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# Prospects for Seaweed Cultivation in India for Local and Export Market

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## Introduction

Seaweeds or marine macro algae consist of taxonomically distinguished groups of Chlorophyta (green seaweeds), Phaeophyta (brown seaweeds) and Rhodophyta (red seaweeds). They are generally found attached to hard substrata such as rocks, pebbles, dead corals or other hard structures in the intertidal or subtidal regions of the sea.Seaweeds are valued for the natural source of phycocolloids like agar-agar, algin and carrageenan. A number of tropical seaweeds including green algae (*Ulva, Enteromorpha, Monostroma, Caulerpa)* brown seaweeds (*Dictyota, Laminaria, Cladosiphon, Padina)* and red seaweeds (*Gracilaria, Porphyra, Eucheuma)* are eaten directly (sea vegetables) for their minerals, vitamins, proteins, essential amino acids and low fat content. The major economic significance of seaweeds is the polysaccharides (agar, algin, carrageenan, agarose, etc) certain red and brown seaweed species contain. *According to the FAO data base during 2008, total world production of marine algae was estimated to 15.8 million tonnes (wet weight) equivalent to the value of 87.4 million US $ with 99.8 percent by weight and 99.5 percent by value contributed by Asian region alone (FAO., 2011).*

## Seaweed Resources

Economically important seaweed resources of the world, as per the harvests made during 1971-1973 is estimated to 2105 million tones wet weight (about 1460 million tones of brown algae; 261 million tones of red algae) dominated by brown sea weeds (Michanek, 1975). The south east and north west coasts of India and the Andaman- Nicobar and Laccadive archipelagoes harbour a variety of seaweeds with rich biomass and species diversity. Luxuriant growth of seaweeds is found in southern coast of Tamilnadu, Gujarat, Lakshadweep and Anadaman-Nicobar Archipelagos. Rich seaweed beds occur at Mumbai, Ratnagiri, Goa, Karwar, Thikodi, Varkala, Vizhinjam, Pulicat and ChilkaLakes. There were about 40 seaweed industries functioning in India producing algin and agar, depending only on natural resources. Indian coastline has 896 species of marine algae belonging to 250 genera and 64 families, of these nearly 60 species only are commercially important. In a revised checklist of marine algae reported by Oza and Zaidi, (2001) and Umamaheswara Rao (2011) indicate a considerable increase in the number of species of seaweeds in India.

## Seaweed utilization

**Agar** is the major constituent of the cell wall of certain red algae(Rhodophycae), especially the members of families Gelidiaceae, Gelidiellaceae and Gracilariaceae. Agar-agar is the Malay word for the gelling substance extracted from Eucheuma, but now known to be carrageenan. The term agar is now generally applied to those algal galactans which have agarose, the disaccharide agarobiose as their repeating unit. Raw materials for the production of agar are red algae such as *Gelidiella acerosa, Gracilaria edulis, G. verrucosa* and species of *Gelidium, Pterocladia* and *Ahenfeltia.*

Agar is an important colloid used extensively in biomedical laboratories and in R& D labs as a basal medium for the culture of microbes, cells and tissue. In food sector, agar is used for gelling and thickening in the confectionary and bakery purposes and as a stabilizer for the preparation of cheese. In fish and meat processing industries, agar is applied for canned products as a protective coating against the effect of metal containers. In brewery agar is used as a clarifying agent for wines, beer and liquors. In

pharmaceutical industry agar is used as a laxative for chronic constipation, as a drug vehicle. Agar is an ion exchanger and is used in the manufacture of ion exchange resins. In cosmetic industry agar serves as a constituent of skin creams and ointments. Agar is also employed in paper and textile industries as finishing and sizing agents.

**Algin** or alginic acid is a membrane mucilage and a major constituent of all alginates. The various salts of alginic acid are termed "alginates" (eg, sodium alginate, calcium alginate etc). In pharmaceutical industry alginic acid is used as emulsifiers in watery emulsions with fats, oils and waxes as filters in the manufacture of tablets, pills and as base of any ointments. An alginate gauze is used as a blood stopping plaster. As a slimming agent, the alginate forms a jelly in the stomach which produces the feeling of satiation. Ammonium alginate wool is used as a filter for microorganisms for laminar flow hood.

**Carrageenan** is a sulphated galactan polymer obtained from various red seaweeds belonging to families such as Gigartinaceae, Soliriaceae and Hypneaceae.In food industry carrageenan finds its use in bakery, confectionery and for the culinary purposes especially in the preparation of condiments, syrups, whipped creams, ice disserts, cheese etc. Carrageenan is used for clarifying fruit juices and other beverages. Quality of wheat flour is improved for making spaghetti and parotta by adding carrageenan. The food sector accounts for nearly 70% of the world market for carrageenan.

**Mannitol** is an important sugar alcohol of the hexite series found in the cell sap of brown algae. Mannitol also occurs as mannitan. The chief raw material for the extraction of mannitol are *Fucusvesiculosus, Bifurcariabrassiformis, Sargassum* spp, *Turbinaria* spp etc. In pharmacy mannitol is used for the preparation of tablets, for making diabetic diet, chewing gum etc. Mannitol is also used in explosives and other pyrotechniques. Mannitol finds its use as plasticizers for the production of resins

**Liquid seaweed fertilizer:** Seaweed extract is made into mineral rich liquid seaweed fertilizer (LSF) and marketed under various trade names. Studies have proved that extracts of *Sargassum wightii, Ulva lactuca,* and *Spathoglossum asperum* at 1% strength show favourable response on the germination, seedling vigour, fruit setting and on the weight of the fruit in crops such as groundnut, maize, gingelly, tomato etc. Liquid seaweed extract was first patented in the year 1912. Another patent was offered in 1962 by Maxicrop Ltd and marketed as "Maxicrop" and "Bioextract" . When foliar feeding became an orthodox method of plant nutrition in the 1950s 'Marinure', 'SM-3' and 'Trident' brands were made in the UK in 1966 and 'Algifert' in Norway in 1970. In India SPIC manufactures and markets LSF in the name of 'Cytozyme'.

**Cattle feed from seaweeds:** Shrinkage of cultivable land due to urbanization and shortage of water limit the possibility of producing more feed and fodder to livestock from land. Sea remains untapped and the seaweed resources have got immense potential to fill the gap in India. Seaweeds as animal feed had been in use as early as first century BC by the Greeks. Seaweed has been used by farmers living near the sea in Europe. In Norway *Ascophyllum*is used as pig meal. *Rhodymenia palmataa*, the red seaweed is called cow weed in Brittany and horse weed in Norway. Dried and processed seaweeds have been used as animal feed in Europe and North America.

Seaweeds are rich in protein (20- 25%), carbohydrate (50-70%), vitamins, minerals and certain drugs. When used in animal feed, cows produced more milk, chicken eggs became better pigmented and horses and pets became healthier (White and Keleshian, 1994). Feed supplemented with *Gracilaria* and/or *Spirulina* to layer chicks (white leghorn) increased the number of eggs, size and colour of yolk(Chaturvedi*et al.* 1985). Dave *et al* (1977) assessed the possibility of seaweeds being used as supplementary animal feed and they reviewed the feeding trials of farm animals with seaweeds conducted in Japan, Germany, the UK and Norway. ICAR- National Dairy Research Institute, Karnal jointly with the ICAR-CMFRI did pioneering studies on cattle feed production from *Sargassum* spp. for the ruminate animals.

| No. | Seaweed cultured | Location | Method adopted | Yield | Reference |
|---|---|---|---|---|---|
| 1. | *Sargassum vulgare* & *S.wightii* | Porbandar | coir net in a pond | 10-42 cm gain in length within 40 days | Thivy,1964 |
| 2. | *Gracilaria edulis* | sandy lagoon | long line of Kurusadi | 3.5Kg/m/yr coir rope | Raju & Thomas,1971 |
| 3. | *Gracilaria edulis* & *G.corticata* coir net raft *et al.*, 1978 | Mandapam | Aquarium tank & | 4Kg/m2/80 days | U.Rao,1973 Chennubhotla |
| 4. | *Gelidiella acerosa* | Bhavnagar | Aquarium tank | 0.01g/ day | Bhanderi,1974 |
| 5. | *G. acerosa* | lagoon of Kurusadi Island | coir rope | 3.13g/m | Krishna-murthy*et al.*, 1975 |
| 6. | *G. acerosa* | Ervadi | Seeds tied to coral stones | 3.3 fold increase | Patel *et al.*, 1979 |
| 7. | *G. acerosa* | Mandapam | Seeds attached to coral stones with nails | 3.1 fold increase | Chennubhotla *et al.*, 1977 |
| 8. | *Acanthophora spicifera* | Mandapam | Coir net rafts in a pond | 1.6 kg/m2 in 45 days | Chennubhotla *et al.*, 1987 |
| 9. | *Ulva lactuca* | Mandapam | Plastic troughs kept at shore laboratory | 2.5 fold in 30 days | *Ibid* |
| 10. | *Gelidiopsis variabilis* | Bhavnagar | Aquarium | 0,04g/day | Bhanderi,1974 |
| 11. | *Gelidium pusillum* | Bhavnagar | Aquarium, free floating method | -- | Mairh & Sreenivasa Rao,1978 |
| 12. | *Hypnea musciformis* | Lagoon of Kurusadi Island | Long line coir rope | 4 fold increase | Rama Rao& Subbaramaiah 1980 |
| 13. | *Hormophysa triquetra* | Bhavnagar | Laboratory Aquarium tank | 0.089g/day | Bhanderi& Trivedi,1977 |

These experiments revealed that *Gelidiella acerosa* could be successfully cultivated on dead corals and hollow cylindrical cement blocks and *Gracilaria edulis* and *Hypnea musciformis* on long line ropes and *Ulva fasciata* and *Enteromorpha compressa* on nets. Among these different seaweed species, the commercial cultivation has been proved economically viable only for *Kappaphycus alvarezii.* Already countries like China, Japan, Philippines and Korean republics are widely cultivating seaweeds and wild harvests are regulated.

There are two methods for cultivation of seaweeds; one by means of vegetative propagation using fragments from mother plants and the other by different kinds of spores such as zoospores, monospores, tetraspores and carpospores. In the vegetative propagation method, the fragments are inserted in the twists of ropes, tied to nylon twine or polypropylene straw and cultured in the inshore areas of the sea. The fragments are also cultured by broadcasting them in outdoor ponds and tanks.

**Vegetative propagation**:

Through the vegetative propagation method, where seaweed thallus (fronds) is the seed material and these can be collected from the natural bed from the intertidal

area during the low tide. Seaweeds are cultivated on substrata such as 2 x 2 m nets (20 cm mesh) made of either nylon or coir (obtained from coconut husks) and on 10 m long ropes. Approximately 5 g each of fronds is inserted or sandwiched between the twists of the rope at a distance of 10 cm in the long line or at each mesh in the 2 sq m nets. These "seeded" ropes or nets attached to floating rafts or bottom set fixed structures in the sea, especially protected bays, lagoons or shallow coast. The seeded ropes/nets are kept afloat in water either at surface or at the subsurface, suitable to the species cultivated by series of floats and sinkers.There are many techniques of seaweed farming through vegetative propagation method to suit the location, season of farming and the species cultivated.

**Reproductive method**

The propagation of seaweed through reproductive method can be carried out by using the reproductive units like zoospores, carpospore, tetraspore, conchospore etc. In India, reproductive propagation of seaweed was successfully done in *Gracilaria edulis* liberating the carpospores on different substrata like nylon twine, cement blocks, HDP rope and old fishing net (Reeta and Ramoorthy, 1997). The spores liberated on the substrata were allowed to grow to germling stage in a nursery and then transplanted to natural environment during favourable period of growth. The spores reached to germling stage within 13-17 days of liberation and attachment to the substrata. Three consecutive harvests can be made from the same seed after 105 days till 135 days of culture period. It was observed that the growth is very encouraging after first and successive harvest by hand pruning. The favourable period of growth for cultivation of *Gracilaria* in southeast and south west coast was found to be from November to March.

**Mariculture of *Kappaphycus*in India**

The Central Salt and Marine Chemical Research Institute introduced this fast growing species of seaweed in the Diu coast (Gujarat) in 1995 for experiments in confined waters from the Philippines. After successful introduction and acclimatization it transferred the material and the technology to PepsiCo only after convincing itself that its cultivation would be ecologically safe. The species is a source of carrageenan, a gel-forming agent widely used in the pharmaceutical and food industries. This alga is commercially cultivated in the open sea in a large area by the Pepsi Foods Limited (PFL) with the help of fishermen with whom the company has a "buy back" agreement. In India, seaweed farming, as common pool resources, stands out as the best example of community based coastal resources management (CBCRM) approaches that have enhanced the levels of employment and income among coastal communities (Krishnan and Kumar, 2010).(Agricultural Economics Research Review Vol. 23). AquAgri Processing is currently engaged in promoting *Kappaphycus* cultivation through self help groups in India which provide livelihood opportunity to coastal communities. The AquAgri model using self-help groups mainly comprising of women is an innovative model not practiced anywhere globally. Offering a fixed pre-determined price to provide a predictable income is also been put into practice for the first time, which eliminates the cultivators' risk in India as the market risk is the biggest impediment faced by the cultivators in other countries.

Contract farming of *Kappaphycusalvarezii* by the fisher folks of east coast of India has touched 2000 tonnes (dry)/ year (Fig 1). Cultivation of this seaweed generated employment for hundreds of thousands of fisher folk in some coastal districts of Tamilnadu *viz.*, Ramanathapuram, Pudukkottai, Tanjavur, Tuticorin and Kanyakumari districts earning Rs. 15000/- to Rs. 16000/- per person per month. Currently some companies like M/S Linn Plantae Private Limited, Madurai and M/S SNAP Natural and Alginate Products Pvt Ltd, Ranipet, are involved in *Kappaphycus* cultivation. The

feasibility of cultivation of this seaweed was successfully done on Okha Mandal coast at Mithapur, Okha and Beyt Dwaraka on northwest coast of India. Subsequently cultivation of this seaweed was carried out at different locations on Indian coast such as Kerala –Vizhinjam and Thangaserry, Narakkal and Padanna; Tamil Nadu – Mandapam, Kilakarai, Tutocorin and Kanyakumari coast; Andhra Pradesh – Chepala Timmapuram and Mukkam and Gujarat – Okha;Porbandar and Diu coast(Kumar *et al.*, 2016).

It is estimated that the entire global harvest of *Kappaphycus* production is 1, 83, 000 tons (dry) and it comes from cultivation alone. The Philippines and Indonesia contribute (92%) of the entire global production. According to the recent report of FAO

(2013) rapid expansion of *Kappaphycus* and *Eucheuma* cultivation have resulted in production increase from 944000 wet tons in 2000 (48% of total red seaweed production) to 5.6 million wet tons in 2010 (63%) with corresponding value from USD 72 million to USD 1.4 billion. The production of other countries *viz.* Malaysia, China and Solomon Island is considerable, while Indian contribution is so meager. In India, *Kappaphycus* farming suffered a major setback in 2014 registering very low levels of production and now restoration efforts are being made to revive the production.

**Sea farming *Gelidiella acerosa* in India**

The red alga *Gelidiellaa cerosa* growing along the intertidal regions of our peninsular coasts as well as the reef flats of Andaman and Laccadive Islands is the most important agarophyte that can yield agar with gel strength above 650 g/cm². *Gelidiella acerosa* is the preferred source of raw material for production of pharmaceutical grade agar. The agar obtained from this seaweed is of superior quality and widely used in a number of preparations in biomedical, food, cosmetics and pharmaceutical industries. *G. acerosa*is harvested from the wild stock occurring in the Gulf of Mannar coast, southeast India. The over-harvesting of *G. acerosa* throughout the year from the wild stock caused severe loss in its resource. Studies carried out on standing crop estimation of *G.acerosa* in the Gulf of Mannar region over a decade of time revealed that the wet biomass of 1400 g / $m^2$ recorded during 1996- 1998 has drastically reduced to 600 g / $m^2$ during 2004- 2005 and recently shrunken to just 450 g / $m^2$ during 2009- 2010. So there is an urgent need felt to conserve and restore the germ plasm of *G. acerosa* and its mariculture at commercial scale is the only viable option to conserve its resources. The farming of *G. acerosa* will ensure consistent production of quality and pure raw materials that can fetch alternative livelihood to the coastal fishers (@ Rs.50000 /ton dry weigh).The Bhavnagar based Central Salt and Marine Chemicals Research Institute (CSIR) has already developed successful technology for the mariculture of this species.

**Conclusion**

Carbon fixation by photoautotrophic algae has the potential to diminish the release of $CO_2$ into the atmosphere. There has been a 35% increase in $CO_2$ emission worldwide since 1990 (IPCC, 2007). It has been estimated that the seaweed biomass occurring along the Indian coasts is capable of utilizing 9052 t of $CO_2$ day-1 against emission of 365 t $CO_2$ day-1, indicating strong sequestration potential of 8687 t of $CO_2$ day-1 by seaweeds (Kaladharan et al., 2009). Mariculture potential of seaweed in India by the year 2020 is already estimated to 2 million tons (Devaraj et al., 1999). Import of seaweeds and seaweed polysaccharides should be reduced in a phased manner while large scale cultivation of seaweeds should be assigned top priority while integrating multitrophic aquaculture (IMTA) in the shelf, bays and even in estuaries. Ideal species recommended for mariculture in intertidal areas is *Gelidiella acerosa* and for deep waters and brackish water areas respectively are *Kappaphycus alvarezii* and *Gracilariopsis lemaneiformis*. Hence large scale mariculture of seaweeds employing *Gracilaria edulis, Gelidiellaa cerosa* for agar, *Kappaphycus alvarezii* for *k*-carrageenan and *Ulva* and *Caulerpa* for their nutraceuticals and other secondary metabolites can help mitigate major greenhouse gas and can check ocean acidification, while the seaweed farmers can ensure alternative livelihood.

**Further reading**


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