

Seaweed cultivation:

Untapped potential of India

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India's long, rich bio-diverse coastline of around 8000 km provides livelihood to millions of fish farmers. While traditional aqua farming has helped shape the coastal economy over the years, the country has been rather obtuse in adopting seaweed cultivation, an allied agricultural sector that holds immense prospects for the nation's economy. In recent years, seaweed farming gained popularity due to the growing demand for commercial seaweed polysaccharides such as agar, alginate, ulvan, carrageenan and other bioactive compounds having potential health benefits. Considering the use of seaweeds as a renewable source of food, animal feed supplement, fertilizer, pharmaceutical and nutraceuticals, the Department of Fisheries, under the 'Blue Revolution' scheme, has started promoting seaweed cultivation in India since 2015–16. As a result, several Self-Help Groups (SHGs) and coastal Fishermen Associations have come forward to take up seaweed cultivation as an additional livelihood option and proven its potential in empowering coastal women.

Keywords: Animal feed, Farming, Fertilizer, Health, Seaweed

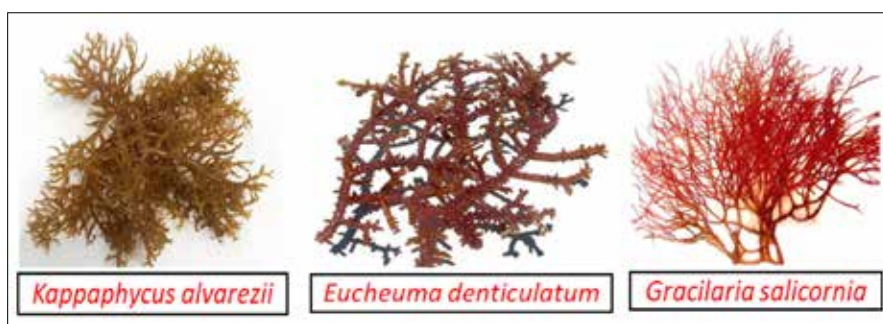
Seaweeds or marine macroalgae are important living resources in the marine environment. They are the main resources for a variety of phycocolloids such as agar, alginates, and carrageenan and these phycocolloids have applications in food, pharmaceutical, animal feed, and cosmetic industries. Seaweeds are a good source of macro (polysaccharides, protein, and lipids) and micronutrients (vitamins and minerals), and also contain several bioactive compounds. These bioactive compounds of seaweeds have a variety of functional benefits including antimicrobial, anti-inflammatory, antioxidant, immunomodulatory and anticancer effects when used as dietary supplements in human and animal diets. As a result, seaweeds gained good demand in recent years in the global market.

As per the FAO report (2021), the global seaweed production is about 35 million tonnes and our country's contribution to global production

is only about 0.01%. The value of cultivated seaweed in the global market was about USD 17.85 billion in 2021 and it is expected to grow at the rate of 10.5% CAGR during 2022–30 (Polaris Market Research 2022). Increased consumption of seaweeds around the world due to their potential health benefits, is the main key factor driving the growth of the global seaweed market and commercial seaweed production. The increased consumption of seaweed and their products around the globe necessitated

their commercial cultivation to support the supply chain in the global market. For this, commercial cultivation of seaweeds with new and better fast-growing techniques is required for a better supply.

In our country, to boost seaweed farming the state and central governments have taken several initiatives and given subsidies to farmers to promote seaweed cultivation in coastal states. Recently, the government of India allocated over ₹640 crores under PM Matsya Sampada Yojana



Commonly cultivated seaweeds in India
Source: Hurtado *et al.* (2013) and Tan *et al.* (2017)

(PMSY) for bringing vibrancy to the sector and raising the level of seaweed production from 25,000 tonnes in 2020 to 1,12,000 tonnes by 2025 through the establishment of seaweed seed banks, nurseries, tissue culture units, processing and marketing units, etc. over the coastal states.

Seaweed cultivation in India

India has nearly 8,000 km of coastal area including the coastal line of Andaman and Nicobar and Lakshadweep Islands. The long bio-diverse rich coastline of the country is providing a huge potential to grow marine algae for human consumption and other commercial purposes. As per the Central Marine Fisheries Research Institute (CMFRI) report, India has the potential to produce around 9.7 million tonnes of seaweeds in 342 identified potential sites but our country was able to produce 34,000 tonnes (in 2021) which is only 0.01% of the world production and 2.5% of the actual production potential of our country. Seaweed cultivation by coastal farmers is a sustainable and environment-friendly activity that can provide additional income for the fisherman community and improve their livelihood.

Seaweeds are broadly categorized into 3 types based on their pigments, viz. Brown (Phaeophyta), Green (Chlorophyta) and Red (Rhodophyta). Red seaweeds are abundant in our country followed by green and brown seaweeds (Table 1). Seaweeds are rapidly growing macroalgae and can be harvested within 2 months (45–60 days) of planting. The Indian coastal area has around 1153 species of seaweed from 271 genera, out of which 60 species have economic value. The maximum number of seaweeds are recorded from the Tamil Nadu state. In Tamil Nadu, Mandapam village alone has 180 species of seaweeds; among them, 40 species have economic potential.

Seaweed cultivation in India started in the early 1990s with the introduction of *Kappaphycus alvarezii* in Goa and later it expanded to other coastal states of India. Initially, the

Table 1. Diversity of seaweeds in India vs world

Seaweed	Seaweed species in India	World wide
Red algae	470	3900–9500
Brown algae	211	1500–2151
Green algae	348	800–1597
Total	1029	6200–13,248

Source: Nivedita and Raghunathan (2016)



Cultivation of seaweed on a bamboo raft

Source: https://www.forbesindia.com/media/images/2021/Nov/img_170751_eco-miracle.jpg

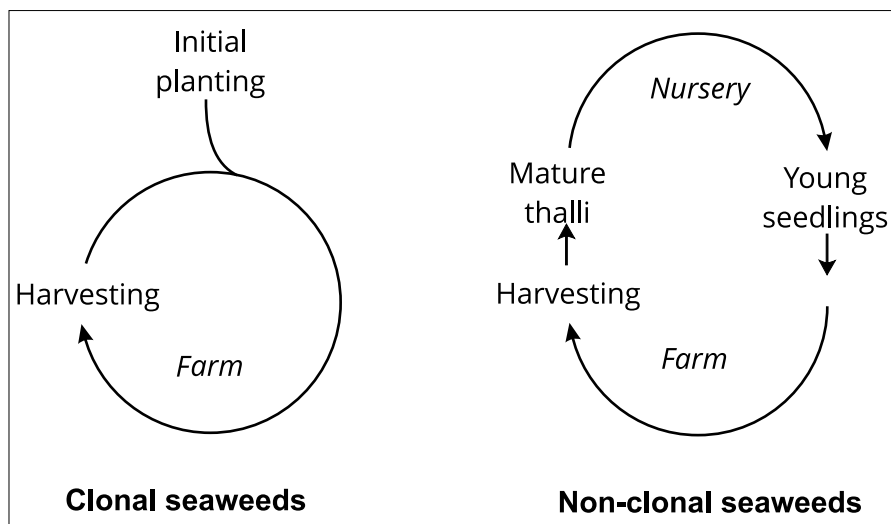
cultivation was done with wild seeds collected from the Andaman and Nicobar Islands. Later in the late 1990s *Eucheuma denticulatum* which is native to the Indo-Pacific region was introduced to India and now, it is mainly cultivated in Tamil Nadu and Kerala states. Both these seaweeds are cultivated and harvested for their carrageenan content which is widely used in the food industry as a food additive and thickener, and in the cosmetic and pharmaceutical industries.

Methods of seaweed cultivation

In our country, seaweed cultivation is mainly done by adopting traditional methods. In this method, farming communities collect the seeds from the wild and sow them on nets or ropes in shallow coastal water. From an agronomic point of view, seaweeds are of two types: clonal and non-clonal. Clonal seaweed cultivation is a single-step method and is very popular in many developing countries as their cultivation does not require nursery

rearing of seedlings and expensive infrastructural support or expertise in cultivation. Clonal seaweeds have the ability to propagate from their fragments when attached to ropes and nets in marine water. After each harvesting, small fragments of seaweeds are allowed to remain attached to nets from which thalli will get regenerated in the next growing season. Whereas, non-clonal seaweed cultivation is a multistep method that requires the rearing of seedlings and installing them on ropes for their cultivation.

The gap between the demand and supply of seaweed can be better overcome by the adaptation of new cultivation techniques for the better cultivation of different types of seaweed species. Seaweed cultivation can be done in two ways, viz. spore inoculated ropes/spore seeded ropes technique and vegetative fragments in raft technique. In India, mostly the vegetative fragment raft technique is used for the cultivation of seaweeds. Usually, one raft of cultivated



Farming method employed for clonal and non-clonal seaweeds
Source: Bast Felix (2013)

seaweed produces 200 kg of seaweed in 45 days. Commercial seaweed cultivation can be done in 4 ways i.e. floating raft method, semi-floating raft method, half-bottom method and bottom planting method. The Central Marine Fisheries Research Institute (CMFRI) at Mandapam in Tamil Nadu developed technology for the commercial cultivation of *Gracilaria edulis* by using a floating raft and rope net/spore method.

Nutritive value

In countries like Japan and China, seaweeds are consumed as a staple food for a very long time. Seaweeds are a good source of a variety of nutrients such as dietary fibre, protein, lipids, vitamins (A, B, C, D and E), minerals (Ca, P, Na, K and I), polyunsaturated fatty acids (PUFA), and many bioactive compounds such as carotenoids, polyphenols and pigments. They are also a rich sources of structural (cellulose, hemicellulose and xylose) and storage polysaccharides (carrageenan, laminarin, fucoidan, alginic acid, alginate and agar) which as prebiotic components improve the gut health by selectively stimulating the growth of health positive bacteria.

Seaweed as a source of phycocolloids

The seaweed cell walls are a good source of phycocolloids such as agar, alginate, ulvan, and carrageenan which have commercial

value in the global market. Seaweed polysaccharides are used in a variety of industries due to their physical properties such as gelation, viscosity, and stabilizing properties. Phycocolloids have a wide range of applications in several industries including the food (as a thickener and stabilizer), biotechnological (agar), and the pharmaceutical industry.

Seaweed as an animal feed

The role of seaweed additives as part of animal feed can play an important role in improving the health of animals through their antimicrobial, anti-inflammatory, anti-cancer, antioxidant, and anti-methanogenic activities which is a matter of global focus, where India has the potential to emerge as a major supplier. The supplementation of seaweed and seaweed-based products had been shown to improve the health and welfare of livestock. Considering all the functional properties of seaweeds, it would be most appropriate to use them as a feed supplement in animal diets. Seaweeds are studied extensively in monogastric animals like swine and poultry and also in ruminants as a feed supplement.

Seaweed as a fertilizer

As seaweeds are a rich source of macro and micronutrients, these can be used as an organic fertilizer to improve soil fertility and plant

growth. Seaweeds have the ability to act as a soil conditioner, bio-remediator and biological pest control agent. Brown seaweeds are most commonly used for fertilizer production. Seaweed fertilizer can be applied directly to the soil as a mulch or compost or it can be applied as a fermented liquid fertilizer. Sagarika is a seaweed-based organic fertilizer that acts as a bio-stimulant, manufactured from red and brown algae.



Sagarika fertilizer
Source: https://sagarika.com/images/sagarika_liquid.jpg

Seaweed as a food/nutraceutical

Seaweeds are widely used for direct human consumption because of the potential health benefits that they offer. Seaweeds are a good source of dietary fibre (polysaccharides), protein, lipids (PUFAs), vitamins and minerals. The seaweed polysaccharides are proven to reduce coronary heart disease by lowering the serum cholesterol level. The hypolipidemic/hypocholesterolemic effect of the seaweed polysaccharides was proved in many studies which is due to their ability to inhibit lipid absorption in GIT. Seaweeds also contain a good amount of omega-3 fatty acids (DHA & EPA) that help in cognitive development. In addition, the bioactive compounds present in seaweeds have a variety of functional benefits including antimicrobial, antiviral, anti-inflammatory, and immunomodulatory activities.

Benefits of seaweed cultivation

- Reduce the impact of greenhouse gas emissions by absorbing more carbon dioxide (carbon



Cadalmin-Antidiabetic extract from seaweeds

Source: <https://www.cmfri.org.in/uploads/images/big/Cadalmin-ADe.jpg>

sequestration) as compared to terrestrial plants and trees.

- Reverse ocean acidification.
- Improve the marine environment and ocean productivity, and abates algal blooms.
- Improved livelihood in coastal communities.
- It does not use land or freshwater.
- Contribute to national GDP.
- Can help in bio-ethanol production.

Economic benefit

Seaweeds acts as an important constituent of food, fertilizer and animal feed. They are main raw material for many industries and certainly, seaweed farming can provide additional income to coastal farmers and improve their livelihood status (Table 2). The rising demand for seaweed-based products around the world is creating potential socio-economic benefits for coastal farming communities. Currently, many industries depend on natural seaweed resources or imports from

Table 2. Economic analysis of seaweed cultivation

Expenditure detail	<i>Kappaphycus alvarezii</i>	<i>Gracilaria edulis</i>	<i>Gelidiella acerosa</i>	<i>Gracilaria dura</i>
Farmer's contribution including infrastructure cost (₹)	2,50,000	3,00,000	3,00,000	3,00,000
No. of beneficiaries/ha	5	5	5	5
Biomass produced/raft (kg dry wt.)	10	2.5	3	2
Cost of dry weed/kg (₹)	40	45	120	100
No. of cycles/year	07	07	03	05
Value of biomass produced (₹)	14,00,000	7,87,500	10,80,000	10,00,000
Net profit/person/month (₹)	19,166	8,125	13,000	11,660

Source: Ganeshan *et al.* (2019)

other countries for the seaweed phycocolloids (agar, alginate and carrageenan). If seaweed cultivation is taken at the appropriate level, this sector will definitely be able to boost the fisherman's income and national income as well.

Way forward

The extensive use of certain species of seaweed having economic potential may lead to the rapid depletion of natural algal biomass. So, there is a need to develop new and fast-growing methods for the cultivation of seaweeds. Selective breeding and genetic improvement of some economically beneficial seaweed varieties have to be done to improve the overall production yield of cultivated seaweed species. The state and central government should encourage the farmers in the coastal areas to take up seaweed farming by providing financial support and necessary schemes. The government and scientists should take care of technology demonstrations for commercial seaweed farming and processing of seaweeds for value-added products.

SUMMARY

Despite its numerous advantages, seaweed cultivation is in the

budding stage in our country, and greater production can be attained with government support and initiatives. Tamil Nadu is the leading seaweed-cultivating state in the country with more than 180 spp. being cultivated. Seaweeds can be used as organic fertilizer which improves soil fertility and further improve crop production. Due to their high nutritive value, they have potential applications in the food industry as well. Seaweeds have the potential to reduce the impact of global warming through their ability to capture atmospheric carbon (carbon sequestration). Commercial seaweed cultivation has to be geared up in the country in order to meet the target production and lead the race globally. The other unknown economical uses of seaweed have to be exploited so that it will increase the income of the farmers and this in turn would contribute to the GDP of the country. Even with all the encouragement from the government and the economic value of the seaweeds, there is still a long way to go, to achieve their cultivation on large scale and hopefully, we will achieve this in the near future.

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