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NATIONAL SYMPOSIUM ON RESEARCH AND DEVELOPMENT IN MARINE FISHERIES

MANDAPAM CAMP
16-18 September 1987

Papers Presented
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(Indian Council of Agricultural Research)
P. B. No. 2704, E. R. G. Road, Cochin-682 031, India

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Limited Circulation

SEAWEED CULTURE IN INDIA-AN APPRAISAL

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ABSTRACT

In recent years there has been a steady increase in the demand for naturally occuring seaweeds as a result of many seaweed based industries coming up. In order to meet the raw material requirement of these industries attempts have been made in this country to develop suitable seaweed farming techniques by some institutes notably the CMFRI at its Mandapam Regional Centre and CSMCRI at its field centre, Mandapam. Experimental culture of economically important seaweeds such as *Gracilaria edulis*, *Gelidiella acerosa* and other species was undertaken since 1972 at Mandapam. In these experiments production rates ranging from 3 to 8 times the initial wet weight were obtained. The techniques of seaweed culture, the favourable seasons optimum duration of culture period and the influence of environmental parameters are discussed in this account with notes on economics of seaweed culture. General information on the seaweed resources along our coasts, their potential for exploitation and culture are also highlighted.

INTRODUCTION

Many commercially important species of seaweeds belonging to the groups Chlorophyta, Phaeophyta and Rhodophyta occur naturally in varying degrees of abundance in shallow bays, lagoons and coastal areas which offer suitable substrata for their growth and propagation. In India, the Gulf of Mannar, Palk Bay, Gulf of Kutch, Lakshadweep and Bay islands are the important areas having considerable natural resources of seaweeds.

Apart from their utility as a source of food, food derivatives, vitamins, proteins etc, seaweeds provide the raw material for many agar-agar and algin based industries. In view of the constant demand for the seaweeds, research programmes on seaweed resources and their culture were taken up by the Central Marine Fisheries Research Institute and Central Salt and Marine Chemicals Research Institute at Mandapam at their Regional and field centre respectively and various other research organisations belonging to the State Fisheries Departments/Universities as at Port Okha and Ratnagiri. As regards seaweed farming experiments were mainly carried out with species of *Ulva*, *Gelidiella acerosa*, *Gracilaria edulis*, *Gracilaria corticata*, *Gelidiopsis variabilis*, *Gelidium pusillum*, *Hypnea musciformis*, *Acanthophora spicifera*, *Hormophysa triquetra*, *Cystoseira* and species of *Sargassum*. The experiments were mainly conducted by the method of vegetative propagation. Some trials were made with spores as well. An appraisal of these farming techniques is presented in this account.

Culture of G. acerosa

Bhanderi (1974) cultured the apical region of the *Gelidiella acerosa* by inserting these fragments in a string and suspended in a seawater aquarium at Port Okha, Gujarat. He observed a linear growth of 0.01 cm/day and an increase of 0.01 g/day in weight. Krishnamurthy *et al.* (1975) conducted some experiments with 2 cm fragments of *Gelidiella acerosa* in a lagoon on the southern side of Krusadi Island. After four months, the fragments grew to full sized plants of about 10 cm in length with seven to eight branches.

In the same area Subbaramaiah *et al.* (1975) carried out experiments on 2 cm length fragments of *G. acerosa* fastened to a nylon string at fixed intervals and the seeded string was wound round a rope kept submerged in coastal waters. The maximum growth attained was 6.6 cm and the rate of production was 3.13 g/m/month (wet). The total production of seaweed was 421 g/m (wet) in a year.

Experimental field cultivation of *G. acerosa* using submerged coral stones as the substrata was done at Ervadi (Patel *et al.*, 1979). An annual yield of 115.83 g/m²/day (dry) on over all basis was obtained which was 33 times over the seed material. Patel *et al.* (1980) reported a maximum yield of 122 g/m² (dry) in one of their six monthly harvests made in January 1979 from the field cultivation of *G. acerosa* at Ervadi.

Culture of G. edulis

Raju and Thomas (1971) cultured *G. edulis* by long line rope method in a sandy lagoon in Krusadi Island. Fragments of 1 cm and 2.5-3 cm length were used for planting and they grew to a length of 35-40 cm in about five months period. Three harvests were made at the end of 5, 8 and 10½ months and the total harvest during the year was about 3.5 kg per 1 m length of rope.

Krishnamurthy *et al.* (1975) carried out cultivation of *G. edulis* in a lagoon in the Krusadi Island. Fragments of 2.5 cm length were introduced in the twists of the ropes, which were tied to bamboo poles planted to the sea bottom. In about five months period the plants attained a length of 30 cm and the average weight of plant was about 300 g. A total of three harvests were made in a period of 10 months.

Culture of other red algae

Bhanderi (1974 b) recorded a linear increase of 0.02 cm/day and an increase of 0.07 g/day in weight in his culture experiments on *Gracilaria corticata* in seawater aquarium. In experiment with *Gelidiopsis variabilis* he obtained a linear increase of 0.12 cm/day with an increase in weight of 0.04 g/day.

Mairh and Sreenivasa Rao (1978) cultured *Gelidium pusillum* in the laboratory under free floating conditions and using nutrient enricher and obtained maximum fresh weight and full size within three to four months. Rama Rao and Subbaramaih (1980) cultured *Hypnea musciformis* and obtained four fold increase in 25 days.

Thivy (1964) conducted culture experiments in ponds at Porbandar by attaching small plants of *Sargassum cinctum, S. vulgare* and *S. wightii* to coir nets with the help of tape. The plants grew to a height of 15-52 cm for an initial 5-10 cm length within forty days.

Bhanderi and Trivedi (1977) made an attempt to study the possibility of culturing *Hormophysa triquetra* by vegetative propagation in an aquarium. The fragments gained 7 times (fresh weight) over the initial weight at a rate of 0.333 g/day.

Seaweed culture experiments at CMFRI

The Central Marine Fisheries Research Institute at its Regional Centre at Mandapam, conducted culture experiments especially with *Gracilaria edulis* and *Gelidiella acerosa*. In seawater aquaria *Gracilaria corticata* was cultured (Umamaheswara Rao, 1973) which showed an increase in length from 1.8 to 5.5 cm in 90 days. Experiments with *Gracilaria edulis* in 0.5 m² coir nets yielded very good results. The average height of the plants varied from 14 to 16 cm at the end of two months and the fragments gained a weight of 213 and 257 g respectively. Experiments conducted in 4 x 2 m size coir rope nets yielded 4.4 kg (fresh wt.) of seaweed per square metre in 80 days (Umamaheswara Rao, 1974 a).

The culture experiments were conducted by introducing fragments of the seaweed into the twists of the coir ropes which in some cases were fabricated in the form of nets of different sizes-which in turn were tied to wooden poles fixed in the coastal waters (Fig. 1—4.)

Experiments conducted in the submerged floating condition (Chennubhotla *et. al.*, 1978) proved to be more beneficial than that at sub-tidal level.

The cultivation was attempted at slightly deeper waters i. e 3-4 m depth on HDP rope nets to avoid intensity of sedimentation and grazing by fish. The yield obtained was about 4 times the initial weight after 70 days. Chennubhotla *et al.* (1977 c) cultured *G.acerosa* by tieing small fragments along with

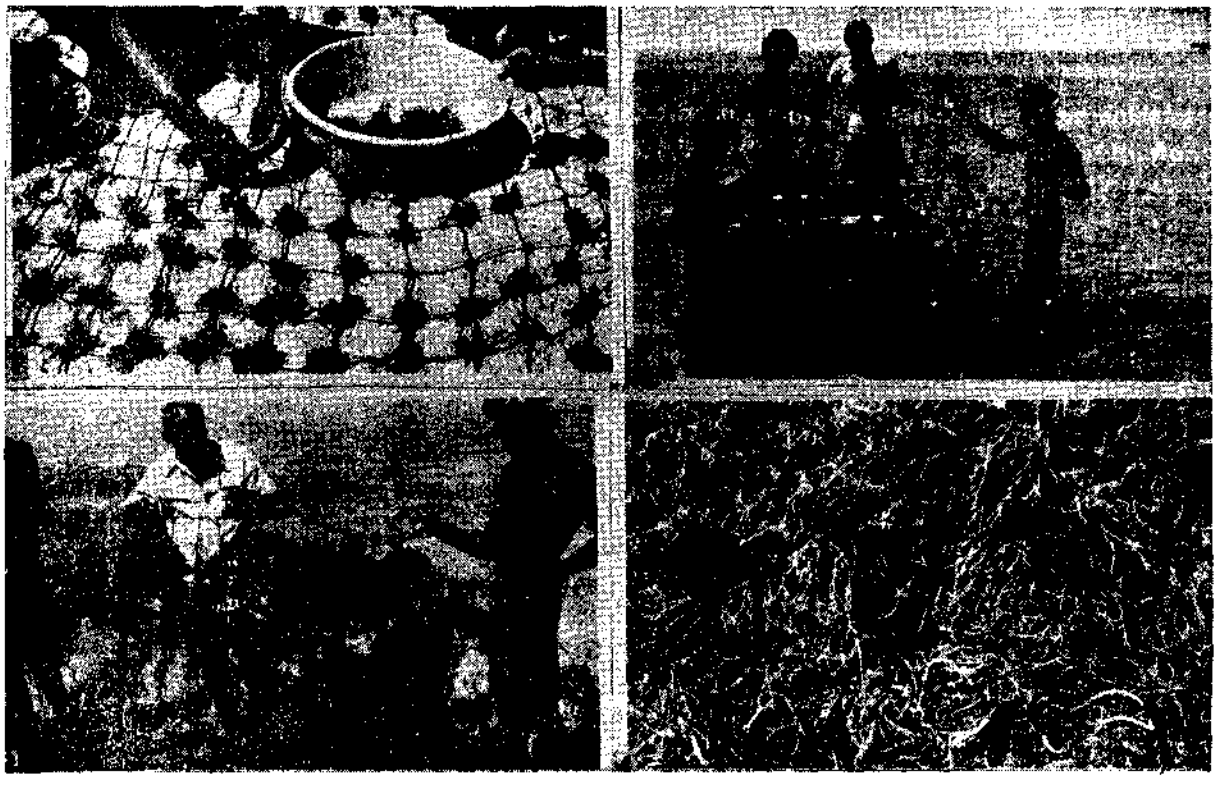

Fig. 1 Seaweed material being seeded in the net; Fig. 2 Seeded net being introduced into the inshore waters; Fig. 3 Cultured seaweed after 30 days growth; Fig. 4 Cultured seaweed after 60 days growth.

substratum (coral piece) to the coir ropes in the net. One frame was introduced with 0.9 kg and the other with 1 kg seed material. An yield of 2.5 and 3 kg were obtained respectively after 76 days.

Experiments conducted by keeping the *G. acerosa* seeded coral stones kept in cages were introduced in 2 and 4 m depth. The growth of the seaweed was found to be very luxuriant.

The culture was attempted by fastening fragments of *G. acerosa* to coral stones with the help of iron nails, reached harvestable size after 5 months and 1 kg of seed material yielded 3.1 kg of fully grown plants.

Fragments of *Sargassum wightii* obtained from the basal portion of plants with holdfast were inserted in the twists of the coir ropes and cultured in inshore waters of Gulf of Mannar at 1 m depth in mid water level. An average growth of 15.5 cm was recorded from an average initial length of 7.7 cm within 60 days. (Chennubhotla *et. al.*, 1976, unpublished).

Cultivation of *Acanthophora spicifera* was carried out on two HDP rope nets in 60 x 30 m size ponds, which are connected through a feeder canal to the sea. An average yield of 22.615 kg (wet weight) was obtained after 45 days from the two nets which was found to be 3.6 times the initial seed material. The remnants were allowed to grow for the second harvest which was made after 35 days. An average yield of 14.4 kg was obtained in the second harvest.

Experiments of *Ulva lactuca*, pre-treated with ascorbic acid were carried out in the seawater of different salinities in the laboratory. It was observed that the trials with 18‰ salinity boosted up the production to eight times in 92 days.

Culture of spores

The number of spores produced by an alga is enormous. In nature only a small number

of spores grow to mature plants since viability, settlement and development of these spores are controlled by hydrobiological factors such as water movement, tidal-exposure, water temperature, competition for space and predators or grazing organisms. When the spores are raised into germlings on suitable substrata in the laboratory or nursery and then transplanted to the field, a high rate of germlings grow to harvestable size plants. Some work in this direction of culturing the spores of economically important seaweeds was carried out in recent years.

Subbaramaiah *et al.* (1967) cultured germlings of *Ulva lactuca*. The germlings were kept growing in attached or in a free floating condition in petridishes containing sterile seawater which was changed once a week. In two months time the germlings differentiated into cylinderical plants with 2-3 branches arising from the basal cells. The floating plants were found to be longer (1.25-1.7 m) and produced branches while the attached ones were shorter (0.75-0.83m).

The effect of different culture media on growth and sporulation of laboratory raised germlings of *Ulva fasciata* was given by Oza and Sreenivasa Rao (1977). Kala and Krishnamurty (1967) studied the effect of plain seawater, Erdschreiber seawater and artificial seawater medium (modified ASP-6) on the growth of germlings of *Ulva lactuca* var *rigida*.

Mairh and Krishnamurty (1968) observed 100% germination of spores of *Cystoseira* and subsequently 94% of their survival. The germlings survived and grew to young and healthy plants under experimental conditions. Chauhan and Krishnamurthy (1967) cultured the oospores of *Sargassum swartzii* in petridishes lined with filter paper. They developed into germlings and some of them grew for a period of five weeks. Experiments were also conducted using different substrata such as coral pieces, shells, granite stones, nylon threads and rough stones. Some of the oospores attached to the substrata developed into healthy germlings while a large number did not survive. Continuous illumination of the culture experiments with a light intensity of 600-800 lux, 23-26°C temperature and circulation of a thin stream of filtered seawater were found favourable for healthy growth of germlings. Chauhan (1972) observed the survival of germlings in *Sargassum swartzii* for about six months under the controlled laboratory conditions. Of the eight different substrata used, the concrete blocks, bricks and filter paper were found to be good substrata as they retained 84.55%, 78.42% and 62% of the germlings respectively. The filtered seawater and enriched seawater were found to be most suitable culture media for the growth of germlings. The use of media like ASP-6 and ASP-12 did not give good growth of germlings. Continuous illumination was found to be more beneficial than 18 hours photoperiod.

Raju and Venugopal (1971) made an attempt to allow the oospores of *Sargassum plagiophyllum* to settle on a concrete substratum with a view to find out the time required for the appearance and growth. The concrete cylinders were lowered in *Sargassum* beds. Observations revealed that the appearance of *Sargassum* germlings on the cylinder took 10 months and another 8 months to grow to maturity. Observations after one year revealed that there were a number of new plants which had germinated from the spores within the year and some had regenerated from persisting holdfasts. There appear to be potentiality for regeneration for a third year in a few plants. Umamaheswara Rao and Kaliaperumal (1976) maintained the oospores of *Sargassum wightii* in a medium of seawater enriched with agar-agar and found that 47.6% of germlings were in healthy condition at the end of 60 days. Krishnamurthy *et al.* (1969) raised the germlings of *Gracilaria edulis* and *G. corticata* on a nylon fabric from carpospores under laboratory conditions. They were transferred to the sea. After four months, young plants appeared and they took another four months to attain maturity and develop reproductive structures.

Chennubhotla *et al.* 1977 (unpublished) conducted laboratory culture experiments on the viability, germination, growth of germlings

of *Turbinaria ornata* and *Gracilaria edulis* under controlled temperature of 18±2°C and light intensity of 4 R lux. The spores of *T. ornata* were found to be viable even after a period of 2 months, but growth of germlings was not satisfactory. Carpospores of *G. edulis* were allowed to germinate and parenchymatous stage of development was noticed.

It is understood tha UNDP/BOBP programme at Madras has embarked on culture of seaweeds by tetraspores in Mandapam-Vedalai area. This may throw light on the aspect of spore culture in the natural environment.

Environmental factors in relation to seaweed culture

In the Central Marine Fisheries Research Institute, the culture experiments were conducted in different seasons of the years from 1976 to 1985 continuously. Although there were variations with respect to the quantity of seed material introduced, the yield rate showed fluctuations during certain seasons. In order to understand these variations, relevant environmental data were collected from the inshore waters where culture operations were carried out.

The average values of each environmental parameters such as surface temperature, salinity, O_2 and nutrients during each culture operation were compared in relation to biomass increase and duration of culture period (Table1). It was observed that no single environmental parameter could be pinpointed as responsible for variation in production. At best it could be inferred that a complexity

Table 1. *Data on seaweed production and related environmental factors*

Year	No. of days of culture operation	Initial weight of seed material (in Kg)	Final weight (Kg)	Ave.gain of seed/ day	Mean values of hydrological data						
					Surface Temperature (°C)	Salinity (‰)	O_2 ml/l	Po_4	No_3 µg-at/l	Sio_6	pH
1976	40	0.90	4.00	0.0775	28.6	29.16	4.57	0.29	0.49	12.59	8.2
Gulf of Mannar	30	1.00	4.30	0.1100	27.7	32.79	4.65	0.45	0.53	8.25	8.2
1977 Gulf of Mannar	88	34	162.17	1.4565	27.3	30.31	4.38	1.55	0.15	0.73	8.13
1979 Gulf of Mannar	60	1800	4.70	48.3300	29.68	32.03	4.59	2.78	12.10	3.65	8.18
1980	90	6.65	16.17	0.1058	29.48	35.29	4.59	0.59	3.13	6.36	8.20
Palk Bay	70	560	733.70	2 4814	28.69	31.76	5.17	0.82	9.85	18.11	8.10
1984-85 Gulf of Mannar	60	2.4	7.50	0.0850	27.3	30.00	4.95				7.9
1985 Gulf of Mannar	55	1.80	9.50	0.1400	29.3	29.72	5.51	0.12	0.44	60.00	7.4

of environmental factors operating in a dynamic inshore area may be responsible for seasonal variation in the yield of seaweeds. The Gulf of Mannar & Palk Bay experience contrasting seasonal changes in wind velocity and direction and wave action. The solar radiation in the region, rainfall, transport of inorganic and organic material into the region are some of the factor other than those observed parameters.

Survey of seaweed resources

The surveys conducted in various maritime states have revealed that the resources of seaweeds along our coasts can be put around 1 lakh tonnes. The break-up figures are given in table 2.

The seaweeds along Indian cost are mainly harvested by small as well as large scale industrialists by engaging drivers. Seaweed collection is a profession by itself and offers employment to rural population. There are a number of agents who deal directly with the collection and supply of seaweeds to the industries. The methods of collection of seaweeds are very crude at present and hence extension work is very essential to educate the people in colletion and management of the natural beds in a judicious way.

Economics of seaweed culture

In view of the importance of marine algae as a source of food, fodder, fertilizer and pharmaceutical compounds, augmentation of this resource by different methods has to be undertaken. The economics worked out by the Central Marine Fisheries Research Institute indicate that atleast a minimum of Rs. 500/- per month accrues to the farmer by taking up cultivation in one hectare area.

Culture experiments conducted in the inshore coastal waters from 1972 to 1986 in Gulf of Mannar and in Palk Bay have revealed that on the culture frames the agarophyte *Gracilaria edulis* reaches the maximum length (harvestable size) within three months while in nature it takes 4 to 5 months time.

These studies have further indicated that the minimum period for the seed material to reach harvestable size is 2 months for *G. edulis* and that the length of the algae at the time of harvest world be 20 to 25 cm. The suitable period for carrying out the culture operations

Table 2. *State-wise annual yield of seaweeds.*

Stn. No.	Area	Annual yield in tonnes (fresh weight)	References
I	Tamil nadu	22,044	Subbaramaiah *et. al.* (1979a)
II	Gujarat	20,000	Chauhan and Krishnamurthy (1968) Bhanderi and Trivedi (1975) Sreenivasa Rao *et. al.* (1904) Chauhan & Mairh (1978)
III	Maharashtra	20,000	Untawala *et. al.* (1979)
IV	Lakshadweep Islands	8,000	Subbaramaiah *et. al.* (1979 b)
V	Goa	2,000	Dhargalkar (1981)
VI	Kerala	1,000	Chennubhotla *et. al.* (1987)
		73,044	
VII	Unexplored area	27,000	
	Total	1,00,044	

are October to April in Gulf of Mannar and May to September in Palk Bay.

Harvesting is done by hand picking or by cutting the crop with sickles leaving the basal portions to the net for regeneration. One Kg of seed material of *G. edulis* yields an average of 3 kg/m² of net after 60 days of growth. In one ha area of nets (i. e. 1000 nets) 30 tonnes of fresh *G. edulis* could be harvested. Based on the above studies the economics of culture of *G. edulis* has been worked out for a hectare area and details are given below:

For the cultivation of *G. edulis* in one ha area, 1000 coir nets of 5 x 2 m size, 2000 casuarina poles of 1.5 m height and 10,000 kg of fresh seed material (for initial introduction) are required. The cost of 2000 casuarina poles is Rs. 6000/- (approximately) and the cost of 1000 coir rope nets is Rs. 33,000/- including charges for fabrication. The seed material will be collected for the initial introduction from the natural beds and from the cultured crop for the subsequent seeding. Wages for seeding, harvesting and maintenance of the farm for 4 persons at the rate of Rs. 10/- per day for 360 days workout to Rs. 14,400/-. The total expenditure for one year would be Rs. 54,000/- including a miscellaneous expenditure of Rs. 600/-. The estimated cost is arrived at on the assumption that a minimum of four harvests could be made in a year. A total of 120 tonnes (fresh weight) of crop could be obtained from the four harvests in a year when the yield is 3 kg/m². If the seaweed is dried (75% moisture) and marketed at a rate of Rs. 2000/- per tonne, the net profit would be Rs. 6000/- for one year.

If the harvested seaweed is dried and converted as agar-agar, the profit will be around Rs. 1,00,000.

Predators

At Mandapam, the culture frames were often the target of attack by certain fishes like *Siganus javus* and *S. canaliculatus*. The crabs *Thalamita crenata* and *T. integre* caused extensive damage to growing parts of the seaweeds by merely clipping them with their chelipeds as they crawl about amongst the seaweed (James *et. al.* 1980). The problem of predators can be solved to a great extent by enclosing the cultivation area with latticed fence or a net of a suitable mesh size.

Effects of hormones on the seaweed growth

Studies on this aspect are very limited. Oza (1971) has found that low concentrations of IAA progressively stimulated the growth of *Gracilaria corticata* while higher concentrations were found to be lethal. Raju (1971) conducted experiments on the effect of hormones and fertilizers on the photosynthetic carbon assimilation in *Ulva fasciata*, *Sargassum* sp and *Gracilaria corticata*. The photosynthetic uptake of C^{14} was found to be maximum in *G. corticata* followed by *U. fasciata* treated with gibberellic acid. In *Sargassum* maximum effect on photosynthetic C^{14} assimilation was observed in plant supplied with ammonium sulphate. Tewari (1975) found that Chlorflurenol in hormonal range increased the fresh weight and the number of proliferations. But the elongation growth was found to be inhibited. Chauhan and Joshi (1979) reported that Indole-3-acetic acid at the concentration of 10^{6} proved a stimulant on the growth of *Sargassum swartzii* germlings than the other concentrations tried. The 10^{-3} to 10^{-6} M concentration of Gebberellic acid helped in increasing the length of pseudophylls of the sporelings.

Conclusions & Recommendations

1) Attempts have to be made to simplify the seaweed culture technology so as to reduce the cost of production and to make the technology economically viable.

2) The seaweed farmer and his family members or some families jointly have to undertake on co-operative basis, the cultivation of seaweeds and extract agar-agar.

3) The cultivation of seaweed is beset with problems such as grazing by fish in the sea and hence some times the yield in

the crop and thereby the production may come down from the expected level. Hence, some attempt should be made to find out the methods of controlling the grazing of the crop by fishes and other predators.

4) In order to enable the fishermen or landless labourers to undertake the seaweed cultivation, the Government may offer credit facilities with subsidies under the programmes such as IRDP, DPAP etc. which will be of immense use to them.

5) Use of hormones and fertilizers must be tried in the culture fields or the seed material may be pre-treated with hormones.

6. Evolving of hybrid varities of seaweeds by genetical methods may be given due consideration.

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