# Hand book on Farming of Gracilaria dura



Monica Kavale
Central Salt and Marine Chemicals Research Institute


Vaibhav Mantri
Central Salt and Marine Chemicals Research Institute

CSIR-Central Salts & Marine Chemicals Research Institute,
Bhavnagar, Gujarat

# Hand book on Farming of *Gracilaria dura*

**Funded By**

## National Fisheries Development Board

**Department of animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Farmers Welfare, Government of India**

**Monica Gajanan Kavale, V. Veeragurunathan, Vaibhav A. Mantri**

## Foreword

In recent times, marine macroalgae (commonly known as seaweeds) drawing considerable attention globally as a renewable feed stock for various industrial applications. Commercial harvesting of seaweeds has reached new milestone with 27 million tones year-1 production (95% accounts to farming) with a market value of over US$ 4.8 billion (FAO, 2016).

CSIR-Central Salt and Marine Chemicals Research Institute has been actively pursuing the seaweed research for nearly half a century. This institute takes pride in being first for pioneering seaweed cultivation, heralding an era of commercial seaweed farming in India. The production of *Kappaphycus alvarezii* has been substantially increased from 21 dry tonnes in 2001 to 1490 dry tonnes in 2013 with concomitant purchase value of < ₹ 4.5 to 35 ₹ $kg^{-1}$ (dry). However, Indian seaweed industry is still depending on natural harvest for agrophytes specifically species of *Gracilaria*, *Gelidium* and *Gelidiella*. The continuous harvesting of natural stocks has been a growing concern for the long-term sustainability of the resource. In order to mitigate the over exploitation pressure on natural stocks, CSIR-CSMCRI developed sustainable cultivation methods of some of these species. Recently, *Gracilaria dura* from Indian waters has been reported to yield quality agarose as high as 20-25% on dry wt. basis with a gelling temperature $35^0$C and gel strength of 1% gel > 1900 g. $cm^{-2}$ this has attracted industrial attention. The fast expanding biotechnology and pharmaceutical sector in India is registering steady demand for agar, underpinning the need to initiate large scale farming of this alga. Thus successful aquaculture practise has been developed for ascertaining a continuous and reliable supply of quality raw material giving impetus to commercial operations especially in Gujarat coast – of which this alga is native.

Among the hydrocolloids, agar is the second most prized product after agarose. According to a recent report, the wholesale price of agar has sharply increased to an all time high of USD 35-45 per kg due to scarcity of raw materials in response to resent regulations imposed by Moroccan government on natural harvest. The ongoing global supply chain crisis of agarophytes can be capitalized by India by spear heading the farming activity. This provides a scope and immense opportunity for India to emerge as a global producer as well as exporter of agarophytes.

CSIR-CSMCRI in association with National Fisheries Development Board (NFDB), Hyderabad is trying to promote young fishermen as an entrepreneur from coastal villages across the country through successfully organizing trainings. The large-scale farming of this alga needs to be further strengthened and promoted by looking at potential socio-economic implication it offers for the inclusive economic growth in rural coastal settings. It would also help in the realization of the goal of doubling farmers' income by the year 2022. I sincerely believe that this manual will help new participants to practice seaweed cultivation more effectively. On behalf of CSIR and our Institute, I convey our best wishes for the successful implementation of the project.

**Dr. Amitava Das**
**J.C. Bose National Fellow**
**Director, CSIR-CSMCRI**

# Acknowledgments

This hand-book is the part of Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Famers Welfare, New Delhi sponsored project entitled ‘Farming of red seaweed *Gracilaria dura* on Gujarat coast for promoting inclusive economic growth in coastal rural settings’ to CSIR-Central Salt and Marine Chemicals Research Institute. We are indebted to National Fisheries Development Board for their financial assistance; especial thanks are due to Mrs. Rani Kumudini, *IAS*, Chief executive, NFDB Hyderabad. We also would like to thank generous financial assistant from our parent organisation Council of Scientific and Industrial Research, Ministry of Science and Technology, New Delhi. We are also very grateful to Dr. Amitava Das, Director, CSIR-CSMCRI for his tireless support during the implementation of this project.

We are thankful to Department of Fisheries, Government of Gujarat, Gandhinagar who are part of project monitoring team and their suggestions during time to time.

We would like to thank Dr. CRK Reddy, Former PI; Dr. S. Kannan, Head, BDIM; Dr. Pradeep Agarwal, DC, Biotechnology and Phycology Division as well as Dr. K. Eswaran, Senior Principal Scientist and  Scientist-in-charge, CSMCRI Marine Algal Research Station, Mandapam for their valuable suggestion.

We would like to express our sincere thanks of gratitude to Dr. Mrs. M. Persis, Senior executive, NFDB Hyderabad, unwavering support and encouragement throughout the project.

We thank to our colleagues Dr. Mangal Singh Rathore, Scientist; Dr. Santalal Jaiswar, Technical Officer as well as Mr. S. Thiruppathi, Technical Officer for their involvement and during various states of implementing the work. Further we are also grateful to President, Grampanchayt of Simar and Rajapara for their valuable support to initiate seaweed cultivation in their village.

Last but foremost, we are gratified to our field staff for their productive involvement in this project.

**General Introduction of Seaweeds:**

Seaweeds are the marine macroscopic algae growing on rocky or any hard substrata in intertidal and shallow subtidal waters of sea. Seaweeds are differentiated in to three groups based on their colour viz. Chlorophyta (green seaweeds), Phaeophyta (Brown seaweeds) and Rhodophyta (Red seaweeds). Seaweeds are found throughout the world's ocean and seas. Seaweeds contain high amount of proteins, lipids, carbohydrates, vitamins, diatery fibers, minerals. Many seaweeds are actually nice and testy to eat and consider as great delicacy in many Asian countries. Besides food, seaweeds are mainly utilized for extraction of phycocolloids. Phycocolloids are the polysaccharides present in the cell wall of seaweeds. Agar, Alginates and carrageenan are the three major industrially important phycocolloids obtained from seaweeds. Agar is extracted from the species of *Gracilaria* and *Gelidiella*, and *Gelidium*, Alginate is extracted from *Sargassum*, *Turbinaria* while carrageenan is extracted from *Kappaphycus* and *Hypena*.

**International status of *Gracilaria* cultivation:**

Seaweeds are harvested throughout the world as a source of food and phycocolloids (Agar, Agarose, carrageenan, Alginate). Seaweeds are commercially cultivated in several Asian countries like Japan, China, Korea, Philippines, Chili, Indonesia, Malaysia etc. In 2014, the global annual production of seaweeds was 27 million tons of fresh wet with a market value of USD 5.6 billion (FAO 2016). The seaweeds namely *Porphyra*/*Pyropia*, *Monostroma*, *Undaria*, *Laminaria* are commercially cultivated food while, *Kappaphycus alvarezii*, *Eucheuma cottonii*, Condrus *Gracilaria* sp., *Gelidiella*, *Sargassum* as a source of phycocolloids.

Among the seaweed cultivation around the world, the genus *Gracilaria* rank highest with over 3.8 million tons of annual production and contributes about 91% of total agar production. *Gracilaria* has been a preferred source for agar production worldwide due to its fast growth and significant agar content. Varity of industries like food, pharmaceuticals and chemical utilized agar for various purpose. There are four main uses of agar viz. fodder for fish and mollusc, human food, fertilizer and agar. The global agar production is 14500 tons with a market value of US$246 million (Porse and Rudolph 2017). It is mostly cultivated in Asian countries, among which China produces 70% and Indonesia 28% of world production (Yarish 2017). The cultivation of Gracilaria was initiated in China in 1950s.The species namely *G. lemaneiformis*, *G. tenuistipitata* var. *liui*, *G. gigas*, *G.*

*verrucosa*, *G. chilensis*, *G. cornea*, *G. parvispora*, *G. asiatica*, *G. salicornia*, *G. eucheumoides*, *G. changii*, *G. fastigiata*, *G. vermcosa*, *G. foliifera*, *G. textorii*, *G. millardetii*, *G. crassa*, *G. firma*, *G. fisheri*, *G. blodgetii*, *G. chorda*, *G. arcuata* are being cultivated worldwide.

**National Status of *Gracilaria* cultivation:**

In India, species belonging to the genera *Gelidium*, *Gelidiella*, *Gracilaria* have been harvested from natural beds along Tamil Nadu and Gujarat Coasts for commercial production of Agar since 1966. *Gracilaria edulis* has been used as a source of food grade agar, while *Gelidiella acerosa* for bacteriological grade agar. To meet out the increasing industrial demands culture of seaweeds has been attempted by Central Salts and Marine Chemicals Research Institute. At this institute, Raju and Thomas (1971) cultured *G. edulis* by longline method in a sandy lagoon at Krusadi Island. Further, in 1973 Umamaheshwara Rao conducted culture experiments on *G. edulis* and *G. corticata*. Experiments were also carried out for cultivating *G. edulis* in the inshore waters of Gulf of Mannar, in submerged free floating condition (Chennubhotla *et. al.* 1978). Recently, *G. dura* cultivation was initiated at Mandapam, Tamil Nadu (Veeraguruntahn et al., 2015) and Simar, Gujarat coast of India.

**Efforts of CSMCRI in the field of seaweed cultivation:**

CSIR-Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI) is a leading institute in the country working on seaweeds since 1960. The pioneering efforts have nurtured the seaweed industry. As a part of mission this institute is involved in a highly creative and result oriented research leading to proper optimal utilization of coastal and marine resources for its own excellence hike as well as boosting society economically and knowledge wise. CSIR-CSMCRI's field station at Mandapam, Tamil Nadu is exclusively working on cultivation of seaweeds since last two decades. Seaweed cultivation is already being practised commercially in Tamil Nadu with great impact on socioeconomic status of coastal villages and people associated with it. The R&D work carried out on seaweeds over many years resulted in development of various processes with potential commercial value. Many of these processes were granted patents and also formed a base for many seaweed industries operating currently in the country.

One such important invention achieved by CSIR- CSMCRI is extracting agarose from red alga *Gracilaria dura*. It is the first Indian seaweed used for the extraction of agarose directly from biomass. Successful development of cultivation techniques has led to the sustainable availability of *G. dura* as a source of agarose and further allowed expansion of agar industry.

Table: Patent details on *Gracilaria dura*

| S.NO | Patent No. | Patent Title |
|---|---|---|
| 1 | US Patent Publication No. US 2005/0267296 A1 (pregrant); December 1, 2005; | A cost-effective process for preparing agarose from *Gracilaria* spp |
| 2 | PCT Patent Publication No.: W0 2005/118830 A1; December 15, 2005 (published in the gazette); national phase filings in progress; | |
| 3 | UK Patent published: GB2429209; February 21, 2007. | |
| 4 | Canadian Patent Published: CA 2 569 495 A1; December 12, 2006. | |
| 5 | Indian Patent Application No. 1189/DEL/2004 A; June 25, 2004. | |
| 6 | Indonesian Patent No. 0019080; April 10, 2007. | |
| 7 | Chinese patent published: CN 1993474A dated 2007-7-4. | |

**Importance *Gracilaria dura***:

1. It directly gives high quality agarose
2. It is indigenous seaweed
3. Easy and cost effective technology available with CSMCRI
4. Withstand with wide range of salinity
5. Being strong and sturdy, it is easy to handle for cultivation

**Distribution of *G. dura***:

Its occurrence is restricted. It is found growing at Veraval coast Saurashtra, Gujarat. The literature also reported it presence form Kanyakumari.

**Bathymetric distribution**:

The natural population has been found to grow in high tide water mark to low tide water mark, in sandy and muddy basins, rocky substrata, in water pools as well as exposed areas. In the sea it is growing up to the depth of 20 meter however, 98% of population is growing in 0.5 to 4-meter depth.

**Biology of *G. dura***:

Plants 10-18 cm tall, 1mm in breadth, greenish brown to reddish brown in color, irregularly branched, cartilaginous, with discoid holdfast, often covered with short branchlets, branches and branchlets are cylindrical, constricted near the base with pointed apices, cystocarps rostrate.

**Life cycle of *G. dura***:

The basic life cycle of *G. dura* is triphasic (three phases) namely gametophytic, sporophytic and terasporophytic. The gametophyte and sporophyte are morphologically identical. Gametophytes are gametes producing plants while sporophytes are spore producing. The gametophytes are dioecious i.e. male and female plants are separate. Male plants are having male gamete namely spermatia while female plants have carpogonium. The spermatium and the egg in carpogonium fuses to form zygote which in turns develop in the macroscopic carposporophyte within a fertile structure called cystocarp. The carposporophyte produces carpospores (2N) which develops in to tetrasporophyte. Tetra sporophyte produces tetrasporangia. Meiosis takes place in tetrasporangia resulting in the tetraspores (N) which in turn develops into gametophytes again completing cyclic event.

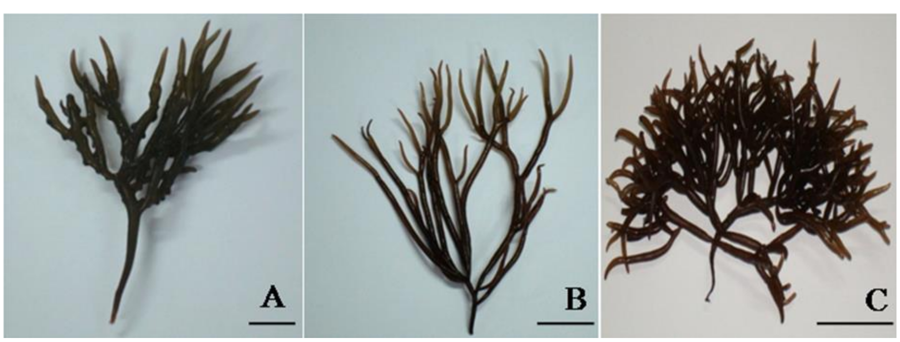


**Fig: A: Female; B: Tetrasporophyte and C: Male**

*Source: Aquaculture (318) 2011: 389 - 396*

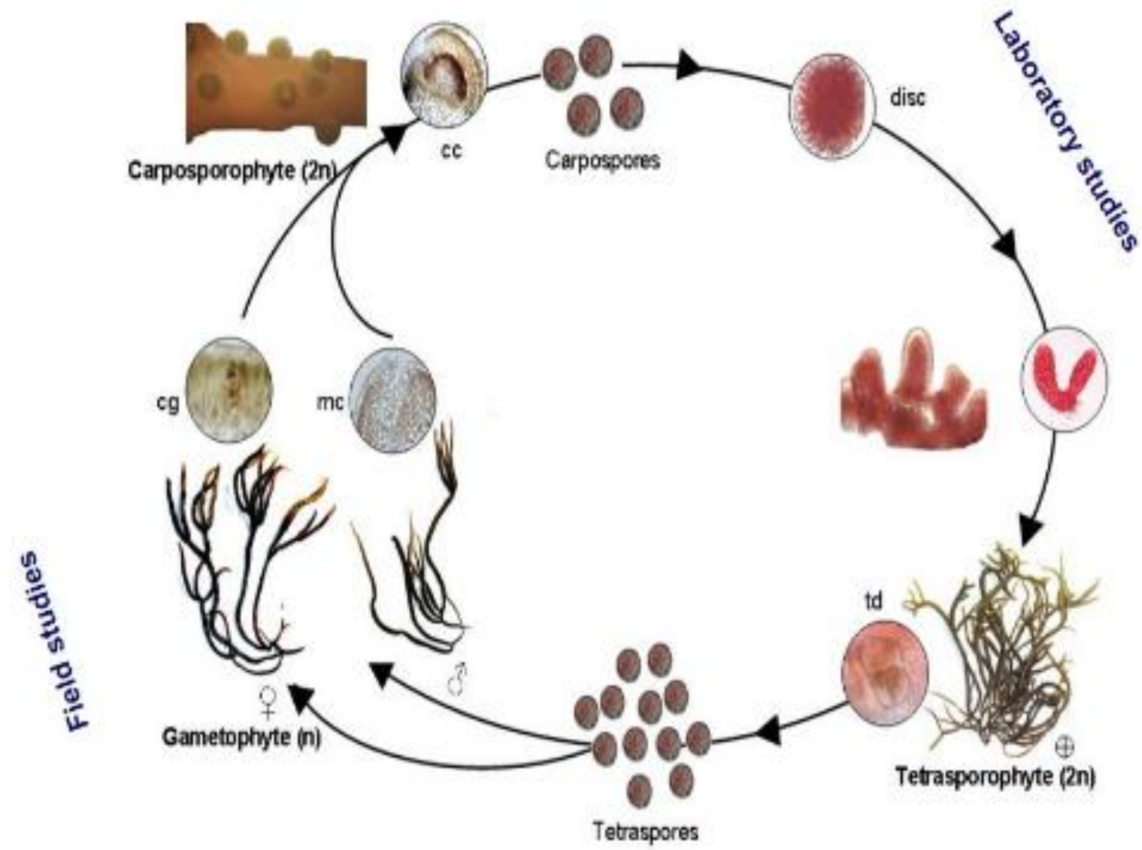


**Fig: Schematic representation of life cycle of Gracilaria dura**

**Methods of *G. dura* cultivation**:

There are several methods attempted worldwide namely pond culture, tank culture, floating raft, polypropylene net, Hanging rope, net bag, net pouch, tubular net for farming *Gracilaria* spp. Among these methods in India two methods were found to be suitable for commercial cultivation of *G. dura* i.e. Floating bamboo raft method along Tamil Nadu coast and Tubular net method along Gujarat coast. Tamil Nadu has comparatively calm water hence floating bamboo raft method is most suitable while due to heavy wave action tubular net method is suitable for Gujarat.

**Bamboo raft method**: The method involves a square frame (2m × 2m size) made of bamboo (7.5 to 10cm diameter) poles. Each raft contains 20 parallel polypropylene ropes (3mm diameter) seeded with *G. dura* that are placed equidistantly. Seedling of approximately 3.0gm fresh wt. has been tied in nylon thread and the seeded thread is again inserted in the braids of polypropylene rope. Each rope has 20 propagules with a total fresh weight of 60g/rope. A raft with 20 such ropes will have initial seedling density of 1.2 kg fresh weight /raft. The raft was completely covered by commercial fishnet and agro net in both upper and lower sides of the seeded ropes and anchored securely with stones of approx. 30 kg. weight.

**Fig: Bamboo raft method**

*Source: Aquaculture (438) 2015: 68 - 74*

**Bottom net method**: A square net (2m × 2 m size) made up of a 3 mm polypropylene rope is used for this method. A total of 40 ropes of 2 m length each are woven vertically and horizontally so as to obtain a net with a mesh size of 10 × 10 cm. Each 2 m long rope has a total of 20 cuttings each has approx. of 3 g fresh wt. planted at 10 cm intervals with a total fresh weight of 60 g rope$^{-1}$. A net as described above has an initial seedling weight of 2.4 Kg. fresh wt net$^{-1}$. The seeded nets are tied at all 4 corners to vertical bamboo poles erected in the sea at 2 m depth. Stone sinkers are used to anchor the seeded nets at 25 cm above the bottom. A biomass of 8 kg fresh wt. is obtained at the end of 45 days of growth.

**Fig: Bottom net method**

*Source: Aquaculture (438) 2015: 68 - 74*

**Single rope floating method**: A 5-meter-long horizontal polypropylene rope (6 mm thick) was attached to two anchors stones on both sides. The rope is kept afloat by means of 5 floats. The cultivation ropes also of the same diameter (6mm) pp rope and 2 meter in length are attached to the floating horizontal rope by hanging. A small stone is attached to the lower end of the cultivation rope so as to keep it vertical position without floating on the surface. Fragments of 3.0 gm fresh weight. are seeded on vertical rope. Generally, 20 fragments of *G. dura* are inserted in each vertical rope. Seven such seeded vertical ropes will have total initial biomass of 420 gm fresh wt. The distance between two seeded rope is 25cm. Maximum biomass yield of 750 gm fresh wt. is obtained from a single harvest by this method after 45 days' growth period.


**Fig: Single rope floating method**

**Net bag Method**: A 75 cm long bag is prepared from commercial fishnet. The bag is then made in to three equal compartments by hand stitch up to nylon thread. Each compartment is seeded with 35 g. of *G. dura* fragments. The entire length of net bag is covered with agro net in order to minimize grazing. The bag is tied on to 8 mm polypropylene rope and the rope is tied on both sides to the bamboo poles erected vertically. Three compartments together have seed material of 100 gm fresh weight and the final biomass harvested is 500 gm fresh weight at 45 days.

**Fig: Net bag method**

*Source: Aquaculture (438) 2015: 68 - 74*

**Net pouch method**: Net pouch is made with similar way of net bag method, but with long tube of 3-meter length Here, each compartment is filled with seed material of about 500 to 800 gm fresh weight. The entire pouch is having seed material of 2 kg. The biomass yield obtained from this method is 6-7 kg. fresh wt. after 45 days of growth.

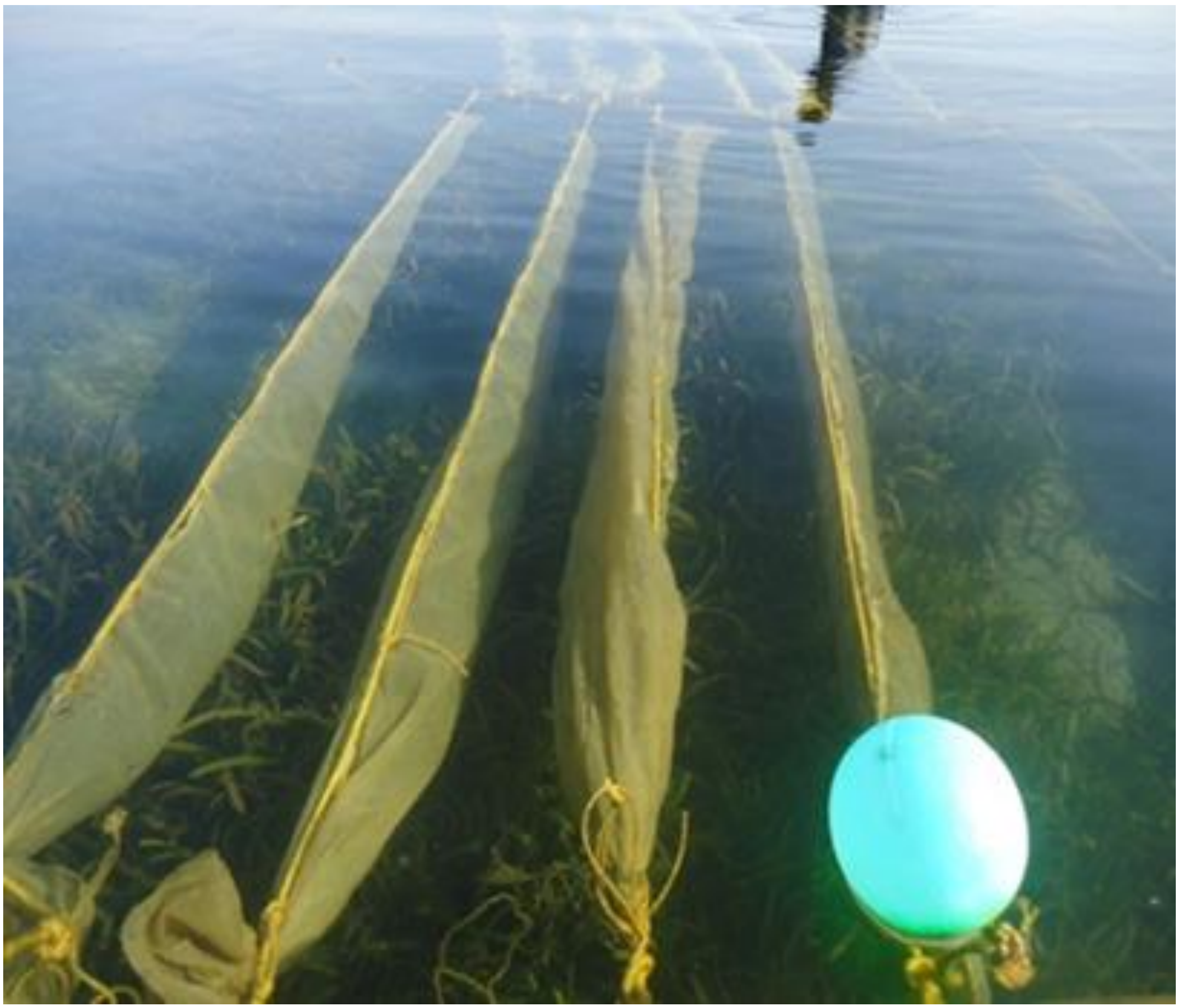

**Fig: Net pouch method**

*Source: Aquaculture (438) 2015: 68 - 74*

**Tubular net method**: This method is suitable for areas where wave action is more than moderate. The seed material is filled compactly, inside tube-nets having 10 cm dia. (mesh size of 1.5 ×1.5 cm) of 25-meter length. The initial seed material (10 kg) is loaded into the tube-nets with the help of a small plastic pipe with less-diameter than tube-net. To start with assembling tube net, the plastic pipe is inserted into the tube-net and the entire tube-net is pulled down, so that the mouth of plastic pipe stands out. Insert the rope in pipe till it passes other end. Tie the end of tube net with inserted rope. While tying let 30 cm rope tail free which is require for anchoring. The seed material is gently filled through plastic pipe till the entire tube-net is filled with seed. The other end of tube net is closed to avoid splitting. The tube-nets are transplanted in the sea, in rows and are held firmly with the help of anchor supports and floats.

**Fig: Tubular net method**

**Long line/monoline method**: it is a simple method in which polypropylene ropes are used for cultivation. Approximate 5 to 10 gm of Seed material is either inserted or tied with braider at equidistance. For inserting seed material, rope is untwisted to make it loop and seed material is inserted in this loop. On releasing rope, it winds up to hold seed material firmly. Or it is winded manually. If the brider is used the plant material is held along the rope and is tied up normally with a knot. These monolines are transplanted in seawater and are stabilized with anchors and floats.

**Fig: Long line method/monoline method**

**Site selection for cultivation**:

The success of seaweed cultivation does not only depend on the cultivation technique, but also to a large extent on the proper selection of the site. In order to reduce time consuming activities for site selection, preliminary screening of potential sites have to be inspected by physical and geographic parameters using maps, tide table, aerial photography, and nautical charts. Generally, the shallow lagoon areas and sea mouth, saline estuaries and shallow bays are preferable for the commercial cultivation of *G. dura*.

Further, second stage of screening will be done by specific parameters like water movement, shelter area, depth, substratum, salinity, sunlight, water temperature, nutrient availability, pollution etc. Based on above mentioned parameters the areas will be ranked as not suitable, marginal, acceptable and good. The farm is located ideally below the low water level, where about 2 ft. of water remains, even during the lowest of low tides. The water movement in the area should be moderate enough such that it would provide flow of fresh nutrients, essential to achieve continuous seaweed growth. The bottom of the site is preferably sandy, without any other seaweeds and/or seagrass beds. Suitability of site can only be confirmed through trial cultivation. The physic-chemical properties of seawater are required to be recorded for selection of suitable sites for cultivation of *G. dura*.

**Fig: Estuarine area near sea mouth (Salinity should be at 35 ppt)**

**Fig: Bay area**

**Fig: Lagoon area**

**Parameters affecting growth**:

**Salinity**: *G. dura* is euryhaline; it can withstand in wide range of salinity between 25 to 35psu.

**Light**: Light is one of the most important factor influencing seaweed growth. *Gracilaria* generally requires high light intensity for the normal growth. The optimum light intensity is 40 -60 µmol $m^{-1}$ $s^{-1}$.

**Temperature**: The temperature has crucial role in growth of seaweed. *G. dura* can grow in the temperature ranging from 15 to 35°C; however best growth was found at 28-30°C.

**Nutrients**: Nutrient availability is an important factor for the growth of Gracilaria. Among the nutrients ammonia plays important role in growth. It was observed that the growth was increased when N/p concentration 50/3.13µM to 400/25µM while the growth was decline when the N/P concentration increases beyond 400/25µ.

**Water depth**: The optimum vertical depth for *Gracilaria* is 0-1m where the maximum growth rate is observed.

**Water movement**: The water motion has been found to be the limiting factor for the growth of *Gracilaria*. Insufficient water motion and calm water may reduce the growth of *G.dura*. Water movement speed up the diffusion of gases and nutrients in and out of seaweed thali.

**Table: Range of conducive parameters required for commercial farming**

| Sr. No. | Parameters | Required optimum range |
|---|---|---|
| 1 | Atmospheric temperature (°C) | 26-35 |
| 2 | Seawater Temperature (°C) | 24-31 |
| 3 | Salinity (ppt) | 25-35 |
| 4 | pH | 7.9-8.5 |
| 5 | Dissolved Oxygen (mg/liter) | 2.0-3.5 |
| 6 | NO2 (µg/liter) | 0.14-1 |
| 7 | NO3 (µg/liter) | 1.2-3 |
| 8 | PO4 (µg/liter) | 0.5-3 |

**Maintenance of a farm**:

The productivity of the *Gracilaria* depends on the management and maintenance practices adopted by the farmer. The tubular nets transplanted in the sea are likely to have mud and epiphytes deposition; sometimes unwanted drifted material or heavy wave action can break the tubular nets. Therefore, it is advisable to have regular observation, cleaning and maintenance of tubes. Continuous deposition of this mud and epiphyte growth can alter the growth of *G. dura* adversely. In order to get maximum production a farmer should visit the farm daily. The damage tubular nets must be repair or replaced regularly.

**Problems associated with cultivation:**

**Grazing**: Seaweeds are the primary food for several herbivorous fishes and animals. Grazing by such herbivores can reduce the seaweed productivity. Grazing is a big challenge for *Gracilaria* cultivation. It can cause complete loss of seaweed production

**Fig: Fish caught inside the raft**

**Epiphytes**: Undesired algal as well as animal growth namely diatoms, *Enteromorpha*, *Hypnea*, *Acanthophora*, *Ectocarpus*, *Lyngbya*, *Asciduans,* mud deposition take place on the surface of *G. dura* which hinders the growth of the desired plant.

**Fig: Animal deposition**

**Fig: Epiphyte- *Acanthophora* sp**

**Fig: Epiphyte-*Hypnea* sp**

**Fig: Epiphyte-*Lyngbya* sp**

**Fig: Mud deposition**

**Drifting**: Due to higher wave action the germlings may break in to pieces and drift through the mesh of the tubular net. While cleaning epiphytes and mud from tubular net, the young plant branchlets may get damaged and detached from tube nets. Cleaning should be done by applying gentle pressure and not haphazardly.

**Fig: Drifting of material from tubular net**

**Bleaching**: IT may be noted that if the tubular nets may get exposed to sunlight for longer time, the tips of the branchlets become white commonly known as bleaching.

**Fig: Bleaching**

*Source: JAPH 2015 (27) 2353–2365*

**Twisting/ tearing**: The heavy wave action, grazing, anthropogenic activities may cause tearing and twist

**Fig: Tarring of tubular net**

**Fig: Twisting of tubular net**

**Harvesting**:

*G*. *dura* attains its full growth within 40-45 days. The growth of *G*. *dura* covers a tube in such a way that it completely hides the mesh of the tube. Such tubes are thus ready to harvest. The tubes needs to be detached from the floats and anchors and brought to shore. The tubes then cut open by knife to remove the biomass from them. The harvested alga is spreaded onto a plastic sheet and sun dried. Direct drying of plants on beach sand is discouraged as the crop might get mixed with sand. The complete drying of material may take 5-6 days period depending on sunshine hours.

**Post-harvest storage**: The dried material, with about 35% moisture content, is compressed and packed in either jute or plastic sacks. All the packed bags are advised to store in moister free area.

**Table: Advantages as well as disadvantages of the cultivation practices**

| Advantages | **Dis-advantages** |
|---|---|
| **Raft Method** | |
| Cultivation always occurs at surface level, with higher amount of light (better photosynthetic performance) and dissolved oxygen (enhanced growth) | The higher density of seedlings per unit area reduces the nutrient level quickly during low water mixing events |
| Can able to hold higher biomass | Destabilized easily during rough weather |
| Ease in clustering, maintenance, seeding, and harvesting | Tissue bleaching after prolonged exposure to solar radiation during summer season |
| Depth is not an issue for cultivating seaweeds in rafts | Growth rates are not uniform. Higher growth is achieved in peripheral seedlings than central ones. |
| Local timber (casuarina) can be used to construct raft frames | The cost of raft is slightly more expensive than other farming methods. |
| Raft harbours diverse population of marine invertebrates and provides nursery for fish | Shading may reduce light penetration to the bottom-dwelling flora and fauna. |
| **Tubular net Method** | |
| Can be planted at any level between sea bottom and surface. | Requires more seed material for planting. |
| Complete absence of drifting of seedlings | Mud and epiphytic infestation common and requires more maintenance efforts. |
| Required minimum infrastructure | Low penetration of light inside the tube |
| Ideal for deeper water | They pose hindrance to the mobility of mechanized boats |
| High stability in rough weather | Difficult to bring fully grown tube to near shore for harvesting |
| Seeding is simple and requires less time | Opening of tube each time for harvesting may add recurring cost on cultivation |
| Growth rates are uniform throughout length of the tube | Plant tubes are non-degradable and require proper disposal |

**Economics of** G**.** ***dura*** **cultivation**:

| particulars | Cost /tube in INR | Total infrastructural cost per year for 500 tube nets and 5 cycles | Initial weight of seedling for 100 tube net | Final weight of biomass produce | Reseeding material needed for next cycles | Net biomass to sell for 5 cycles | Cost of plant per kg of fresh weight | Net cost of biomass produce during 5 cycles | Net profit (cost of biomass produced - infrastructural cost) | Net profit gain by a single farmer per month |
|---|---|---|---|---|---|---|---|---|---|---|
| Infrastructural cost: It includes anchor stones (@ Rs. 80.00), tubular net (@ Rs. 50.00), polypropylene ropes (@ RS. 30), plastic floaters (@ Rs. 50.00), and other unforeseen miscellaneous items (@ RS. 10.00) | 220 | 49000 | 1000kg | 3000kg | 5000 | 10000 | 10 | 100000 | 51000 | 7285.00 |

**Germplasm preservation during monsoon season**:

It is highly difficult to cultivate the seaweed during monsoon season. The first and foremost reason is rough sea with huge waves dashing towards coast with heavy rainfall. During this season fishing activity is also halted. Further, because of monsoon the surface salinity goes down below 25 ppt, sometimes it leads 0 ppt under this circumstances the *G. dura* will not survive. For the conserving viable germplasm net pouch method has been proved best. In this method two types of nets are used namely fishing net of 1X1 cm mesh size with 6X6 PLY and mosquito net. To prepare a bag of 12X12 cm length of mosquito net is being used; which is then covered with fishnet bag of same size. Approximately 50gm of *G. dura* plant is being seeded and the mouth of the bag is closed with with 3mm polypropylene rope. This bag is being tied to 6mm polypropylene rope and transplant in open sea with anchor stones and floaters. While transplanting, care should be taken that the rope of pouch should be tied at least 1 to 1.5 feet below the water surface. Further plants will also be safe, if the net pouch ropes will be tied in water pools where wave action is moderate.

**Fig: Net pouch**

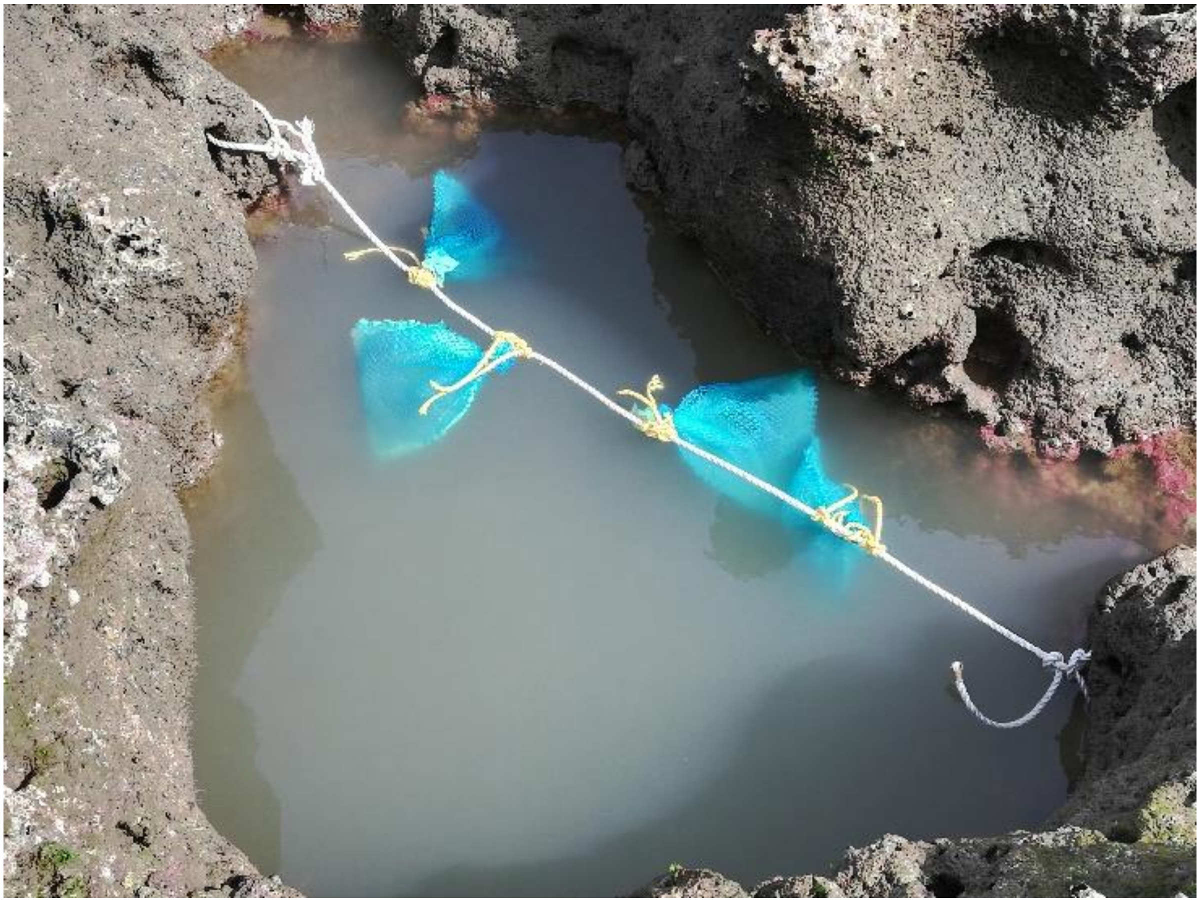

**Fig: Net pouches in water pools**

**Fig: Photographic illustration of monoline method of *G. dura***

**Tying approximately 10 gm of *G. dura* to fishing twine**

**Take a polypropylene rope**

**Untwisting of polypropylene rope**

**Insertion of fishing twine of *G. dura* into untwisted loop of polypropylene rope**

**Tying of *G. dura* fishing twine to polypropylene rope**

**Seeded monoline ready for transporting in the field**

**Cleaning of monoline in the sea**

**25-meter length monoline ready for harvesting**

## Fig: Photographic illustration of tube net method of *G. dura*

**Insertion of plastic pipe and polypropylene rope in tubular net**

**Loading of *G. dura* seed in to tubular net with the help of plastic pipe**

**Shifting of seeded tubular net near shore**

**Tying of two tubular net together with thermocol floater**

**Tubular net with thermocol**

**Aligning of loaded tubular nets for transplanting in to the sea**

**Shifting of tubular net in to the boat**

**Tubular net after 8$^{th}$ day of planting**

**Tubular net at the time of harvesting**

**Harvested tubular nets**

**Drying of harvested biomass in Sun**

**Table: Do and Don’ts in commercial cultivation**

| Sr. No. | Do | Don’t |
|---|---|---|
| 1 | Every day cleaning of tubular nets is must | After planting lying tubular nets in the sea unattended for a long |
| 2 | Apply gentle pressure while cleaning | Forceful cleaning will lead to breaking of tubular nets |
| 3 | Maintain the number of tubular nets per farm area | Over crowing of tubular nets will lead to slow or retarded growth |
| 4 | Remove all the epiphytes regularly from tubular nets | Keeping epiphytes on tubular nets leads to competition for space, nutrients and light |
| 5 | Always keep tubular net below water | Exposure of tubular nets to sunlight leading to bleaching |
| 5 | While reseeding the tubular net cut fragments will be preferred as those fragments have ability to fast growth | Reseeding harvested bulgy plants |
| 6 | While reseeding clean the plant thoroughly | Reseeding harvested plants as it is |

**Table: Contact details of phycocolloid producing industries in India**

| Sr. No. | Name of the company | Address of company | Contact details |
|---|---|---|---|
| 1 | M/S. SNAP Natural & Alginate Products Private Limited | Head office<br>Plot No.1, Sipcot Industrial Complex, Ranipet- 632403, Tamil Nadu | Tel.: +91-4172 – 244278<br>https://snapalginate.com/ |
| | | Branch office<br>334, Samuel St, Koliwada, Masjid Bandar West, Masjid Bandar, Mumbai, Maharashtra 400003 | Tel: +91-22-23439659<br>+91-9821145685 |
| 2 | M/S. Aquagri Processing Private Limited | Head Office<br>284, Sultan Sadan, L-3, West End Marg Saidulajaib, New Delhi-110030 | Tel.: +91 011-29 53 64 06,<br>+91 011-29 53 64 07<br>http://aquagri.in/ |
| | | Branch office<br>Plot No. F 1 Sipcot Industrial Complex Manamadurai-630606 (District Sivaganga) Tamil Nadu | Tel.: +91 04574 25 82 52<br>Phone: 094441 93080 |
| 3 | M/S. Agar & Alginate Manufacturers Welfare Association | No 10, Thirunagar, Madurai - 625006, Behind M M Higher Secondary School Thiru Murugan Colony | Tel.: +91-452 2482601<br>+91-7373733006<br>+91-9442996824<br>http://maditssia.com |
| 4 | M/S. Marine Hydrocolloids | Santo Gopalan Road, Chullickal,<br>Cochin - 682 005, Kerala, India. | Tel.: +91 484 2227241/2223703/2220802/2227341<br>+91 484 2220801<br>info@meron.com,<br>marine@vsnl.com<br>www.meron.com |
| 5 | M/S. Hi Media Leading Bio Sciences Company | A-516, Swastik Disha Business Park, via Vadhani Industrial Estate, L.B.S. Marg, Mumbai, Maharashtra 400086 | Tel.: +91 022 6147 1919<br>+91-22-6147 1919, 2500 3747, 2500 0970,<br>2500 0278<br>info@himedialabs.com<br>http://www.himedialabs.com |

**Details of the agencies which can provide support for infrastructure**

| Sr. No. | Name of the funding agency | Address | Contact details |
|---|---|---|---|
| 1 | NABARD National Bank For Agriculture & Rural Development | Head office: Plot C-24, G Block, Bandra Kurla complex, BKC Road, Bandra East, Mumbai, Maharashtra 400051 | Tel.:+91 022-26539895/96/99 |
| 2 | NFDB National Fisheries Developmental Board | Department of Animal Husbandry, Dairying and Fisheries<br>Ministry of Agriculture and Farmers Welfare, Government of India<br>"Fish Building" Pillar No:235, PVNR Expressway<br>SVPNPA Post,Hyderabad-500052. | Tel: + 91 - 040 - 24000201/177/24015553; info.nfdb@nic.in; Web: http://nfdb.gov.in |
| 3 | National skill development fund National skill development corporation<br><br>Ministry of Skill Development and Entrepreneurship | Ministry of Skill Development and Entrepreneurship<br>2nd floor, Annexe building, Shivaji stadium,<br>Shaheed Bhagat Singh Marg, Connaught place, New Delhi - 110001. | Tel.: 011-23450855<br>jsadmn-msde[at]gov[dot]in |
| 4 | Commissioner of Fisheries, Gujarat | 3rd Floor, Block no-10, Jivraj Mehta Bhavan, Gandhinagar - 382010. | Tel.: 079- 232-53739 |
| 5 | Commissioner of Fisheries, Maharashtra | Taraporwala Aquarium, Netaji Subhash Road, Charni Road, Mumbai-400002<br>(Maharashtra state, India) | Tel.- 022-22821239<br>comm_fisheries@maharashtra.gov.in |
| 6 | Directorate of Fisheries, Goa | Dayanand Bandodkar Marg, Patto Colony, Panaji, Goa 403521 | Tel.: 0832 222 4838<br>dir-fish.goa@nic.in |
| 7 | Directorate of Fisheries, Karnataka | 3rd Floor, Podium Block, V.V. Center, Dr. Ambedkar Road, Bangalore, 560 001 | Tel.: 080-2286 4681<br>dof-blr-ka@nic.in |

| | | | |
|---|---|---|---|
| 8 | Director of Fisheries, Kerala | Fisheries Complex, Moplabay, 17, Kannur, Kerala | Tel.: 0471-2303160 9496007020 |
| 9 | Directorate of Fisheries, Tamil Nadu | Directorate of Fisheries Administrative Office Buildings, DMS Complex, Teynampet Chennai-600006 | Tel.: 24320199, 24320197 & 24336311 |
| 10 | Commissioner & Director Department of Fisheries, Andhra Pradesh | Government of Andhra Pradesh,<br>Shanthinagar, 4th Street, Masab tank, Hyderabad | Tel.: 091-040- 23308585/ 86, comfish@rediffmail.com, Url: http://www.apfisheries.cgg.gov.in |
| 11 | Directorate of Fisheries, Odisha | Behera Colony, BOSE Colony, Professors Colony, Cuttack, Odisha 753007 | Tel.: 0671-2414061<br>director@odishafisheries.com<br>director.odifish@gmail.com |
| 12 | Director of Fisheries, U.T.Of. Lakshadweep | Director of Fisheries, U.T.Of. Lakshadweep, Agatti -682553 | Tel.: 04894 242876 (Office)<br>242786 (Per)<br>242298 (Office) |
| 13 | Directorate of Fisheries, Andaman &Nicobar | Directorate of Fisheries, A&N Administration, Opp. APWD Petrol Bunk, Port Blair - 744101 | Tel.: 232770-231474<br>dirfish@ and.nic.in |
| 14 | Fisheries Department, Daman; | U.T. Administration of Daman & Diu, Government of India; Department of Personnel & Administrative Reforms, Ground Floor, Secretariat, Fort Area,<br>Moti Daman, Daman (U.T.) - 396220 | Telefax : 02602231707<br>E-mail : pers-dd@nic.in<br>URL : www.daman.nic.in |

**Selected readings:**


Chenubhotla VSK, Kaliaperumal N and Kalimuthu S (1978) Culture of *Gracilaria edulis* in the inshore waters of Gulf of Mannar (Mandapam). *Indian J Fish*, 25:228-229.

FAO (Food and Agriculture Organisation of the United Nations) (2016) The state of the world fisheries and aquaculture 2016. Food and Agriculture Organisation of the United Nations, Rome.

Ganesan M, Eswaran K and Reddy CRK (2017) Farming of agarophytes in India—a long time sustainability for the industry and preserving wild stocks. *J Appl Phycol* doi:10.1007/s10811-017-1128-0.

Kim JK, Yarish C, Hwang EK, Park M and Kim Y (2017) Seaweed aquaculture: cultivation technologies, challenges and its ecosystem services. *Algae*, 32(1):1-13.

Meena R, Chaudhary JP, Agarwal PK, Maiti P, Chatterjee S, Raval HD, Agarwal P, Siddhanta AK, Prasad K and Ghosh PK (2014) Surfactant induced coagulation of agarose from aqueous extract of *Gracilariadura* seaweed as an energy-efficient alternative to the conventional freeze-thaw process. *RSC Advances*, 4:28093–28098.

Porse H and Rudolph B (2017) The seaweed hydrocolloid industry: 2016 updates, requirements, and outlook. *J Appl Phycol*, DOI 10.1007/s10811-017-1144-0.

Raju PV and Thomas PC(1971) Experimental filed cultivation of *Gracilariaedulis* (Gmel.) Sila. *Bot Mar*, 14 (2):71-75.

Veeragurunathan V, Eswaran K, Saminathan K, Mantri VA, Malarvizhi J, Ajay G, Jha B (2015a) Feasibility of *Gracilaria dura* cultivation in the open sea on the South eastern coast of India. Aquaculture 438, 68–74.

Veeragurunathan V, Eswaran K, Malarvizhi J, Gobalakrishnan M (2015b) Cultivation of *Gracilaria dura* in the open sea along the southeast coast of India. J Appl Phycol. 27, 2353 – 2365.

Umamaheswara Rao M (1974) On the cultivation of *Gracilaria* in the near shore are around Mandapam. *Curr Sci*, 43(20): 660-661.


*********