qingdao Laboratory.

3. Nitrogen: Nitrogen nutrition experiments were conducted in three ponds in which the total nitrogen contents were different. Water samples were analyzed for ammonium-nitrogen (Gao. Zhang er al. 1980) and nitrate-nitrogen (Shi, Dai et al. 1980) periodically. Growth in fresh weight was also measured.

4. Culture, Depth And Density: Triplicates of 20 g of vegetative fragments were cultured in net cages at 30, 60 and 90 cam deptns respectively in a pond and increments in weight measured. At the same time. photosynthetic rates were measured by using the white-black bottle method. Culture density experiments were set up in two ecologically similar sites, each site covering an area of 30 m^2. The culture densities were 150 g/m^2 and 450 g/m^2 respectively. In each of the five plots selected at each site, a 0.04 m^2 net cage was used to culture Gracilaria at the same density. Fresh weight was measured every 15 days.

Results and discussion

1. Temperature

G. tenuistipitata grew in the experimental field all year round. The mean daily growth rate was 2.4% which meant that the weight was doubled each month. March to May and September to November were the months of maximum growth, with a mean daily growth rate of 3.3%. Growth during the remainder of the year was only 1.5%. In the course of the experiment, temperature ranged from 1.5-32°C. Minimum growth rates were recorded at both the lowest temperature (15°C) and the highest temperature (32°C). Optimum growth, which was over 2%, was achieved in the temperature range 20-30°C and this was considered to be the most favourable temperature for growth.

2. Salinity

After one month of experimentation the best growth of Gracilaria was obtained in pond B at a salinity of 24 ppt. The weight of G. tenuistipitata in pond B was 1.3 times higher than that in pond A. This demonstrates that salinity is an especially important factor influencing the growth of this alga. Results obtained from tank culture shown in Table 1 indicate that growth peaked at 21 ppt, with a broad plateau between 7 and 27 ppt. Decolorization of apical segments occurred at 3 ppt salinity within two days, and necrosis appeared after four days. At higher salinities, for example at 34 ppt, segments grew branches that were slender and soft, whereas at 47 ppt segments became discoloured after two weeks.

Table 1: Growth in weight as a function of salinity

Salinity (‰)	Fresh weight (g)	
	1 week	2 weeks
3	–	
7	26.3	29.5
14	27.1	33.2
21	29.1	35.2
27	26.2	32.0
34	25.0	28.1
40	24.2	26.6
47	23.7	26.0

Maximum photosynthetic rate was obtained at 21 ppt and was not markedly affected when the salinity was reduced to 14 ppt or increased to 27 ppt. Under different light intensities, the photosynthetic rates of the alga cultured at 21 ppt salinity were higher than those at 7 ppt and 40 ppt. These data indicate that 21 ppt is the optimum salinity for growth, and confirm the fact that this species is euryhaline and grows well in estuaries where salinity is low and nitrogen content is high.

3. *Nitrogen*

Fresh weight was measured after one month of experiment and the results are given in Table 2.

Table 2: Effect of total nitrogen concentration on growth rate

NO,- N + NH4- N (µm)	Mean daily growth rate (%)
2.97	1.5
3.99	2.7
4.36	3.1

It is apparent that mean daily growth rate increased with the increase of N concentration up to 4.3 µm. Although the growth of *G. tenuistipitata* did not saturate within the concentrations used in this experiment, a high growth rate of 3.1% was attained. It is therefore suggested that in order to support a high growth rate in pond culture a nitrogen level of about 4 µm is desirable.

4. *Culture depth and density*

The pond used for the culture depth experiment was l-I.5 m deep with two openings for the exchange of water. The depth of pond water was usually kept at l-l.2 m. Tables 3 and 4 show that growth and photosynthetic rates increased significantly with decreasing cultivation depth up to 30 cm.

Table 3: Relationship between growth rate and culture depth

	30 cm		60 cm		90 cm	
Culture time (days)	Fresh wt (g)	Daily increment (%)	Fresh wt (g)	Daily increment (%)	Fresh wt (g)	Daily increment (%)
8	26.1	3.3	25.2	2.9	24.9	2.6
15	30.6	2.3	29.6	2.3	25.1	0.1

Table 4: Effect of culture depth on photosynthetic rate

Depth (cm)	30	60	90
Light intensity (pE.m? sec[1])	250	208	156
Photosynthesis rate (mgO_2.gdw$_1$ hr,)	5.21	4.28	3.25

This coincides with Lapointe's (1981) result that G. *foliifera* did not saturate within the light intensity used in his experiment at maximum levels of natural irradiance. The possible reason for the high photosynthetic efficiency of *Gracilarin* (Lapointe and Ryther 1978) is its ability to utilize maximum levels of natural light.

Data in Table 5 show that growth rates of the two culture density treatments were similar, but increments in weight were very different within 30 days. Thereafter, differences between treatments were apparent.

Table 5: Effect of culture density on growth rate

Culture time (days)	A. Culture density 150g/m^2			B. Culture density 450g/m^2		
	Fresh wt (g/m^2)	Increment (fw.g/m^2)	Daily growth rate (%)	Fresh wt (g/m^2)	Increment (fw.g/m^2)	Daily growth rate (%)
15	270	120	3.9	787	337	3.7
30	372	102	2.1	1000	213	1.8
45	500	128	2.0	1292	292	I.4

Growth rate of treatment B decreased as the density increased to more than 1000 g/m^2, but the increment per unit area was still higher than that of treatment A, because of the high biomass. The experiment indicated that higher culture density in every case increased seaweed production. It is therefore suggested that a density of 500-1000 g/m^2 is suitable for this kind of pond culture.

References

ADB-FAO. (1983). Second Fish Market Study. The world seaweed industry and trade. 6: 3-30.

CHIANG. Y.M. (1981). Cultivation of Gracilaria (Rhodophycophyta. gigartinales) in Taiwan. Proc. Int. Seaweed Symp.10: 569-575.

CODERO. P.A.. JR. (1984). Economic uses of seaweeds in the Philippines. In: First Philippines – US Phycology Workshop Seminar Report. Oct.24-Nov.5, 1984. Manila and Dumaguete. Philippines.

GAO FENMING, ZHANG SHUHUA el. al. (1980). Sodium hypobromite oxidation method for determination of ammonium-nitrogen in seawater. Transactions of Oceanology and Limnolugy 4: 41-56.

LAPOINTE, B.E. (1981). The effects of light and nitrogen on growth. and biochemical composition of Gracilaria foliifera V angustissima (Gigartinales, Rhodophyta). J. Phycol. 17: 90-95.

LAPOINTE. B.E. AND RYTHER. J.H. (1978). Some aspects of the growth and yield of *Gracilaria* likvahiae in culture. Aquaculturc. 15: 185-193.

MATHIESON. A.C. (1975). Seaweed aquaculture. Mar. Fish. Rev. 37: 2-14.

SHI ZHILI, DAI GUOSHENG et. al. (1980). Determination of nitrate in seawater hy cadmium-copper reduction method. Jour. Shandong College of Oceanology. 10(3) : 53-63.

TSENG. C.K. (1981). Marine phycoculture in China. Proc. Int. Seaweed Symp. 10 : 123-152.

WU ('HAOYUAN, ZHANG YANXIA, LI RENZHI, PENG ZUOSHENG. ZHANG YINGFANG. LIU QINGCHEN, ZHANG JINGFU AND FAN XIAO (1984). Utilization of ammonium-nitrogen by Prophyra yezoensis and Gracilaria verrucosa. Hydrobiologia, 116/l 17: 475-477.

SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

THE DEVELOPMENT OF COMMERCIAL-SCALE *GRACILARIA* FARMING IN SULAWESI, INDONESIA

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ABSTRACT

Gracilaria verrucosa was located in 1986 in coastal areas of south Sulawesi, Indonesia. A local company started venturing into Gracilaria culturing and encouraged farmers to take up seaweed culture in abandoned shrimp ponds. The same company exported 60-80 tonnes of Gracilaria per month in 1989. A plan for constructing a processing plant able to consume 50-100 tonnes of raw material per month is under way.

Introduction

Prawn fever started in Indonesia in early 1980. South Sulawesi, with its large area of brackish-water ponds, was no exception. Seventy thousand hectares have been developed out of a potential 150,000.

When we started our company in 1986 and looked at supply and demand, we had our doubts about prawn farming. After all, if every one was going into prawn production, over supply and price declines were only a matter of time. Thus, we began to look at other resources and decided to go into Gracilaria farming.

Another consideration was that Gracilaria can be grown together with prawns, In fact, we found Gracilaria growing naturally in abandoned prawn ponds: further confirmation that the two could be cultured together.

Our company charter mandates a social function. Consequently, we wanted to involve low-income people of the province in seaweed farming.

Prawn prices have dropped in recent years, encouraging farmers to look to seaweed as an alternative source of income requiring little additional investment. Many shrimp farmers are heavily mortgaged and short of capital.

2. Gracilaria development in south Sulawesi

As of 1986, there was no Gracilaria culture in south Sulawesi. Nevertheless, 1,400 tonnes of seaweed harvested from wild stocks were exported during the same year. This consisted mostly of Eucheuma spinosum. There were also orders for Gracilaria from Japan.

We decided to culture Gracilaria, but at the time we did not know much about culture technology. We found difficulty locating seed stock and began with material from Chile, originating from export quality parent stock. But finally, after surveying the coast of south Sulawesi, we located good material near Ujung Pandang at Tanjung Bunga. This Gracilaria produced agar similar to that of the Chilean species. We also found similar seed stock in the Janeponto district. Eventually, we found that the species was Gracilaria verrucosa. Concurrently, in 1986, the University of Hasanuddin, at Ujung Pandang, the Regional Planning and Development Bureau of south Sulawesi and the Fisheries Department of south Sulawesi began investigating Gracilaria and we are now working together to develop pond culture of Gracilaria.

We set up our first pilot project in a 10 ha pond area at Tanjung Bunga. Our company provided seed stock, gave training seminars and paid for maintenance and operation costs. The pond owner only observed our activities at the beginning. Once we developed the technology, the owner took over and we purchased the seaweed from him. After harvesting Gracilaria in September 1986, we decided to transplant seed stock to Takalar. Unfortunately, the rainy season began in the area the following December and affected seaweed growth. But since it was the dry season along the coast of the Gulf of Bone to the west, we decided to take some of the Gracilaria from our initial site to Sinjai. Our activities at the original site were reduced to maintenance of the existing stocks and transplantation to new ponds. When we started seaweed farming, we were interested in locating seedstock, and were not really aware of the weather pattern in south Sulawesi. Now we know how to use this unique climatic pattern to maintain year-round production.

In addition to the challenge posed by climate, the company encountered problems in finding farmers willing to take up seaweed culture. In 1986 prawns fetched good prices, but some farmers unable to succeed with prawn culture were interested. However, they had doubts about marketing-who would buy their production? So we began work with these farmers, providing free seed stock and distributing brochures on farming methods. They still remained sceptical, but our persistance has paid off and farmers who seriously took up Gracilaria farming in their defunct shrimp ponds are gradually improving their living standards.

3. Export development

Eight months after the company started distributing seed stock, we harvested 110 tonnes wet weight. Ten tonnes were set aside as seed stock and the remainder converted to 10 tonnes of dried seaweed.

After Japanese buyers accepted our product we sent off our first export shipment. Three months later, the company exported 10 tonnes of dry Gracilaria.

In April 1988, we exported another 20 tonnes. Luckily for us, Gracilaria farming is picking up in several areas with some farmers developing new ponds for seaweed culture.

Now we have another problem-traders trying to muscle into our business and manipulate the price. But our good relationship with our farmers has protected us from such speculators, who are to be found in any business.

4. Our stable period

In the beginning we were dependent on farmers whose production output was variable. In order to stabilise production, we decided to develop our own ponds. This would enable the company to develop the best culture technology and operate to its own standards.

In December 1988, we rented a pond of 6.8 ha from a farmer. Although not too large an area, it enabled us to produce more seed stock for distribution to interested farmers.

By the beginning of 1989, our business started to show good prospects and we decided to buy a 20 ha pond in Takalar Regency. We can now harvest 20 tonnes of dried Gracilaria every two months which translates into 10 tonnes dry weight every month. Production has now stabilized.

A new factor entered the scene in March 1989, when prawn prices on the world market started falling. Now, farmers are getting more interested in Gracilaria because they are looking for alternative crops. Many farmers are asking us how to grow seaweed and are even willing to buy seed stock. Trade in seedlings of Gracilaria is building up, which reduces our costs since we have to supply less seed stock to get the farmers started. Increased availability of seed stock means production will increase.

Since the middle of 1989, we have been able to export 60-80 tonnes of Gracilaria per month. We are now developing a seeding strategy to enable year-round stable production.

5. Further development

Because Gracilaria farming is taking off in south Sulawesi, the company will develop new sites in southeast Sulawesi and some sites further east. In southeast Sulawesi we are constructing ponds on a 200 ha site. Full development of the site will allow us to harvest SO tonnes of dry Gracilaria per month.

Culture methods will differ from those in south Sulawesi because we are working in new ponds. Acidic soil has forced us to wash out pyrites by cyclically pumping water out of the pond and refilling.

Based on our past success and bright prospects, the company will construct an agar processing plant in the region. It will consume 50-100 tonnes of raw material per month, hence our expansion into pond culture. Locating the plant in the production area will reduce transport costs and expand market outlets for the farmers.

6. Conclusions

Gracilaria farming in Sulawesi has a bright future. Involving local farmers reduces the company's costs, and while the company is developing new farm sites we will continue to involve them. But to stimulate further interest on the 'part of farmers, farm gate prices will have to be raised. We expect overseas buyers to raise their prices instead of having a situation similar to that of the falling price of prawns. We would also like to co-operate with international organizations to do more research. Raw material can be semi-refined in processing plants.

7. Acknowledgement

We want to thank the following organizations for contributing to our success: Regional Planning and Development Bureau of South Sulawesi; Department of Fisheries of South Sulawesi; University of Hasanuddin at Ujung Pandang; UNDP (through Mr Leroy Hollenbeck); Bank Rakyat, Indonesia; Ministry of State for Research and Technology (through Mr Jana Anggadiredja); and FMC Corporation · Marine Colloids Division.

SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

PRELIMINARY OBSERVATIONS ON THE CULTURE OF *GRACILARIA EDULZS* USING SPORE-SETTING TECHNIQUES

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ABSTRACT

While very little work has been done in Sri Lanka on vegetative culturing of Gracilaria edulis, practically no work has been done on culturing Gracilaria by using spores. This paper presents preliminary results obtained during the culture of Gracilaria, using carpospores of the plant. Of the different substrata tested for spore setting, synthetic rafia cleaned in freshwater was the most successful. The plant's growth rate showed a positive correlation with low salinity.

Introduction

The growing interest in the development of the seaweed resource is primarily due to the recognition of its economic importance as a source of food, as **raw** material for the manufacture of commercial products such as agar, alginates and carrageenan and as an additional source of livelihood for communities that inhabit the coastal areas.

Grucilaria reproduces both vegetatively and by sporulating. Whilst some work has been done on culturing Gracilaria sp in Sri Lanka from vegetative fragments (Sivapalan 1975; Sivapalan and Theivendirajah 1985). until now no work has been attempted in Sri Lanka on culturing Gracilaria by sporulating.

A joint NARA/BOBP project at Kalpitiya has been attempting to culture Gracilaria using spore setting techniques. These techniques were earlier tested in a similar BOBP Project in Malaysia (BOBP, 1987). Trials began in August 1988 and some of the preliminary results are presented here.

Methodology

An experimental hatchery was set up at Etalai, adjoining the Puttalam lagoon. Two cement tanks were fed from the Puttalam lagoon using a pump and a filtering mechanism. Water was pumped UP to a level of 20 cm from the bottom of each tank. During each spore setting, 6 kg of female Gracilaria (Carposporophyte) collected from the lagoon were cut into pieces and sprinkled over a net floating inside the cement tanks. Twelve frames (40 x 80 cm) made out of polyvinyl chloride pipes were set at the bottom of each tank. Synthetic rafia, synthetic rafia cleaned with fresh water, monofilament lines and coir ropes were tested as substrate lines for spore setting on the frames.

The frames were made out of each type of substrate lines, and all of them were kept in the tanks for three nights. One of the tanks was given extra light for four hours each night. Glass slides were kept on the frames of both tanks to examine whether there were any spore settlements. These slides were examined every day under a microscope. Frames with spore settlement were removed from the tanks, and were submerged in the lagoon and allowed to grow. Growth of the plants after successful spore settlement was monitored by counting the number of plants on the frames and measuring their length randomly. Frames with high growth of Grucilaria were harvested (cropped) after six months. After harvesting, the length of the plants was measured regularly to monitor further growth.

The salinity, temperature and pH were monitored. A hand-held refractometer and HACH salt water test kit were used to measure salinity (in parts per thousand) and pH respectively. Other environmental parameters **such** as nutrients NO_2^-, NO_3^-, NO_4^+ were monitored once a fortnight.

Results

A total of 24 frames (12 from each tank) were placed in the lagoon after successful spore settlement. During the first three months there were no indications of growth in the plants on the frames. Twenty frames were observed **to have** *Gracilaria* plants after three months. Some of the frames were found to have fallen to the bottom of the lagoon and were covered with mud. There were no plants on these frames. Plants on some of the frames which were in deeper water showed stunted growth.

A comparison of the performance of the frames in the two tanks is presented in Table 1. A larger number of plants were observed on the frames kept in the tank supplied with normal light hours.

Table l : Average number of plants in each type of frame

		Average number of plants/frame			
Tank No	Treatment	Rafia	Cleaned rafia	Coir	Monofilament
A	extra light hours (6-10 p.m.)	5	10	2	8
B	normal light hours	67	150	25	20

Of the different types of substrate lines tested, rafia frames cleaned with fresh water were the most successful, averaging 150 plants per frame with a maximum of 235 plants in one frame.

The growth of plants was also best on this substrate (Table 2). Coir ropes showed some plant growth but also had extensive sediments attached to it. These were also found to be of low durability. Growth of plants on other materials tested was very low.

Table 2: Average length of the plants (cm) in each type of frame after 3 months

	Average length of the plants (cm)			
Tank No	Rafia	Cleaned rafia	Coir ropes	Monofilament ropes
A	4	5	3	4
B	12	30	5	6

Monthly variations of pH, nutrients and salinity were also shown throughout the culture period (Table III). After the initial harvest, the plants attained an average length of 30 cm in four months, a growth rate of 0.25 cm per day.

Table 3: Average monthly values of pH and salinity throughout the culture period

Month	Salinity ppt	PH
August 1988	44	8.3
September	45	8.5
October	41	a.3
November	41	8.5
December	40	8.5
January 1989	40	8.6
February	39	8.4
March	40	8.4
April	41	8.5
Mav	42	8.5

Discussion

These preliminary investigations show that spore-setting techniques could be considered as a feasible method for culturing *Gracilaria* species. Low light-intensity and sedimentation may have affected the growth of plants on frames that were at the bottom and in deeper waters.

The fewer number of plants observed on the frames placed in the tank subjected to extra light hours confirms the observation of Rao (1976). Spore emission from Gracilaria edulis is highest during the night, and the reduction of dark hours may have caused the reduced emission of spores in the tank provided with extra light hours.

Even though the frames were transferred to the lagoon in August, small plants were not visible on them until late October. This could be due to one of two factors; either the growth of germinated spores was very slow, or natural spore setting could have taken place. However, controls introduced in subsequent trials ruled out natural spore-setting. Since there were no drastic fluctuations in other factors such as pH and nutrient values, changes in salinity may have affected growth of the plants. In August 1988, a salinity level of 44 ppt was recorded (Table III). In October, it decreased to 41 ppt, and this lower salinity could have influenced the germination of spores and the growth of the plants.

Of the substrates tested for setting, rafia cleaned in freshwater was the most successful. The number of plants observed on rafia cleaned in fresh water was double that found on untreated rafia. It is not certain whether there was a difference in the intensity of spore settlement between the two.

Correlation of Gracilaria growth with salinity indicates that the plants grow best in a salinity of less than 40 ppt. Plant growth was drastically affected above a salinity of 45 ppt. There was very little variation in the other environmental parameters such as pH, nutrients and temperature during this culture period. Therefore, the effects of changes in these parameters on the growth of seaweed could not be ascertained.

In this study, Gracilaria edulis attained a growth of 30 cm in four months, averaging 0.25 cm per day. A previous study in Jaffna lagoon (Sivapalan and Theivendirajah 1985) attained a growth of 12 cm from 2 cm fragments in 8 weeks, a growth rate of 0.18.

Several spore setting experiments were carried out subsequently, but very few plants were observed growing. This may be due to the low percentage of female plants in the seed material, and also to the high salinities in the lagoon water caused by the prevailing drought.

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References

BOBP (1987). Experimental culture of seaweeds *(Gracilaria* sp) in Penang, Malaysia. BOBP/WP/52 (Based on a report by Maxwell Doty and Jack Fisher), Madras, India. August 1987.

RAO UMAMAHESWARA. M. (1976). Spore liberation in Gracilaria corticata J. Agardth &owing at Mandapam. J. exp. Mar. Biol. Ecol.. 1976. Vol. 21: 91-98.

SIVAPALAN. A. (1975). Cultivation of *Gracilaria lichenoides* in Puttalam lagoon. Bull. Fish. Res. Stn. Sri Lanka Vol. *26* Nos. 1 and 2: 1-3

SIVAPALAN. A. AND THEIVENDIRAJAH, K. (1985). Studies on agarophyte. Grucilaria edulis. Experimental field cultivation and methods of improving yield and quality of agar. J. Natn. Sci. Coun. Sri Lanka 1985. 13(2): 197-212.