सत्यमेव जयते

NITI Aayog

Model Curriculum for Diploma in Seaweed Farming and Entrepreneurship

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NITI Aayog (2024). Model Curriculum for Diploma in Seaweed Farming and Entrepreneurship

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Message by the

Hon’ble Minister

(Fisheries)

राजीव रंजन सिंह उर्फ ललन सिंह
RAJIV RANJAN SINGH ALIAS LALAN SINGH

सत्यमेव जयते

पंचायती राज मंत्री
एवं मत्स्यपालन, पशुपालन एवं डेयरी मंत्री
भारत सरकार
Minister of Panchayati Raj and
Minister of Fisheries, Animal Husbandry and Dairying
Government of India

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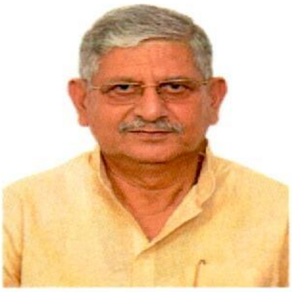

Message

The seaweed industry holds immense potential for growth and sustainability in India, yet its true value remains underutilized due to a lack of awareness and technical knowledge. As highlighted in the recently published seaweed policy document, "Strategy for the Development of the Seaweed Value Chain," there is a critical need for convergence across research organizations, industries, universities, Fish Farmer Producer Organizations (FFPOs), and millions of fish farmers nationwide. Despite the significant benefits of seaweed cultivation, many fish farmers and budding entrepreneurs remain unfamiliar with its potential.

To address this gap and overcome the myriad challenges identified in the strategy document, skill development and capacity building emerge as paramount. Recognizing this, NITI Aayog has developed a comprehensive curriculum for a Diploma Course in Seaweed Farming and Entrepreneurship. This initiative aims to provide a structured and formal approach to skill development, essential for fostering a knowledgeable and skilled workforce in the seaweed sector.

Adoption of this Model Curriculum by Agricultural and Fisheries Universities across India, particularly in coastal states, is crucial for the success of this strategy. Therefore, I urge the universities, especially in the coastal States, to launch a diploma program on seaweed farming and entrepreneurship, guided by this model curriculum. This model curriculum can be very resourceful to not just the public but also private universities, vocational training institutions, organizations promoting seaweed cultivation at grassroot level. By integrating this curriculum, we can significantly enhance the capabilities of our fishers and entrepreneurs, offering them new avenues for growth and development.At the same time, I urge FFPOs, Self Help Groups, fishers, and other aspiring entrepreneurs to explore opportunities in seaweed cultivation and processing. The future of this sector is promising, and with the right skills and knowledge, there are vast opportunities for success and innovation.

I extend my best wishes to the NITI Aayog and commend the core team for their exceptional efforts in creating a comprehensive curriculum.

(Rajiv Ranjan Singh)

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Message by the Hon'ble

Member (S&T), NITI Aayog

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सत्यमेव जयते

G20 भारत 2023 INDIA

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Government of India
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NITI Aayog, Parliament Street
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MESSAGE

The scope of India's seaweed value chain covers vast amplitudes not just in terms of cultivation but also processing, marketing, exporting etc. The realization of this potential depends to a large extent on 5 million fishermen folk in coastal India, seaweed processing industries, aspiring entrepreneurs, researchers, etc. In seaweed cultivation, India has great potential, and currently, we are operating at less than two percent of the same. India cultivated around 34,000 tons of seaweeds in 2021 and has scope for over 9 million tons more. In order to achieve the fullest of our potential, it was imperative that a large-scale capacity building and skill development program be initiated. Thereby, this Model Curriculum for Diploma Course in Seaweed Farming and Entrepreneurship has been designed to cater to this need of the value chain.

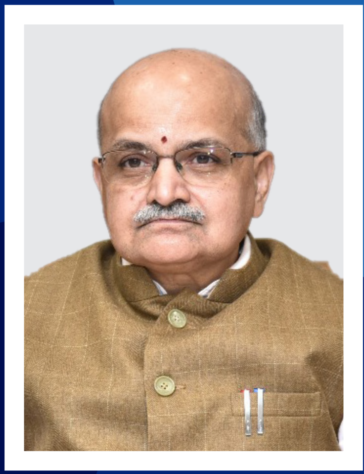
The curriculum is designed very comprehensively touching various facets of seaweed value chain, starting with preparation of planting materials, harvesting, disease management, post-harvest handling that is required for a farmer to cultivate it. It lays down the best practices, dos and don'ts during cultivation, different techniques of cultivation, etc. Further, it is not just limited to cultivation, but also lays down the various products that can be made from seaweed, their different methods of processing, identification of markets etc. It is designed in such a way so that it does not remain a theoretical course, rather a very practical-based course; thus, very crucial to produce the desired learning outcomes. Any graduate who completes this course, shall be able to not just cultivate seaweed on their own, but also be able to take up seaweed-based entrepreneurship. This also aligns with the Hon'ble Prime Minister's vision of Making India the Skill Capital of the World.

I therefore urge the Indian Agricultural and Fisheries Universities, both public and private, vocational training institutes and seaweed promoting organizations to adopt this curriculum and launch their diploma course on the same. Prerequisites for the institutions adopting this course should, is that they have the required human resources, infrastructure and capacity to provide the desired level of exposure to the learners of this diploma course. If it is adopted in the best possible way, India shall stand very close to not just realize but also discover its true seaweed value chain potential. With this in anticipation, I congratulate Dr. Neelam Patel (Program Director) and Mr. Paremal Banafarr (Young Professional), NITI Aayog, for their hard work and enthusiasm in bringing out this comprehensive curriculum.

VKSaraswat

(Dr. V.K Saraswat)

New Delhi
29.08.2024



Message by the

CEO, NITI Aayog

बी. वी. आर. सुब्रह्मण्यम
B.V.R. Subrahmanyam
मुख्य कार्यकारी अधिकारी
Chief Executive Officer

सत्यमेव जयते

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MESSAGE

The next quarter century marks the Amrit Kaal, a period during which India will unlock its untapped potential across all sectors and become a developed nation. To achieve this potential, availability of skilled human resources is vital. It is for this reason that the Hon'ble Prime Minister of India consistently emphasizes the significance of skill development, innovation and entrepreneurship in India. With over 65% of its population in the working-age group, India stands to benefit from an unprecedented demographic dividend, which is unmatched by any other nation. To fully harness this advantage, it is crucial to equip Indian students and youth with skills needed to thrive in the country's rapidly growing sectors. The seaweed value chain is one such sector with vast unexplored possibilities.

2. In May 2024, the Agriculture and Allied Sectors Vertical of NITI Aayog had launched a report on 'Strategy for the Development of Seaweed Value Chain'. The success of any strategy depends largely on the availability of skilled human resource and entrepreneurs who would man the value chain. To facilitate this process, the Vertical has come up with this 'Model Curriculum for Diploma Course in Seaweed Farming and Entrepreneurship'. With 50 lakh fishermen and women along the coasts of India, there is a tremendous opportunity for skill building in seaweed cultivation including harvesting and post-harvest management. This would create new and sustainable employment opportunities for farmers, processors, and entrepreneurs in seaweed farming, processing techniques, quality control, and product development. Moreover, seaweed farming has the potential to generate a revenue of over Rs. 13 lakh per annum and can transform the economic status of its value chain participants. Hence, availability of skilled manpower would not only strengthen the prospects of the seaweed industry but also enhance the income of fishermen, farmers and entrepreneurs in this sector.

3. The Ministry of Skill Development and Entrepreneurship and the National Skill Development Corporation would greatly benefit students and youth interested in this sector by incorporating this model curriculum under the Pradhan Mantri Kaushal Vikas Yojana (PMKVY). Along with adoption of the recommended curriculum, the required infrastructure may also be setup, especially in the Pradhan Mantri Kaushal Kendras so that the model curriculum can be delivered in the most effective way possible. Moreover, National and State Agricultural and Fisheries Universities, both in the public and private sectors, would do well by adopting this curriculum. The recommended Diploma Course would play an important role in creating skilled workforce in this sector with immense socioeconomic potential.

4. I congratulate my team in the Agriculture and Allied Sectors Vertical of NITI Aayog, especially Dr. Neelam Patel (Programme Director) and Mr. Paremal Banafarr (Young Professional), for their diligence and enthusiasm in preparing and releasing this comprehensive curriculum.

(B.V.R Subrahmanyam)

2nd September, 2024

स्वच्छ भारत
एक कदम स्वच्छता की ओर

Message by the

Secretary (DARE) & Director General (ICAR)

सत्यमेव जयते

डॉ. हिमांशु पाठक
Dr. Himanshu Pathak
सचिव (डेयर) एवं महानिदेशक (आईसीएआर)
Secretary (DARE) &
Director General (ICAR)

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली–110 001

GOVERNMENT OF INDIA
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MESSAGE

NITI Aayog recently developed the *Strategy for the Development of Seaweed Value Chain*. NITI Aayog also prepared *Model Curriculum for Diploma Course in Seaweed Farming and Entrepreneurship* to strengthen capacity-building programs for the youth of India with new career opportunities. This *Model Curriculum* has been designed by incorporating the scientific techniques and principles of seaweed farming. The comprehensiveness of the model curriculum is evident from its module progression that touches various arenas of the seaweed value chain from planting material preparation, cultivation techniques, and management of farms, to products derived from seaweed, processing techniques, and economic feasibility studies and marketing. It has also incorporated the various product development, industrial practices and economic feasibility studies for business model initiatives. It is required to adopt the model curriculum to initiate diploma courses in agricultural universities. Universities should also design curriculum suited for graduate and post-graduate levels as well. The universities are encouraged to introduce further innovation in their teaching methodologies and expand the scope of this model curriculum to augment the employability of the youth in future.

I compliment the efforts of Agriculture and Allied Sectors Vertical of NITI Aayog in bringing out this publication and hope that the model curriculum will be useful for universities, aspiring youths, entrepreneurs and other stakeholders.

(Himanshu Pathak)

Dated the 28th August, 2024
New Delhi

Acknowledgements by the Senior Adviser, Agri & Allied Sectors, NITI Aayog

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September 3, 2024

Acknowledgements

It gives me immense pleasure to present this first-of-its-kind model curriculum for seaweed farming and entrepreneurship for the seaweed enthusiasts of India. This curriculum has been designed alongside the seaweed policy titled "*Strategy for the Development of Seaweed Value Chain*". Skill development and capacity building is one of the key recommendations laid down by the seaweed policy, and this curriculum is designed to supplement the same.

First and foremost, I would like to acknowledge the continuous mentorship provided by Dr. V.K. Saraswat, Hon'ble Member (S&T), NITI Aayog who has mentored the Agriculture Vertical in NITI Aayog in this task. I would like to acknowledge the guidance of CEO, NITI Aayog, under whose leadership, NITI Aayog is able to develop a common understanding between all stakeholders. I extend my deepest thanks to Dr. Himanshu Pathak, Secretary (DARE) & Director General (ICAR) and Dr. Joykrushna Jena, Deputy Director General (Fisheries), ICAR for providing their inputs and feedback from time to time and exhibiting proactivity throughout the stakeholder consultation process. I look forward to the same proactivity from them in the promotion of this model curriculum, resulting in its adoption by the fisheries and agriculture universities of India. I express my gratitude to all the esteemed experts and organizations of the expert committee that has reviewed the draft policy report and the draft curriculum before its finalization. Notable amongst them are ICAR, CSIR-CSMCRI, ICAR-CMFRI, NCSCM, NIOT, MoEFCC, MoFAH&D, governments of maritime states/UTs, and the industry stakeholders.

I acknowledge the efforts by the former Vice-Chancellor of Gujarat University, Dr. Himanshu Pandya who has provided inputs through his team's expertise for the drafting of this curriculum. I would like to sincerely acknowledge the pivotal role played by Mr. Paremal Banafarr, Young Professional, NITI Aayog, in the crafting of this curriculum.

I thank Shri Yugal Joshi (Program Director), Communications Vertical, NITI Aayog for providing a thorough review of the draft document. Ms. Keerti Tiwari (Director), NITI Aayog has to be thanked for providing creative graphics and diligent proofreading to the document. I acknowledge the contribution made by Ms. Manisha Kumari, Research Scholar, NITI Aayog in developing this curriculum. Lastly, I would like to thank and acknowledge the role of every other stakeholder who has contributed actively or passively in making this document as and when time demanded.

(Dr. Neelam Patel)

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Table of Contents

List of Figures

List of Tables

List of Abbreviations / Acronyms

Sr. No.	SHORT FORM	FULL FORM
1)	*K. alvarezii*	*Kappaphycus alvarezii*
2)	*G. edulis*	*Gracilaria edulis*
3)	ICAR-CMFRI	Indian Council of Agricultural Research - Central Marine Fisheries Research Institute
4)	CSIR-CSMCRI	Council of Scientific & Industrial Research- Central Salt & Marine Chemicals Research Institute
5)	FAO	Food and Agriculture Organization
6)	EEZ	Exclusive Economic Zone
7)	IMTA	Integrated Multi-tropic Aquaculture
8)	HDPE	High-Density Polyethylene
9)	BCR	Benefit-Cost Ratio
10)	RFS	Raw Fresh Seaweeds
11)	IPR	Intellectual Property Rights
12)	IMTA	Integrated Multi-Trophic Aquaculture
13)	SRC	Semi-Refined Carrageenan
14)	MUZE	Multi-Stream Zero-Effuent
15)	IVRI	Indian Veterinary Research Institute
16)	CARI	Clean Air Research Initiative
17)	NDRI	National Dairy Research Institute
18)	ROS	Reactive Oxygen Species
19)	PVC	Poly Vinyl Chloride
20)	BFAR	Bureau of Fisheries and Aquatic Resources
21)	SWOT	Strengths, Weaknesses, Opportunities, Threats

Course Details

Pre-requisites for the Course

The candidate should be minimum SSC or equivalent from a recognized educational institution.

Duration of the Course

The duration of the course shall be 9-10 months, including theory and practical demonstrations.

Assessments

The faculty is advised to conduct at least 4 theory and 1 practical assessment through the course, with the practical assessment being 30% in weightage and theory being 70%.

Module 1

Introduction to Seaweed Cultivation

At the end of this module, you will be able to understand-

- The diverse types of seaweed
- Nutritional benefits of seaweed
- Value chain of seaweed
- Benefits of seaweed cultivation
- Seaweed cultivation in India
- Seaweed diversity
- SWOT analysis of seaweed cultivation in India

1.1 Seaweed Types

Seaweeds can be classified into three broad groups based on pigmentation: brown, red, and green (Figure 1.1). Botanists refer to these broad groups as *Phaeophyceae, Rhodophyceae* and *Chlorophyceae*. Brown seaweeds are usually large and giant kelp is often 20 m long, leather-like seaweeds from 2-4 m long to smaller species of 30-60 cm long. Red seaweeds are usually smaller, generally ranging from a few centimetres to about 1 metre in length; however, red seaweeds are not always red: they are sometimes purple, even brownish red, but botanists still classify them as *Rhodophyceae* because of other characteristics. Green seaweeds are also small and similar in size to red seaweeds. Seaweeds are also called macroalgae. This distinguishes them from micro-algae *(Cyanophyceae)*, which are microscopic in size, often unicellular, and are best known by the blue-green algae that sometimes bloom and contaminate rivers and streams.

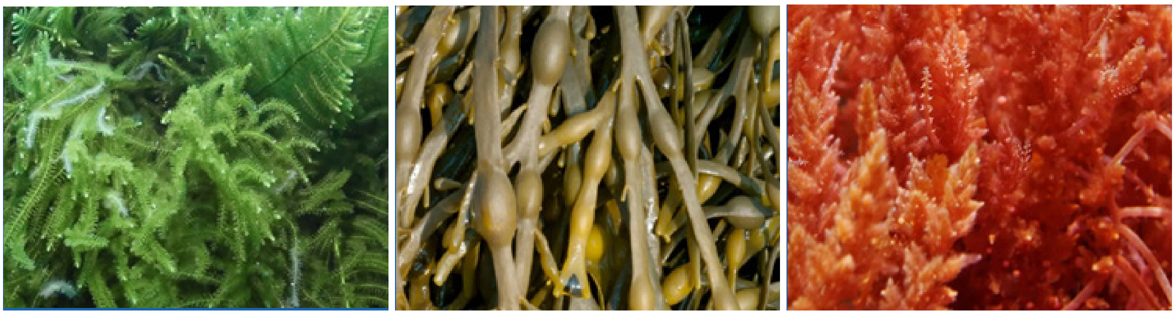

Figure 1.1: (i) Green seaweeds; (ii) Brown seaweeds; (iii) Red seaweeds

1.2 Benefits of Seaweed Cultivation

1.2.1 Nutritional Benefits

(i) Proteins

It is well known that seaweeds have been utilized as a protein source for several decades, especially in developing countries. Nowadays, seaweeds have become a cheaper protein alternative source, mainly due to high-value proteins containing essential amino acids. The protein content of seaweeds varies according to the following factors: species, environmental conditions, and the method applied for determining the protein concentration (Fleurence, 1999; Lourenço et al., 2002; Fountoulakis and Lahm, 1998). In general, red and green seaweeds have relatively high protein concentrations, with an average value of 10-30% dry matter (Mabeau and Fleurence, 1993; Burtin, 2003; Ramos et al., 2000), while brown seaweeds are low, with an average of 3-15% of dry weight (Burtin, 2003; Dawczynski et al., 2007). In winter and early spring months (February to May and November), the highest nitrogen contents in seaweeds were reported, and the lowest values were observed in summer and autumn from July to October (Gorham and Lewey, 1984). The protein content in seaweed is often estimated by multiplying the total nitrogen value, which is determined by the Kjeldahl method, by a nitrogen conversion factor of 6.25. Due to higher amounts of other nitrogen compounds (such as nucleic acid, free amino acids, nonprotein amino acids, amines, amides, nitrites, vitamins, phospholipids, and other nonprotein nitrogen compounds) or smaller amounts of nonprotein nitrogen compounds in seaweeds, the protein content results might be overestimated or underestimated. Compared to terrestrial plants and animal-based foods, seaweeds are rich in some health-promoting molecules and materials such as dietary fibres, ω-3 fatty acids, essential amino acids, and vitamins A, B, C, and E.

(ii) Minerals

Seaweeds contain significant amounts of essential minerals (Na, K, Ca, and Mg) and trace elements (Fe, Zn, Mn, and Cu), which play an important role in building human tissues and regulating vital reactions as cofactors of many metalloenzymes due to their cell surface polysaccharides (e.g., agar, carrageenan, alginic acid, alginate, salt of alginate acids, and cellulose), enabling them to absorb inorganic substances from the ambient environment (Leary et al., 2007; Yoshioka et al., 2007; McCall et al., 2000; Tanaka et al., 2000). Different mineral element contents in seaweeds vary, depending on diverse seaweed genera, seasonal differences, geographic location, light intensity, and seaweed types such as wild type and cultivated type (Teas et al., 2004; Villares et al., 2002).

(iii) Lipids

Lipids in seaweeds are present in relatively lower contents (1-5 % of dry matter), and thus they benefit human health as a food energy source due to low energy. However, almost half of the lipids are polyunsaturated fatty acids such as eicosapentaenoic acid (EPA) and arachidonic acid (AA), which can regulate blood pressure, blood clotting, and reduce the risk of cardiovascular diseases, osteoporosis, and diabetes (Maeda et al., 2008). The lipid content and fatty acid composition are commonly influenced by different ambient conditions such as light intensity, seawater salinity, and temperature. For example, the exposure of high salinity to green seaweed *Ulva pertusa* resulted in a high content of total fatty acids, while high light intensity and low salinity conditions resulted in a decreased level of total fatty acids in the same species (Floreto and Teshima, 1998).

(iv) Vitamins

Vitamins, called endogenous essential catalysts in humans, must be obtained from the diet because they are only synthesized to a restricted extent. It has been reported that seaweeds contain many vitamins, such as l-ascorbic acid (VC), thiamine (VB1), riboflavin (VB2), cobalamin (VB12), folic acid, and its derivatives (such as 5-metiltetrahydrofolate, 5-formyltetrahydrofolate, and tetrahydrofolate), tocopherols (VE), and carotenoids (Mišurcová, 2011). Vitamins of the B group, especially thiamine and riboflavin, are found in most red and brown seaweeds (MacArtain et al., 2007; Hegedüs et al., 1985). The vitamin E content in brown seaweeds is generally higher as compared to red and green seaweed (Ortiz et al., 2006). Carotenoids, strong antioxidants, are also found in brown, red, and green seaweed (Norziah and Ching, 2000). In general, the above-reported vitamins are all present in seaweeds, and their contents vary depending on collecting time, species, seasons, and environmental conditions, as well as seaweed processing type. (Lordan et al., 2011).

1.2.2 Ecological Benefits

Seaweed farming represents a climate-resilient form of aquaculture that offers numerous benefits. Seaweed cultivation is advantageous as it requires no land, freshwater, or fertilizers. It provides sustainable and diverse livelihood options along with employment generation to coastal communities. Moreover, seaweed farming mitigates the adverse effects of oceanic eutrophication and acidification while promoting a healthy ecosystem by oxygenating seawater. Seaweed farming plays a role in carbon sequestration. They release carbon, which can be either buried in sediments or exported to the deep sea, effectively acting as a sink for CO_2. Mariculture seaweed's estimated carbon sequestration rates amount to 57.64 tons of CO_2 per ha per year, while pond-cultured seaweeds sequester 12.38 tons of CO_2 per ha per year. Globally, seaweed production reached 35.1 million tonnes of wet weight, with a first sale value estimated at 16.5 billion USD in 2022 (FAO, 2022). Seaweed cultivation demonstrates remarkable adaptability to changing environmental conditions, making it a resilient alternative for coastal communities contending with climate change impacts. Seaweeds can thrive in diverse temperature ranges and require minimal freshwater inputs, reducing the strain on limited freshwater resources.

Specifically, *K. alvarezii* has been estimated to sequester 19 kg of CO_2 per day per ton of dry weight, or equivalently 760 kg of CO_2 per day per ton of dry weight per ha (Johnson et al., 2023a). Furthermore, seaweeds enhance water quality by absorbing excess nutrients, thus aiding in improving marine environments. They also serve as essential habitats and protect a wide range of marine biodiversity, fostering the preservation of various species and their ecological interactions.

Seaweed-based bio-stimulants have numerous applications in climate change. For instance, the biostimulant derived from *Kappaphycus* seaweed extract (KSWE) applied at 5% concentration increased plant and ratoon crop productivity by 12.5 and 8 %, respectively. When used at a 5% concentration, the KSWE can reduce greenhouse gas emissions by at least 2.06 kg CO_2 equivalents per ton of cane produced (Singh et al., 2018). Additionally, it has been claimed that cattle greenhouse gas emissions can be decreased by using biostimulants derived from seaweed.

1.2.3 Economic Benefits

Seaweed cultivation diversifies marine production, doubles coastal farmers' income, reduces reliance on traditional fishing, and diversifies coastal communities' livelihoods. Seaweed farming offers a sustainable and profitable alternative for economic stability and growth. *Kappaphycus alvarezii* farming has a crop duration of 45-60 days, allowing for multiple harvests per year. Farmers can earn Rs. 16/-per kg of fresh seaweed and Rs. 70/-per kg of dried seaweed with an average dry weight percentage of 10%. Under optimal conditions, the net revenue from 1 ha (400 rafts) in dry weight might reach up to Rs. 13,28,000/- per year. A family of two persons can handle around 45 rafts, providing income opportunities.

Besides, seaweed and its products trade can also be good for the forex accounts of India. Demand for seaweed-derived products, including biofuels, fertilizers, and food additives, presents income diversification and expansion opportunities.

1.3 Value Chain of Seaweed

Brief summarization of the entire value chain from seed to different final products, along with the interim processes, should be discussed (Figure 1.2). This would enable the learner to decide what kind of seaweed they should be choosing to cultivate to suit the needs of a particular type of industry that they are targeting, to sell the seaweeds.

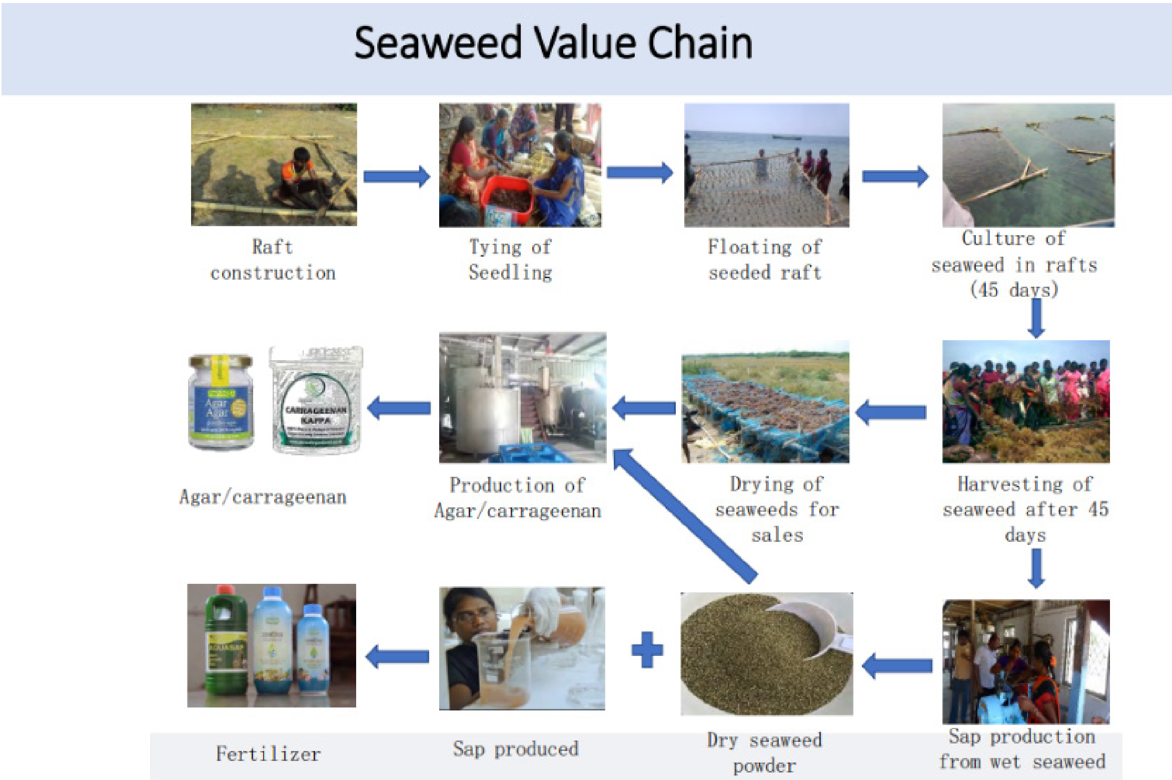

Figure 1.2: Value chain of seaweed

1.4 Seaweed Cultivation in India

Seaweed cultivation has enabled households to raise their economic status significantly, with members contributing substantially to total household income, and the majority of them are fisherwomen. The higher and more stable income for fisherwomen will improve the living standards of their families, education for the children, health, and accessibility to better amenities. These accrued benefits would attract more participation and offer opportunities for the economic empowerment of women contributing positively towards reducing gender bias. The population growth is steadily leading to unemployment, persuading the migration of the younger generation in search of better livelihood prospects to nearby towns and cities. The establishment of seaweed farming in rural areas would help to reduce emigration trends. In India, presently, nearly 33,345 tons of wet-weight seaweed per year are being harvested from natural seaweed beds (species of Sargassum, *Turbinaria, Gracilaria* and *Gelidiella)* by 5,000 families in Tamil Nadu (FRAD, CMFRI, 2022). India, which has an annual revenue of about Rs. 200 crores, provides less than 1% of the world's seaweed production. Among the global seaweed production through farming, *Kappaphycus alvarezii* and *Eucheuma* denticulatum contribute to 27.8% of the total production (FAO, 2022).

1.5 Seaweed Diversity

India is among the 12 mega-biodiversity nations in the world. India's coastline is 8100 km long and has an Exclusive Economic Zone (EEZ) of 2.17 million km^2 (equal to 66 % of the total mainland area). Nearly 30 % of its human population is one way or another, dependent on the rich, exploitable coastal and marine resources. The Indian coastline, with its different coastal ecosystems, supports the luxuriant growth of diverse seaweed populations, having considerable economic importance.

The first report on seaweed diversity was published by Iyengar (1927) on the flora of Krusadai Island on the Southeastern coast of India. Subsequently, Boergesen (1928) investigated the seaweeds of the West Coast and published a new record of Rosenvingea stellate Boergesen. Later Thivy (1948), Krishnamurthy (1957) and Umamaheswara Rao (1969) made substantial contributions to increase our knowledge of India's seaweed diversity. During 1980-1990, the Central Salt and Marine Chemicals Research Institute (CSMCRI), jointly with the Central Marine Fisheries Research Institute (CMFRI), conducted a comprehensive survey and estimated the total seaweed standing stocks as 97,400 tons wet weight from the coast of Tamil Nadu, 7500 tons wet weight from the coast of Andhra Pradesh and 19,345 tonnes wet weight from the Lakshadweep islands (Kaliaperumal and Kalimuthu, 1997).

Oza and Zaidi (2001) updated the checklist of seaweed diversity based on secondary data and reported 844 species of seaweeds, with 434, 194, and 216 species of red, brown, and green seaweeds, respectively. The CSMCRI team explored the seaweed diversity of the Gujarat and Tamil Nadu coasts (Jha et al., 2009), known for their relative abundance of seaweeds. These two maritime states, collectively, are home to 366 seaweed species that account for nearly half of India's total seaweed diversity.

1.5.1 Seaweed Diversity of Gujarat Coast

The Gujarat coast, more than 1600 km long, is located in northwest India. The coastline has varied topography, geomorphology, coastal processes and river discharges into the Arabian Sea and has been broadly segmented into five regions viz. the Rann of Kachchh, the Saurashtra coast, Gulf of Kachchh, Gulf of Khambhat and the South Gujarat coast. Among these regions, the Gulf of Kachchh, extending over 1000 km, is a wealthy coastline with the Marine National Park and Marine Sanctuary that includes 42 islands, rocky intertidal regions and mangrove forests supporting rich seaweed diversity. The Gulf of Khambhat is a delta region with several major rivers flowing into the sea, including the Narmada, Tapi and Mahi Sabarmati rivers. The intertidal region comprises mud and sand flats with minimal seaweed diversity. The survey documenting the intertidal seaweed diversity of the Gujarat coast revealed 198 species representing all three major groups of seaweed; Rhodophyta, 109 species from 62 genera; Chlorophyta, 54 species from 23 genera; Phaeophyceae, 35 species from 16 genera. Seaweed diversity is rich in the Gulf of Kachchh islands totalling 130 species from Dani, Dhabdhaba, Kalubhar, Manmarodi, and Narara Islands. Species collected varied from 93 species from Kalubhar Island to a minimum number of 14 species collected from Narara Island (Jha et al., 2009).

1.5.2 Seaweed Diversity of Tamil Nadu Coast

The Southeast Indian State of Tamil Nadu's coastline is 1076 km long with 13 coastal districts and 15 major ports and harbours. The convergence of the Bay of Bengal, the Arabian Sea, and the Indian Ocean at India's southern tip is the unique feature of this coast. Distinct variations are seen in the nature of substratum in the intertidal and subtidal regions. The northern coastal area has long, and wide sandy beaches intermittently populated with flat rocks, boulders and stones in the lower and upper intertidal regions, experiencing severe surf energy. Species belonging to the genera *Ulva, Chaetomorpha, Bryopsis* and *Grateloupia* inhabit the rocks and boulders. The central Tamil Nadu coast includes Palk Bay, which falls within the Cauvery deltaic region. The region's muddy intertidal and subtidal coast is due to the confluence of many rivers flowing to the sea. Several species of *Gracilaria,* including *G. edulis, G. foliifera, G. verrucosa* and *G. salicornia* are dominant and commercially harvested in this region.

The Gulf of Mannar, located in the southern part of Tamil Nadu, has a rich diversity from all three seaweed groups. Intertidal and subtidal rocks extend up to 1 m deep, and they support abundant growth of *Sargassum, Acanthophora* and *Hypnea* species. The subtidal coral reefs are populated with *Gelidiella, Turbinaria* and *Sargassum* species. The southern Gulf of Mannar's rocky intertidal and lower intertidal regions maintain rich populations of several *Ulva* species. *Ulva* has been collected from all 20 Gulf of Mannar islands supporting high seaweed diversity with potential economic importance. Studies carried out to determine seaweed diversity from 42 Indian coastal stations and 14 Gulf of Mannar islands showed a total of 282 seaweed species (Anon., 2012). Among these, 80 species were Chlorophyta, 56 species were *Phaeophyceae*, and 146 species were *Rhodophyta.* The genus *Caulerpa* was represented by the highest number of species (24) among the green algae, followed by Codium with seven species and Halimeda and *Ulva* with six species each. The genera *Acrosiphonia, Anastomonas, Boergesenia, Dictyosphaeria, Neomreis, Microdictyon, Struvea, Valonia* and *Valoniopsis* have a single species each. In brown algae, the genus *Sargassum* had the greatest number of species (15), followed by *Dictyota* with 10 species and *Padina* with seven species. The genera *Turbinaria, Dictyopteris* and *Chnoospora* had three species each, and the genera *Ectocarpus, Hormophysa, Hydroclathrus, Iyengaria, Rosenvingea,* and *Zonaria* were each represented by a single species.

Among the red algae, the genus *Gracilaria* represented the highest number of species (20), while the genus *Laurencia* had 12 species. Other red algal genera found include seven species of *Hypnea,* 6 species of *Grateloupia* and several genera that were represented by a single species, including *Asparagopsis, Bostrichia, Botryocladia, Chondrococcus, Chondrocanthus, Dasya, Dictyurus, Digenea, Enantiocladia, Griffithesia, Halichrysis, Helminthocladia, Neurymenia, Nitophyllum, Peyssonnelia, Tenaciphyllum and Wrangelia* (Anonymous, 2012).

1.6 SWOT Analysis of Seaweed Cultivation in India

1.6.1 Strengths

- Long coastline.
- Vast wasteland belts along the coastline.
- Availability of infrastructure and expertise.
- Availability of resources.
- Low cost of technology.
- Low labour cost.
- Domestic market availability.
- Diversified livelihood options.

1.6.2 Weaknesses

- Lacking advanced technologies in seaweed farming and processing.

- Lack of awareness of seaweed farming and its uses.
- Weak industry, R&D institute collaborations and linkages.
- Non-availability of proven technologies for commercialization.
- Limited expertise.
- Absence of technology transfer documents with clear investment, cost-benefit, and market analysis.
- Inadequate and differential policy guidelines across states.
- Lack of market predictions and technology forecasting.

1.6.3 Opportunities

- Opportunity for exports.
- Reduced import of seaweeds.
- Multiple value-added products.
- Fertilizer savings and organic agriculture promotion.
- Fuel the blue economy and inclusive economic growth in the country.
- Promote coastal rural prosperity.
- Scope for rural entrepreneurship.

1.6.4 Threats

- Imports of seaweed.
- Climate change and global warming.
- Troubled sea conditions and monsoons.
- Lack of preventive measures for disease control and grazing.
- Free market.
- Conflict with traditional fishermen.

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Module 2

Basics of Seaweed Cultivation

At the end of this module, you will be able to understand-

- Principles of seaweed farming
- Tools, equipment, and materials required for seaweed cultivation.
- Key steps involved in the cultivation and harvesting of seaweed.

2.1 Principles of Seaweed Farming

In spite of the thousands of seaweed species distributed around the world, their presence is typically limited to relatively shallow coastal waters. This is because they need sufficient sunlight passing through the water in order to photosynthesize and to be attached to a substrate to grow. At sea, attachment is normally possible only at the floor or benthos, thus seaweeds are formally classified as benthic organisms. Also important, seaweeds do not have true roots but are attached through their holdfast, a root-like organ in appearance that serves to anchor them to a substrate but does not supply them with nutrients and water as roots of land plants do. Seaweeds take up nutrients and water as well as dissolved gases directly from seawater through their entire body. There are three exceptions to the shallow water "benthic" nature of seaweeds that are relevant to farming.

47. The **first exception** is that two species of *Sargassum (S. natans* and *S. fluitans*), a ubiquitous genus of brown seaweeds, live free-floating at the surface of the Sargasso Sea and nearby Atlantic areas, where they comprise millions of tons of biomass (Huffard et al., 2014; Lapointe et al., 2014) through their many air bladders. However, although *Sargassum* species found around the world and many other seaweed species also have air bladders, only these two *Sargassum* species are holopelagic (i.e., have a completely pelagic life cycle) and, as far as it is known, inhabit only the Sargasso Sea and nearby areas. For example, free-floating *Sargassum* masses in the South China Sea have been shown to be detachments from benthic growth (Komatsu et al., 2008). Such free-floating, holopelagic growth, which is in many ways analogous to "green tides," may have applications for farming.

The **second exception** is the opportunistic growth that occurs when seaweed propagules are attached to floating structures that provide a substrate (e.g., a drifting log or a buoy and its ropes). This ability of seaweeds to attach to floating objects is the basis of seaweed farming. Just about any propagule of any seaweed can be attached to ropes or nets and will grow as long as it receives adequate sunlight and nutrient and gas requirements are satisfied, no matter how deep the sea is beneath it.

The **third exception** is when seaweeds are grown without attachment in tanks or other confined spaces provided adequate circulation (Neori et al., 2004). This is often referred to as tumble culture. Therefore, it is clear that seaweeds are not at all obligate benthic organisms and can grow very well as epipelagic organisms, be they attached or freely floating at the surface or submerged in seawater of adequate temperature and salinity, as long as their requirements for water, sunlight, nutrients, oxygen, and carbon dioxide are adequately provided for.

The cultivation or farming of seaweeds can thus be defined as the optimized planting of seaweed crops in water for growth. This means optimizing for photosynthesis, the interception of solar radiation mostly on an area basis, and the interaction with water for the uptake of nutrients, gases, and water on a volumetric basis, also related to water movement. From there on, during the grow-out phase, farming mostly ensures continued photosynthesis at the optimized rate until yield. This entails making sure seaweeds stay in place to grow in the desired spatial arrangement while controlling for hazards to the extent possible.

These include hazards of biological nature, such as herbivory and fouling; those related to water and climate, such as storms, strong currents, and changes in salinity and temperature; and those related to other users of the sea - both humans and animals. However, most of these hazards are difficult to control, and vulnerability to them must be minimized in the pre-cultivation periods, particularly by matching seaweed species with cultivation techniques for each site selected.

Though the availability of water, sunlight, and gases can usually be taken for granted in the selection of a location for seaweed farming, an adequate supply of nutrients may be an important consideration. In a successful farm, the capacity of seawater in the given locality to provide nutrients through motion or upwelling is matched with or surpasses the uptake potential of the cultivated seaweed.

Importantly, and at least to date, no pesticides or other chemicals, such as hormones or antibiotics used in fish farming, are used in seaweed farming. This not only marks another major difference between agriculture and fish farming in terms of production cost, but it also adds to the sustainability and eco-friendliness of seaweed farming, at least at this stage of its development.

A key aspect of seaweed farming is recognizing a number of biotic and abiotic stressors ("hazards") that impinge on yields in terms of both quantity and quality. Loureiro et al. (2015) consider that "the protocols that are currently used to mitigate crop losses are rudimentary" and that "in contrast to land-based agriculture, the nature and epidemiology of seaweed pathogens is dramatically understudied".

Biotic stressors are mainly the following:

- Pathogenic microorganisms.
- Fouling organisms, varying from other seaweeds and cyanobacteria (epiphytes) to a variety of invertebrates that use the cultivated seaweeds to attach to and grow on them (zoophytes).
- Invertebrates that feed on tissue, such as snails, sea urchins, crabs, and copepods; and
- Vertebrates that feed on tissue, such as herbivore fishes and sea turtles.

Abiotic stressors, which are often considered a more widely occurring limitation, perhaps due to their severity, are usually the product of adverse or non-optimal environmental conditions, often happening in a short time, such as very low or too high irradiance, water temperature, and salinity. The effects of abiotic stressors can be direct, promoting a variety of undesirable responses, including complete disintegration of the crop, or indirect, by triggering or favouring pathogenicity, like with ice–ice, a bacterial disease favoured by nonoptimal environmental conditions.

Seaweed production requires nutrients, light for growth, salinity, and temperatures that are not limiting to the species being cultivated. The mesotrophic boreal temperate coastal ocean is ideal for growing many species.

2.1.1 Dimensions of Sustainability in Seaweed Farming

An aquaculture activity is sustainable when three components are present and fulfilled (Figure 2.1):

i) Social - the ability of a community to persistently achieve good social well-being.

ii) Economic - requires that a community uses its natural resources efficiently and responsibly so that it can operate in a sustainable manner to consistently produce an operational profit; and

iii) Environmental - means that a community lives within the means of their natural resources ensuring that ecosystem services of coral reefs, mangroves, seagrass and seaweed communities are sustainably used. These dimensions of sustainability have to be considered in evaluating the feasibility of impact investment in community-based seaweed farming.

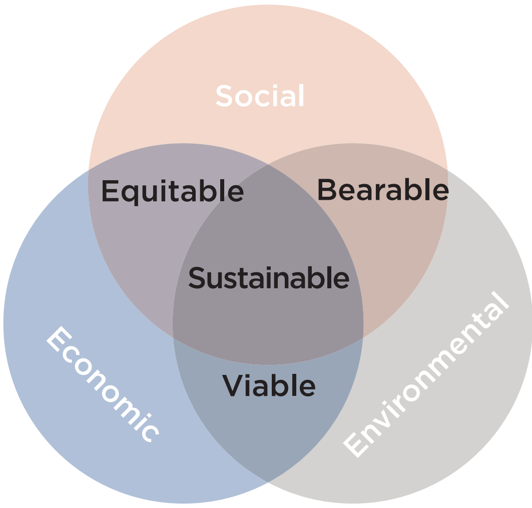


Figure 2.1: Dimensions of Sustainability in Seaweed Farming

It is crucial to involve and consult with local communities and stakeholders throughout the process of introducing and cultivating seaweed, to ensure that their livelihoods and traditional uses of the coastal environment are respected and integrated into the development plan. Seaweed cultivation has the potential to provide multiple benefits, including food security, income generation, coastal protection, and climate change mitigation.

2.2 Tools, Equipment, and Materials Required for Seaweed Cultivation

The faculty should discuss all tools, equipment and materials required for seaweed cultivation, if possible through a practical demonstration of the same. The following are some of the key tools required (Figure 2.2):

- Automatic seaweed drum dryer.
- Seaweed cutting machine.
- Seaweed grinding machine.
- Substrate washing equipment.
- Seaweed substrates 6-24 mm.
- Seaweed packing equipment.
- Seaweed conveyor Rolgang with castors.
- Seaweed conveyor Rolgang.
- Seaweed belt conveyor.

(all other tools involved in the value chain may be included).

(a) Plastic straw, softie *(b) Plastic strap, double strand, class A* *(c) Recycled PET bottles*

Figure 2.2: Tools required for seaweed cultivation.

2.3 Key Steps Involved in the Cultivation of Seaweed

2.3.1 Site Selection

The right site(s) must be selected, emphasizing local conditions in relation to the seaweed species selected. The criteria for identifying the potential seaweed farming sites have been based on the suitability of the site for the cultivation of seaweed and the availability of the site free from any environmental concerns. The criteria that should be adopted are given below:

i. Near shore areas within 1000 m distance from the lowest low tide line.
ii. Intertidal and sub-tidal zones with a rocky or sandy bottom.
iii. Previous existence of seaweed farming activity.
iv. Seaweed collection from natural seaweed beds.

v. Sheltered areas with adequate current and tidal exchange.

vi. Areas with moderate wave action.

vii. Areas free from silt deposits.

viii. Optimum basic water quality parameters:

- Salinity (28-38 ppt),
- Sea Surface Temperature (26-31°C),
- pH (6.5-8.5) and Transparency (2-6 m).
- Besides these, species specific optimum water quality parameters may be taken into consideration. Also, minimum water depth (may be considered for various modules of sea weed farming)

ix. Areas away from fishing harbour / landing centre.

x. No hindrance to existing fishing, fishing space and other allied activities.

xi. Accessibility for inputs, transportation, marketing, watch and ward.

xii. Areas away from freshwater runoff and domestic or agro-industrial effluents discharge.

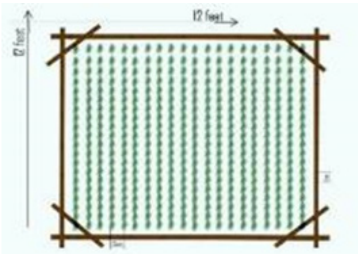
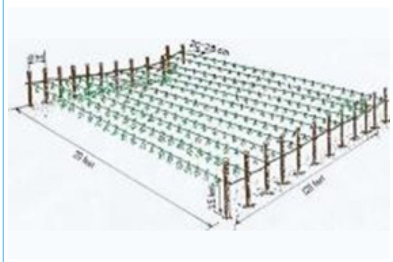
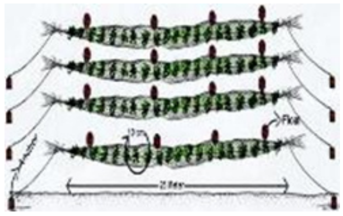
xiii. Apart from these, the following factors may be taken into consideration while identifying sites suitable for seaweed cultivation:

- Lower seawater salinity due to heavy influx of freshwater by rivers and their tributaries
- Adverse current in the inshore area, high turbidity or less seawater transparency
- Cyclone's effect (for example, in the state of Odisha).

2.3.2 Selection of Suitable Cultivation Technique

The various techniques of seaweed cultivation are briefly discussed in Table 2.1. Along the Tamil Nadu coast, bamboo rafts and monoline seaweed farming technologies are widely used. In coastal states such as Andhra Pradesh and Gujarat, the tube-net approach is suitable. When the tube-net technique is combined with open sea cage farming, as in the case of Integrated Multi-tropic Aquaculture (IMTA), seaweed grows at a faster rate than it does in a tube-net monoculture. Tube-net seaweed farming has overwhelmingly favourable socio-economic advantages as it incorporates the idea of resource integration and maximum utilization, benefitting fisher folks. Harvesting species such as *Eucheuma spp., Gracilaria spp., Kappaphycus spp., and Porphyra spp*. have been demonstrated to benefit diverse communities.

Table 2.1: Seaweed farming techniques adopted in Tamil Nadu.

Bamboo Raft technique	Monoline method	Tube-net x
		
		
In calm and shallow places, the floating bamboo raft method (12 × 12 feet bamboo poles) is ideal.	In places characterized by moderate wave action, shallow depth, and the presence of less herbivorous fishes, the monoline method of seaweed farming is ideal.	The tube net method is being adopted in places with higher wave actions.
		

2.3.3 Maintenance of Seaweed Farm

There are different ways to maintain the seaweed farm, such as

- Management of disease
- Management of epiphytism
- Management during natural calamities

It is very important to make sure that the crop stays in place in the desired spatial arrangement during the entire cropping period for biosynthesis to occur while aiding the growth process by maintaining biotic and abiotic stresses as low as feasible.

Besides these, the faculty should also discuss the different best management practices from the references.

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Module 3

Economics of Seaweed Cultivation

At the end of this module, you will be able to understand-

- Economics of seaweed cultivation
- Seaweed Farming using High-Density Polyethylene (HDPE) raft-based tube net method in rough sea conditions.
- Economics of other seaweed species

3.1 Economics of Important Seaweed Species

The economics of seaweed cultivation differs according to species and the technique adopted for cultivation. The faculty should discuss the different techniques and species-wise economics in detail in this part. The bamboo raft system is preferred for all industrially valuable Indian seaweeds. Rafts are located at the sub-surface seawater column, providing adequate sunlight exposure; rafts are easily handled and relocated to suitable locations free from epiphytes and grazing; and bottom nets minimize herbivore grazing of algae. Materials for making rafts (e.g. bamboo, anchor stones, polypropylene rope, etc.) are commonly available near the farm areas.

The economics of two important species of seaweed, viz. *Kappaphycus alvarezii (K. alvarezii)* and *Gracilaria edulis (G. edulis)* should be discussed in detail. The crop life of *Kappaphycus alvarezii* is 45-60 days. Depending on the climatic conditions, four to six crops or cycles (6 to 9 months) can be harvested annually. In 45 days, a 150 g seedling grows to 500 to 1000 g. The typical seed required for one raft of 12 ft x 12 ft size is 60 kg, but it is 15 kg for a tube net of 25 m in length. The harvested seaweed has an average dry weight percentage of 10%. Farmers currently receive Rs. 16/- for fresh seaweed and Rs. 70/- for dried seaweed, respectively.

Gracilaria edulis farming takes 45 days to complete. Depending on the weather, five to six crops or cycles (9 months) can be harvested yearly. In 45 days, a 50 g seedling can grow to 500 to 1500 g. The typical seed required for one raft of 12 ft × 12 ft size is 20 kg. The harvested seaweed has an average dry weight percentage of 15% (25% moisture). Farmers can get Rs. 20/- per kg of dried seaweed. A comparison of economics of *Gracilaria edulis vis-à-vis Kappaphycus alvarezii* is given in Table 3.1.

Table 3.1: Comparison of Economics for *K. alvarezii* and *G. edulis*

S. No.	Components	Value for *K. alvarezii*	Value for *G. edulis*
1.	Gross Seaweed production (wet weight in kg per raft per year)	1,000 kg	2000 kg
2.	Number of crops per year	4	5
3.	Seaweed is to be retained for usage as seed material next year	240 kg	100 kg
4.	Net seaweed production (wet weight in kg per raft per year)(1 minus 3)	760 kg	1900 kg
5.	Dry weight proportion	10% of wet weight	15% of wet weight
6.	Weight of dry seaweed	76 kg	285 kg
7.	Price of seaweed per kg of dry weight	Rs. 70	Rs. 20
8.	Total revenue generated per year per raft	Rs. 5,320	Rs. 5,700
9.	The annual total cost of production (including capital costs) per raft	Rs. 2,000	Rs. 2,578
10.	Net revenue per raft per year (8 minus 9)	Rs. 3,320	Rs. 3,122
11.	**Total Net revenue in dry weight per year**	45 x Rs 3,320 = Rs. 1,49,400/- (For 45 rafts)	25 x Rs 3,122 = Rs. 78,050/ year (For 25 rafts)
12.	**Net revenue from one hectare (400 rafts) in dry weight per year**	**Rs. 13,28,000/-[1]**	**Rs. 12,48,000/-[2]**

Native species (*Gracilaria*) are certainly economically attractive – if the biomass processed is considered for multiple products. Further, 3m x 3m raft of *K. alvarezii* yields an average of 150-250 kg; but 2m x 2m raft produces 15

1. A family of two person can handle an average of 45 rafts (12 ft x 12 ft)
2. A person can handle an average of 25 rafts (12 ft x 12 ft)

kg of *Gracilaria edulis* biomass and 30 kg of *G. debilis.* Thus, it is apparent that the volume of the feedstock obtained per unit area, say 1 ha is much higher for *K. alvarezii* than other seaweeds growing in Indian waters. Thus, economic feasibility is several folds high for *K. alvarezii.* However, we have advocated differential pricing of agarophytes and carragenophytes as the products obtained from agarophytes are priced relatively higher in the international market. CSIR-CSMCRI has developed relevant downstream processing technologies that match global standards. Moreover, given that the labour involved per unit area for both *K. alvarezii* and agarophytes is similar, a higher price, if offered to agarophyte seaweeds, would bring more and more people to opt for it. The detailed techno-economic analysis of farming of *K. alvarezii* (Aquaculture 2022; 551: 737912) and agarophytes (Aquaculture International 2022; 30: 1505-1525) also revealed this.

3.2 Seaweed Farming Using High-Density Poly Ethylene (HDPE) Raft-Based Tube Net Method in Rough Sea Conditions

Seaweed cultivation is more difficult in tumultuous waves than in calm seas. The floating bamboo raft-based monoline approach is popular in India and best suited for calm, shallow locations with little tidal influence. This bamboo raft is unsuitable for rough seas. Furthermore, seaweeds sown in the monoline are immediately exposed to rough waters and are readily harmed. As a result, a new HDPE raft-based tube net approach supported by grid mooring is developed for growing *K. alvarezii* in harsh climatic circumstances occurring mostly on India's Northeast and Northwest coasts. The current approach was tested along the Northeast coast, off the coast of Visakhapatnam, and could withstand rough weather conditions.

The square-shaped (3m x 3m) floating raft is made of High-Density Polyethylene (HDPE) pipes with an outer diameter of 90 mm (PE 100 grade, PN 10). The corners of the pipe are linked using butt fusion welding at 210 °C to form the raft's square shape. The tube net is made from 18-ply (1.25 mm string thickness) HDPE net material with a mesh size of 25 mm (knot to knot). For optimum development of K. *alvarezii* through tube net meshes, a mesh size of 25.0 mm (knot to knot) is recommended for tube net preparation. Seeds weighing 5.0 kg per tube net are sown separately in plain rectangular nets. Then, both ends of the net were braced with 4.0 mm polypropylene (PP) rope to form the tube net. For even distribution of *K. alvarezii* across the tube net, a few meshes were tied at 1.0 m intervals across the length of the net; otherwise, after a few days of culture, *K. alvarezii* will congregate in the middle of the net tube due to growth increment. Seeded tube nets were tied across the length of the raft, with 10 of these tube nets utilised for each raft.

Raft structures should preferably be moored by a grid mooring system. However, a single mooring anchoring technique is also advised. To keep the seeded raft in the water, utilise dead-weight permanent anchors constructed of concrete cement blocks. The five concrete blocks in each grid corner are linked by a long-link alloy steel mooring chain (13 mm diameter, 80-grade quality). This mooring chain should be linked to the floating HDPE raft at the top using D-shackles. Prior to connecting to the raft, 200-litre capacity fibre-reinforced plastic (FRP) cans filled with air are linked to the mooring chain at each corner to promote chain flotation, so stopping the direct downward pulling force on the raft construction.

Each raft structure is linked with 50-litre capacity cans at each corner, boosting the raft's buoyancy. The chosen location determines the length of the mooring chain; nevertheless, a chain length 1.5 times greater than the water depth is recommended to disperse additional tension. The suggested mooring system helps to hold the 25 rafts as a single unit. It has been observed that the seaweed seeded with approximately 5 kg/tube net yields a production of approximately 30 kg. A 300 kg /raft consisting of 10 tube nets could be obtained. Therefore, *K. alvarezii* can be cultured for six cycles in a year, 45 days of culture period/crop. This culture method will help yield approximately 45000 kg of seaweed/year/ cluster of 25 rafts with a net profit of 1.43 lakhs/year. The annual costs and returns for *K. alvarezii* farming in 25 HDPE raft-based tube nets are given in Table 3.2.

Table 3.2: Annual costs and returns for K. alvarezii farming in 25 HDPE raft-based tube nets

	Particulars	Quantity	Price per unit (Rs.)	Total Value (Rs.)	Economic Life (Years)
A.	**Initial Investment**				
1.	Rafts (nos.)	25	5000	125000	10
2.	HDPE Net (nos.)	25	500	12500	2
3.	Cement blocks (nos.)	20	1000	20000	10
4.	Mooring Chain (mts.)	60	600	36000	4
5.	Buoy (nos.)	100	100	10000	2
6.	Mooring buoy (nos.)	4	1000	4000	5
7.	Mooring Installation		5000	5000	
	Total Initial Investment (Rs.)			**212500**	
B.	**Fixed Costs**				
1.	Depreciation (Rs.)			35550	
2.	Interest on investment @ 7% per annum (Rs.)			14875	
	Total fixed costs (Rs.)			**50425**	
C.	**Operating Costs (Rs.)**				
1.	Seed material (Kg)	1250	16	20000	
2.	Labour charges for seeding and deployment (nos.)	12	600	7200	
3.	Harvesting (nos.)	24	600	14400	
4.	Maintenance and Miscellaneous Expenditure (Rs.)			15000	
5.	Interest on working capital @4% per annum (Rs.)			2264	
	Total Operating Costs (Rs.)			**58864**	
D.	**Total cost of production (Rs. 50425 + Rs. 58864)**			**109289**	
E.	**Returns**				
Total Production					
Gross Revenue (Rs.) Total production from 25 rafts is 45000 kg fresh weight (6 cycles @ 300 kg/cycle/raft). Excluding the seed material, the production is 37500 kg fresh weight (45000-7500 kg). Total production in dry weight is 3750 kg (10%)					

Particulars		Quantity	Price per unit (Rs.)	Total Value (Rs.)	Economic Life (Years)
Gross revenue @ Rs.70 per kg of dry weight				**262500**	
2.	**Net Income (Rs.)**			**153211**	
Total Production Gross Revenue (Rs.) Total production from 25 rafts is 45000 kg fresh weight (6 cycles @ 300 kg/cycle/raft)					
Excluding the seed material, the production is 37500 kg fresh weight (45000-7500kg). Total production in dry weight is 3750 kg (10%)					
Gross revenue @ Rs.70 per kg of dry weight				**262500**	
Net Income (Rs.)				**153211**	

3.3 Economics of Other Seaweed Species

The production, profits, and revenue from seaweed differ significantly due to their characteristics. Not only do these characteristics affect their economics but also the processing process. In this interest, it becomes imperative to understand the significance of cultivating a few other seaweed species. They are mentioned below. The faculty should discuss the economics of these species as well.

- *Gracilaria dura*
- *Gracilaria debilis*
- *Gracilaria salicornia*
- *Hypnea musciformis*
- *Sarconema filiforme*
- *Gelidium pusillum*

The basic production data, including market value and infrastructure cost of some of the different agarophytes, is given in Table 3.3. The analysis is done at the rate of 1 ton per day (1 TPD) and 5 tons per day (5 TPD) dry biomass with low and high-range yield scenarios.

Table 3.3: Basic production data, including market value and infrastructure cost of different agarophytes

Para-meters	*G. acerosa* (Ganesan et al., 2009)				*G. debilis* (Veeragurunathan et al., 2019)				*G. dura* (Veeragurunathan et al., 2015b)				*G. edulis* (Ganesan et al., 2011a)			
	1 TPD		5 TPD		1 TPD		5 TPD		1 TPD		5 TPD		1TPD		5 TPD	
	Yield scenario				Yield scenario				Yield scenario				Yield scenario			
	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range
Seed biomass (kg) raft^{-1}	0.5	0.5	0.5	0.5	3	3	3	3	1	1	1	1	1	1	1	1
Yield (kg) raft-1 @ 90 days *Ge. acerosa @ 45 days G. debilis, G. dura, G. edulis*	5	6	5	6	14	43	14	43	2	10	2	10	6	28	6	28
Yield after deducting seed material for subsequent crop raft^{-1} (kg)	4.5	5.5	4.5	5.5	11	40	11	40	1	9	1	9	5	27	5	27
Dry to fresh weight ratio (Water content)	4	4	4	4	8	8	8	8	7	7	7	7	10	10	10	10
Dry weight (kg)	1.12	1.38	1.12	1.38	1.38	5	1.38	5	0.14	1.29	0.14	1.29	0.5	2.7	0.5	2.7
Number of rafts required for @ 1 TPD or @ 5 TPD	889	727	4,444	3,636	727	200	3,636	1,000	7,000	778	35,000	3,889	2,000	370	10,000	1,852

Para-meters	*G. acerosa* (Ganesan et al., 2009)				*G. debilis* (Veeragurunathan et al., 2019)				*G. dura* (Veeragurunathan et al., 2015b)				*G. edulis* (Ganesan et al., 2011a)			
	1 TPD		5 TPD		1 TPD		5 TPD		1 TPD		5 TPD		1TPD		5 TPD	
	Yield scenario				Yield scenario				Yield scenario				Yield scenario			
	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range
Number of people required for seeding @ 2 rafts day^{-1} $person^{-1}$	444	364	2,222	1,818	364	100	1,818	500	3,500	389	17,500	1,944	1,000	185	5,000	926
Number of rafts growth $cycle^{-1}$ @ 90 days *Ge. acerosa* @ 45 days *G. debilis, G. dura, G. edulis*	80,000	65,455	4,00,000	3,27,273	32,727	9,000	1,63,636	45,000	3,15,000	35,000	15,75,000	1,75,000	90,000	16,667	4,50,000	83,333
Area required (ha)	32	26.18	160	130.90	13.09	3.6	65.45	18	126	14	630	70	36	6.667	180	33.33
Total days of farming year-1 @ 3 harvests of 90 days for *Ge. acerosa* @ 6 harvests of 45 days for *G. debilis* and *G. edulis* and 5 harvests of 45 days for *G. dura*	270	270	270	270	270	270	270	270	225	225	225	225	270	270	270	270

Para-meters	*G. acerosa* (Ganesan et al., 2009)				*G. debilis* (Veeragurunathan et al., 2019)				*G. dura* (Veeragurunathan et al., 2015b)				*G. edulis* (Ganesan et al., 2011a)			
	1 TPD		5 TPD		1 TPD		5 TPD		1 TPD		5 TPD		1TPD		5 TPD	
	Yield scenario				Yield scenario				Yield scenario				Yield scenario			
	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range
Total days of obtaining harvest	180	180	180	180	225	225	225	225	180	180	180	180	225	225	225	225
Total produce year^{-1} (tons)	180	180	900	900	225	225	1125	1125	180	180	900	900	225	225	1125	1125
The market value of biomass tons^{-1} as prevailing rates (Million USD) @ USD 1603 for *Ge. acerosa*, @ USD 601 for *G. debilis* @ USD 534 for *G. edulis* and @ USD 1336 for *G. dura*	0.29	0.29	1.44	1.44	0.14	0.14	0.68	0.68	0.24	0.24	1.20	1.20	0.12	0.12	0.60	0.60
Infrastructure cost (Million USD) @ USD 8.016 raft^{-1}	0.64	0.52	3.21	2.62	0.26	0.07	1.31	0.36	2.52	0.28	12.65	1.40	0.72	0.13	3.61	0.69
Total investment (Million USD) @ 50% subsidy from Fisheries Department Government of Tamil Nadu	0.32	0.26	1.60	1.31	0.13	0.04	0.66	0.18	1.26	0.14	6.30	0.70	0.36	0.07	1.80	0.34

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Module 4

Planting of Seaweed

At the end of this module, you will be able to understand-

- Preparation of planting material
- Different methods of plantation of seed stock

4.1 Preparation of Planting Material

The capacity to produce propagules of the desired species or cultivar in sufficient number and quality whenever required is a key aspect of any farming operation. This is particularly important for seaweed species or locations because abundant material for vegetative propagation is not always available, and sexual or asexual reproduction is often complex and requires expertise to be implemented (Lin et al.,2008).

Seed stock of seaweeds is traditionally collected from natural waters along the southeastern coast. However, continuous, indiscriminate, and unorganized harvesting has resulted in the depletion of natural resources. Careful selection of seedlings is necessary. Healthy, strong branches should be chosen. Good seedlings are usually found at the centre and near the tip of a healthy plant. To prepare the seedlings following procedure needs to be followed:

- Use a clean and sharp stainless knife to cut the branches in order to leave a smooth surface.
- Never cut the branch in a slant position.
- Do not produce seedlings with any cuts on their branches.

4.2 Different Methods of Plantation of Seed Stock

In seaweed farming, primarily vegetative fragments or reproductive cells (spores or gametes) from seaweeds are used as a source of seedlings (propagules) for propagation in the sea.

4.2.1 Vegetative Propagation

The vegetative propagation has undoubtedly been successful for those seaweed species with higher proliferation potentials of vegetative fragments, as in the case of *Kappaphycus, Gracilaria, Gelidiella* and *Gelidium* etc.

Seedling fragments are directly planted on 3 mm (dia.) polypropylene rope of appropriate length at regular intervals. Each rope is held floating in the water column below the surface with appropriate size floats at regular intervals as shown in Fig. 4.1.

Fig. 4.1. Raft seeded with *K. alvarezii*

Anchor stones (suitable weight) are used at each end to hold the seedling rope steadily in the water column. The seedlings grown for 40-45 days attain their full growth. These lines, ready to harvest, are towed ashore, and the ropes are detached and brought to the beach, where the materials are pulled out from the lines manually. The *K. alvarezii* grown on the rafts finally is shown in Fig. 4.2.

Fig. 4.2. *K. alvarezii* grown on raft

4.2.2 Spores

In the majority of cases, spores have been used as a source of seeding material for farming these seaweed species. The following species, namely *Porphyra, Pyropia, Ulva, Monostroma, Saccharina, Undaria,* etc., had greater reproductive potentials. Spores are seeded on artificial substrata and cultured in a land-based seedling-rearing facility under controlled conditions until a suitable plantlet size is needed for transplantation. Following the seeding operations, the ropes with growing plantlets were out-planted in the open sea for field cultivation.

Due to adaptational behaviour, many seaweed species naturally tend to disintegrate totally after reproduction or in response to seasonal or other drastic or rapid changes. For example, cold winter may damage the crop, and the shortening of day length may trigger undesirable reproductive changes (Vásquez, 1995). Russell (1986) described the process of selecting infertile plants of the red seaweed *Chondrus crispus,* which tend to disintegrate when they reach reproductive maturity, as the basis for developing cultivars for farming. If unaccounted for, this type of behaviour may represent a hindrance to farming, not only for propagation but also in terms of obtaining yields. Based on this, for the main temperate zone seaweeds, *Saccharina, Undaria,* and *Pyropia,* propagation through spore formation has occurred (Hurd et al., 2014).

For subtropical and tropical farmed species, fragments of thalli are often sufficient as vegetative propagules. While all of *Eucheuma* and *Kappaphycus* production is based on simple vegetative propagation obtained from the previous harvest (Teitelbaum, 2003; Valderrama et al., 2013), for *Gracilaria* and *Sargassum* vegetative propagation is the most common method, although they are also reproduced by spore formation (Redmond et al., 2014a,b).

Nursery procedures have been developed to produce clean and healthy propagules at commercial scale, including sexual or asexual spore formation. Tip culture (vegetative micropropagation) is also growing as an advanced means of vegetative propagation. There are more than 85 species of seaweeds for which tissue culture has been reported (Reddy et al., 2008). A depiction of a model for sustainable production of seedlings for large scale farming in marine nursery is shown in Fig. 4.3.

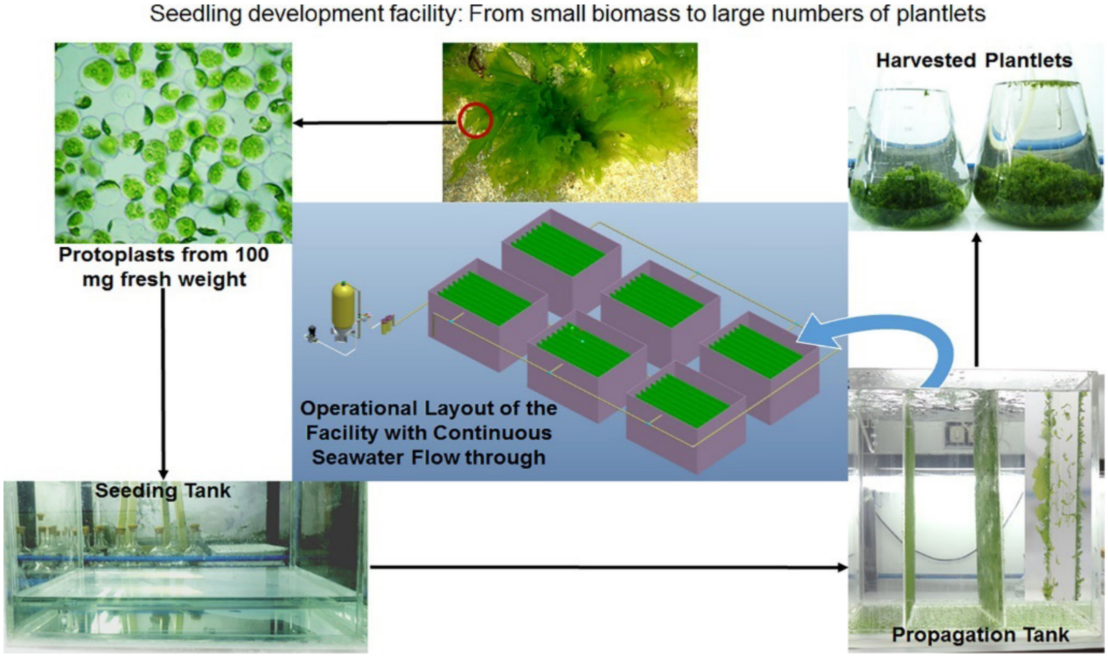

Fig. 4.3. Seedling development facility: Marine nursery model

Laboratory-produced spore propagules attach themselves directly to ropes or nets or to strings that are then attached to ropes and nets and planted for the growing season. Nursery tanks are often necessary to keep a selected vegetative stock for reproduction and planting when seasonal changes do not allow continuous farming throughout the year, also reducing natural stands. An advantage of nursery or laboratory reproduction is that high-quality and uniform propagules from selected vigorous and healthy parental lines can be used, promoting higher yields and quality. However, when simple vegetative propagation is feasible, dependence on laboratories to supply propagules may initially inhibit farming and increase costs until it becomes competitive with vegetative reproduction at the proper scale.

Although the use of vegetative propagules obtained from the last seaweed crop is advantageous for production at a small scale and with low investment through selecting, cutting, and attaching vegetative propagules of 20-150 g each spaced at 0.2-0.25 m apart to ropes or nets is very time-consuming (Breton, 2006). Vegetative propagules are attached either by tying them (tie-tie system) or inserting them in the rope fabric. Using vegetative propagules also requires seaweed biomass in the order of one to several tons per hectare, up to one-fourth of the harvest, several times a year.

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Module 5

Seaweed Cultivation Techniques

At the end of this module, you will be able to understand -

- Different techniques of seaweed cultivation such as-
  (i) Tube net technique,
  (ii) Floating bamboo technique and
  (iii) Bottom monoline technique

The faculty should discuss these techniques through practical demonstrations.

5.1 Different Techniques of Seaweed Cultivation

After obtaining or producing propagules, planting is done using the main cultivation techniques, which are variations in many ways determined by the species being farmed and the distance to the shore and to the sea floor.

5.1.1 Shallow Waters

Wooden pegs, posts, or poles buried in the sea floor are used. Pegs (e.g., 0.7 m long) are sufficient to hold off-bottom plantings. Poles of varying lengths are used for plantings at midwater or the surface.

A modality in areas where tides fluctuate moderately is to take advantage of the fixed depth allowed by poles to subject the planting to varying depths of water to the point that at some hours of the day, the whole planting is exposed to air. This does not usually affect the seaweed yet substantially decreases the load of fouling, parasites, and herbivores.

5.1.2 Deeper Waters

Waters varying from 3 m to 10 m depth or more during low tide, which represent the vast majority of the marine environment, to expand farming, a spatial arrangement based on anchors and buoys is necessary, similar to shallower sites. Anchors vary in cost and individual capacity, from burlap sacks filled with sand to concrete blocks weighing a ton or more. Buoys vary from reused plastic bottles, jugs, and barrels to factory-sourced buoys. For floating rafts, the shape of the structure is given by the rigid frame. The shape and tensional integrity of floating line plantings are obtained through the push-pull of the properly matched interactions between the sinking and buoyancy provided by water and the opposite effects from buoys and anchors. The number and characteristics of the different types of anchors and buoys depend on various conditions for each operational unit. For example, small buoys are placed along lines and larger ones at key structural points. Currents play a significant role, and, to the extent that the distance to the bottom is varied, waves and tides require a "sagging" of extra rope length from the structure or raft to anchoring. This sagging is particularly noticeable at low tides and tends to disfigure the spatial arrangement to an extent.

Cultivation techniques are mostly based on the use of ropes and nets. These are some of the most widely used techniques currently, including variations such as supporting nets with bamboo framing. After attaching the right number or density of propagules of desired characteristics to ropes or nets ("seeding"), planting consists of placing these at sea at a given depth in a predetermined spatial arrangement based on an optimized density of many plants per area. Density is determined for each species based on the expected size at harvest and other considerations by establishing the number of plants within and between rows for ropes or the equivalent parameters for nets. Both ropes and nets provide an adequate substrate for the cultivation of seaweeds, though their success in this role often depends on the type of fabric being used.

They are a customizable component of farming infrastructure, and their use allows for varying lengths and widths of plots for a variety of situations, both floating and submerged. They are also accessible, being generally available, low cost, and light yet durable and flexible - critical characteristics for withstanding deployment in the marine environment. The desired spatial arrangement of "seeded" ropes -

or lines- and nets is obtained by holding them in place and depth through two main methods, depending on the depth to the floor or the bottom.

5.2 Net Technique

It is the first commercially adapted technique of seaweed farming. The planting unit is a rectangular net measuring 2.5m × 5m with a diagonal meshwork having a 25 cm bar length. The net is made up of monofilament nylon or stranded polypropylene lines (110-150 lbs test) for the margin and 30-100 lbs test for the meshwork. The nets are installed horizontally their corners, provided with loops, are tied to stakes or wire stretched between the stakes. Each net unit has 127 mesh intersections. Seedlings are tied at these places using soft plastic straws (tie-tie). The net farming method has the advantage of intensive production because more plants can be grown in a given area.

5.3 Floating Bamboo Technique

Tie each corner of a 2.5m × 5m net to a with an evelon cord so that the net is stretched tightly. Cut a one-meter piece of bamboo and tie one piece to each corner of the net. Add an additional net to the previously constructed one (Figure 5.1).

Figure 5.1: Floating bamboo technique

Optionally, you may install a mangrove stake bipod and tripod 6 meters apart in rows with 11 bipods or tripods in each row (Figure 5.2). The rows should be 6 m apart (11 rows can hold 20 nets) (BFAR Handouts). Attach 2.5m × 5m net to the bipods and tripods. Make sure all nets are stretched tightly and are at least 2 feet above the bottom but below the lowest tide level.

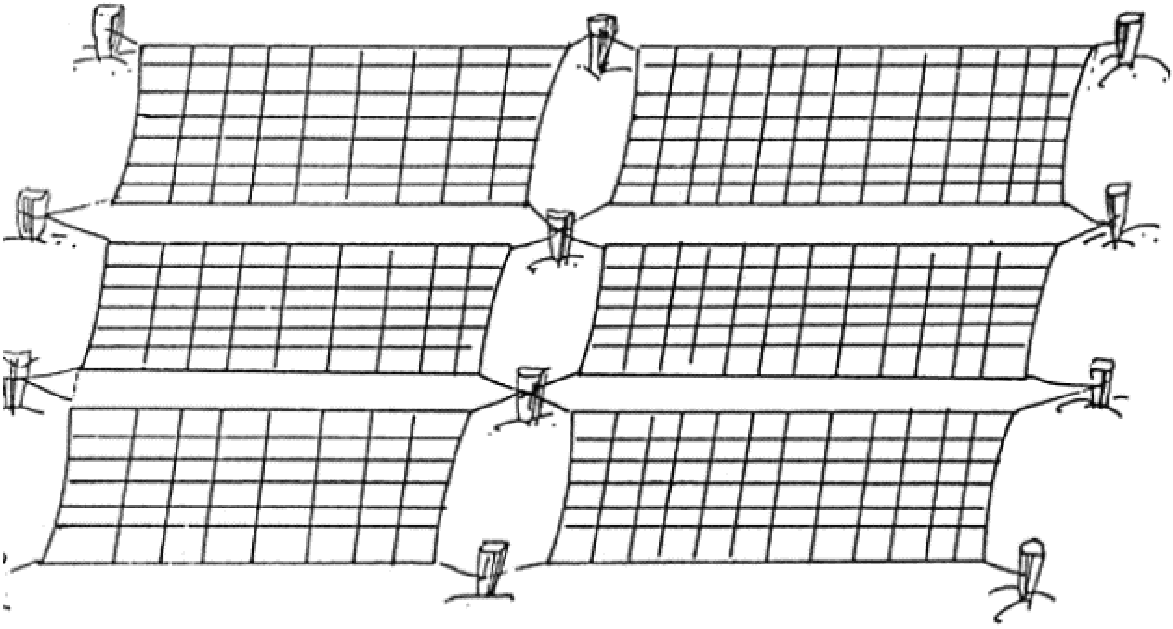


Figure 5.2: Mangrove stakes and nets

5.4 Bottom Monoline Technique

This is cheaper to establish, easier to maintain and not so prone to surface weather conditions as compared to the raft method. This method consists of modules which are units of planting in a hectare. A module has 28 monolines (single line), each measuring 30 ft (9.8 m) in length. About 36 plants can be tied to a monoline. A hectare of 35 modules consequently contains 35,000 plants, with about 1000 plants per module. A typical bottom monoline is shown in Figure 5.3.

Procedures followed in the construction of monoline:

- Using a mallet, drive wooden posts to the bottom one meter apart in rows and 10 meters between rows.
- Tie nylon monolines at both ends of the posts, parallel to each other.

- The distance of the line from the bottom should be about 20-25 cm (8-10 inches).

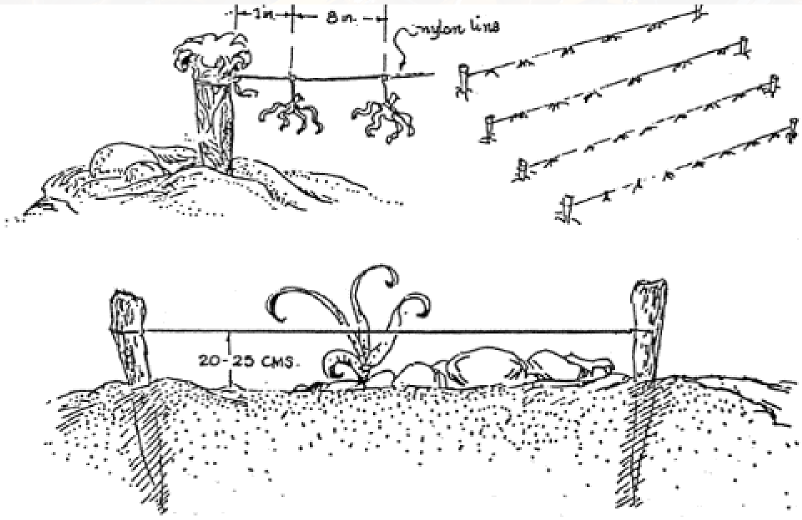


Figure 5.3: Bottom monoline technique

Technological interventions in seaweed farming are low as compared to crop plants. There is ample opportunity for technological interventions in seaweed farming in India, not only for harvesting but also for farming technologies and seeding practices as well. A triangular raft design (Figure 5.4) to achieve higher yield is one such intervention. The study (Mantri et al., 2015) describes the utility of triangular raft design and the cluster arrangement in improving the yield of commercially important agarophytes *Gracilaria edulis*. This simple modular design is cost-effective, expandable, requires no specialized skills to assemble and could be easily practiced at the individual level.

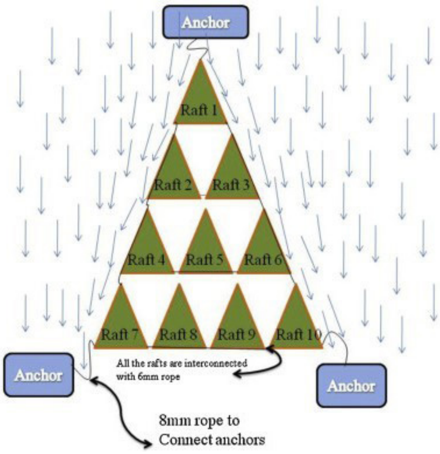


Figure 5.4: Triangular raft design

Although the average daily growth rate achieved in the triangular raft (5.01 ± 0.64 % per day) was quite comparable to conventional square rafts (4.58 ± 0.25 % per day), the biomass yield per square meter in the former was considerably higher (68.77 %) than the latter. The mean drag coefficient values were 1.726 and 2.51 for triangular and rectangular configurations, respectively. Thus, the triangular configuration was subjected to less force on the front face (more stable) than the rectangular configuration. Changing the orientation of the raft helps in augmenting yield during the lean period. Altering the positioning of rafts from horizontal to vertical alignment improved the growth and yield under open sea conditions at two different locations along the southeastern coast of India.

5.5 Other Cultivation Techniques

Other cultivation techniques include planting directly on the sea bottom in a manner similar to planting on land, such that farms resemble natural kelp forests and seaweed prairies. Given the distinct tendency of kelp-type seaweeds to grow several meters tall in temperate waters, the term "forest" is used to describe their occurrence; however, most seaweeds that cover extensive bottom surfaces are much shorter and resemble prairies more than forests. While this approach is limited to shallow coastal waters where sufficient sunlight reaches the bottom, its proponents argue that cultivated seaweed forests and prairies can act as carbon sinks and provide additional ecosystem services (Chung et al., 2013).

Other bottom-planting modalities include rock-based culture practiced with *Eucheuma spinosum* on western Indian Ocean coasts, tying seaweed cuttings with an elastic band to rocks, which after a few weeks establish their own fixation points (De San, 2012), and planting seaweed propagules directly on the seabed or using artificial substrates placed on the floor, as has been described for *Gracilaria* farming in Chile (Hernández-Rodríguez et al., 2001). Tank and pond seaweed culture, often considered small-scale though intensive, can have large-scale applications. Schemes for very large marine seaweed farms in deserts by the sea have been proposed (FAO, 2010). One of the more ambitious ones is The Green Desert Project (GDP), a concept for regreening coastal flatlands of deserts (Garcia Reina, 2010; FAO, 2010) that consists of IMTA modules that can include fish, seaweeds, shrimp, microalgae, molluscs, cyanobacteria, worms, halophytic land plants, and other organisms, depending on market considerations, local species, and local conditions in each farm (Shpigel, 2013).

To take advantage of extensive ocean areas, it makes sense to consider seaweed production on the open sea on a much larger scale. Large adrift culture rafts for free-floating cultivation have been proposed (Notoya, 2010), whether resembling growth on the Sargasso Sea or using an unanchored structure that holds shape on its own with seaweeds seeded on ropes or nets. This can be implemented particularly in gyres, where the farms will be largely kept in place by currents and /or to clean and recover hypoxic ocean areas. If structures that hold shape on their own are utilized, then single-point moorings can be used, possibly regardless of the depth to the bottom.

Seaweed nutrition can be enhanced by artificial upwelling (e.g., as in Maruyama et al., 2011). Issues such as dewatering and processing at sea are under development. Energy conversion processes, able to make use of wet biomass, have also been proposed, such as anaerobic digestion to methane, fermentation to ethanol or butanol, and several processes of thermal decomposition (Pickett et al., 2008 & Roesijadi et al., 2010).

5.6 Good Management Practices in Seaweed Cultivation

The faculty should discuss in this part, in detail, the dos and don’ts of seaweed cultivation. This should be preferably demonstrated practically on the site, if possible. The faculty should also emphasize a detailed reading of the references in this section. The various good management practices for the techniques discussed above are given in Tables 5.1 to 5.4.

(a) Bamboo raft technique

Table 5.1: (a) Bamboo raft technique

	
Hollow bamboo poles of 3-4" diameter for a 3.6m x 3.6m main frame and 1.2m x1.2m diagonals must be chosen and attached using 4 mm rope.	Bamboo with natural holes, fissures, and so on must be rejected.
	
3 mm or 3.5 mm polypropylene twisted rope can be cut into 20 bits each ranging in length from 4.0 - 4.5 m for seeding.	HDPE fishing nets that have been damaged must be rejected.
	

Cut the long braider into 20 pieces (for 20 plantation ropes) so that 400 pieces of HDPE braider with a length of 25 cm each can be made.	Damaged ropes have to be rejected.
	
Each braider should be twined at 15 cm intervals (on the 4.5 m length polypropylene twisted plantation rope). This allows 0.5 m on either side for fastening on the pole.	Damaged braiders have to be rejected.
	
To keep seaweeds from grazing, a used HDPE fishing net 4x4 m must be fastened to the raft bottom using 2mm rope.	Unhealthy seeds should be rejected.
	

Seeding should be done on the beach or on land, ideally in the shade.	Seed material should not be placed in open places which are exposed to direct sunlight, rain, temperature, and humidity fluctuations. This would impact the quality of seed material.
	
A cluster of five rafts is connected by 6 mm rope. The cluster is positioned at near shore region having depth of 1.0 to 1.5. This is done using a 30 kg anchor tied with 12-14 mm rope.	400 rafts of 12 x 12 feet size are excellent for one hectare of land. This allows for adequate space between the rafts for proper seawater circulation, maintenance, and other farm operations.
	
Seedlings brought from other districts/states should be placed in a clean net bag and stored at the bottom of the sea (1-2 m depth) for a few days before planting.	Total of 150-200 gm of seaweed fragments are tied at 15 cm intervals throughout the length of the rope. A total of 20 seaweed fragments are linked together in a single rope, and 20 of these ropes are strung together in a raft. The seed needed for this is 60-80 kg.

Source: Johnson et al., 2023a

(b) Monoline technique

Based on the location, the dimensions of the monoline units will vary. The procedure followed in the Ramanathapuram district of Tamil Nadu is depicted below in Table 5.2.

Table 5.2: Monoline technique

	
Casuarina/eucalyptus poles of 3-4” in diameter and 10 feet in length, free of natural holes, fissures, and so on, should be chosen.	Poles with natural holes, fissures, and other damage should be refused.
	
Four casuarina poles of the above dimensions are placed at 10-20 feet intervals in each corner for one unit.	The seaweed seedling rope is linked on two sides with a 6 mm rope.
	
Total of 150-200 gm of seaweed fragments are tied at 15 cm intervals throughout the length of the rope (6.75m).	Each rope has floats tied to it to increase its floatability.

The total seed consumption per monoline unit is 60-80 kg.

A single rope is made up of 40 seaweed bits.

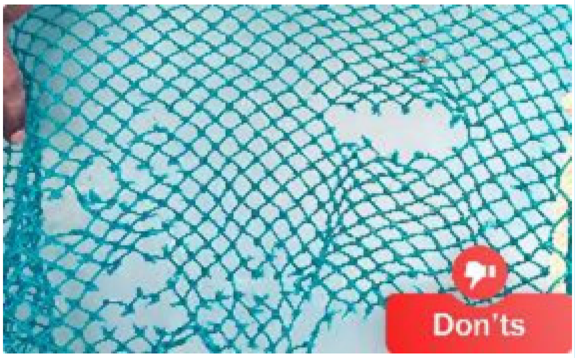
The monoline is oriented parallel to the water movement or beach. This protects seaweeds and casuarina poles. It also reduces the attachment of floating debris.

One segment (120 feet long and 20 feet wide) equals ten monoline units (in terms of production, one monoline unit equals one raft).

Source: Johnson et al., 2023a

(c) Tube net technique

Table 5.3: (c) Tube net technique

	
Tube nets (25 m length, 10 cm diameter) can be produced from HDPE food-grade nets (1.5 cm mesh size).	Damaged nets should be rejected.
	
The tube nets are held floating in the water column below the surface. A sufficient number and size of floats are placed at regular intervals. Anchor stones (about 30 kg) are used at each end to hold the tube nets steady in the water column; if required, additional anchors can be fixed in between.	A 15 kg fresh-weight seed material is put into the tubes using a 1.0 - 1.5 m long plastic pipe that acts as a funnel or hopper. For efficient seeding, the pipe diameter should be slightly smaller than that of the tube net. The plastic pipe is inserted into the tube net, and the entire tube is pulled down so that the mouth of the plastic pipe stands out of the tube. The tube net is carefully pushed down from the bottom of the plastic pipe, so that seedling material is placed into the tube sequentially, with no gaps between the seedlings. This technique is repeated until the entire tube net has been seeded with algal biomass. The tube nets are closed at both ends with rope to prevent material from being lost.

(d) Sea cage-based tube net technique

The first activity involves site selection and installation of sea cages by stocking them up with marine finfish species. Preparation of the tube net for installation in the cage should be done using fishing nets of square mesh (10 mm) of 5 m length and 12-15 cm diameter. An average of 1000 gm of good-quality seed material can be placed in each net tube. PVC pipe cut-outs are placed at regular intervals of 45 cm to maintain the firmness of the tube net structure. The ends of the tube nets should be tied to the cage rings to hold the structure steady in the water column. A total of 5 tube nets of 5 m in length for one sea cage of diameter 6 m can be installed. The process is depicted in Table 5.4.

Table 5.4: Sea cage-based tube net technique

	
Selection of seaweed planting material.	Tube-net preparation in process.
	
Installation of prepared tube-net inside the cage.	Tying of the ends of the tube net to the cage ring.

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Module 6

Harvesting and Post-Harvest Handling of Seaweed

At the end of this module, you will be able to understand-

- Harvesting of seaweed- partial and total harvests
- Commercial harvest of seaweeds along the Southeast Indian Coasts
- Post-harvest handlinzg of seaweed

6.1 Harvesting of Cultivated Seaweeds

Harvesting cultivated seaweeds and bringing them to land is a key and relatively costly aspect of sea farming. Harvesting the product and bringing it to land or processing it at sea site should be discussed here for different seaweed species. Depending on the scale of the operation, the methods employed vary substantially, from manually bringing in an armful load on foot from intertidal off-bottom plantings to mechanized harvesting of floating line plantings from large barges in deeper waters. In many ways, farmed seaweed harvesting is analogous to harvesting from agriculture operations - varying according to the crop being farmed and its intended use, the scale of the operation, available technology, and sea and weather conditions.

6.1.1 Harvesting of Seaweed- Partial and Total Harvests

Depending on the crop being produced or the cultivation technique, harvesting may be total or partial. Total harvests include ropes or nets and the seaweed material, as is done with *Saccharina, Eucheuma*, and *Kappaphycus*.

In partial harvests, only new growth from the initial planting or the previous harvest is taken, leaving behind sufficient material from each plant for regrowth, allowing for multiple harvests, as is done with several species, including *Pyropia* (Porphyra), *Gracilaria,* and *Sargassum* (Hurd et al., 2014).

Differences in harvesting techniques occur for several reasons. A total harvest may be required at the end of the growing season when maximum growth has been achieved and /or to avoid the crop suffering negative effects from seasonal changes. Another reason, as applied to *Eucheuma* and *Kappaphycus*, is that although harvesting may occur at 45-60 day intervals throughout the year, the highest accumulations of carrageenan are normally found in older tissue. Harvested lines holding these seaweeds are often passed through a hole (line stripper), where all material is removed from the rope. Therefore, taking all the seaweed material, rather than just new growth, makes sense to obtain all the older tissue (Valderrama et al., 2013).

Partial harvest, in contrast, allows for several harvests of up to 4 years with *Sargassum* (Redmond et al., 2014a) without replanting, substantially decreasing farming costs. Partial and frequent harvesting also allows farmers to count on several crops per year, avoiding complete losses of a single crop while decreasing the compounding effects of epiphytic and epizootic fouling and other biotic stresses.

Frequent harvests also allow farmers to take advantage of varying market conditions by managing the supply of produce when demand is high, although seaweed maturity considerations are important (Barta, 2008).

When farming for food, tender tissue obtained by clipping off new growth often has better gastronomic characteristics than older tissue; "hard" seaweed pieces were a common negative comment from testing panels trying different seaweed food recipes (Radulovich et al., 2015).

Hand harvesting produces the highest quality material, partly because of the opportunity for on-site removal of sea-borne contaminants (fouling, opportunistic animals and epiphytes, sea debris). Although machine harvesting is faster, it may require more careful off-site separation of undesired material from the harvested crop before use or processing.

Large seaweed farming operations use a variety of mechanical harvesters, including winches and cranes, mounted on large boats or barges to remove the complete planting setup or just the desired new growth from lines and nets. Some harvester barges bring several ropes aboard at a time or one or two nets, through either motorized or hand operation, scraping most of the growth by hand or through mechanical cutters and placing the lines or nets back for regrowth. Once the boat or barges reach shore, cranes may be used to unload the harvested material, including lines or nets in total harvest operations, placing it on carts, trucks, or conveyor belts to bring it to facilities for cleaning and processing.

6.1.2 Commercial Harvest of Seaweeds along the Southeast Indian Coasts

According to FAO (2014), global seaweed harvests from wild stocks varied between 1.0 and 1.3 million tonnes from 2000 to 2009. Unlike Southeast Asian countries, Indian seaweed industries rely heavily on wild harvests for phycocolloid production. *Gelidiella acerosa* (Forsskal) Feldmann & Hamel, and *Gracilaria edulis* (S.G. Gmelin) P.C. Silva are harvested for agar production. At the same time, *Sargassum spp.* and *Turbinaria spp.* are the source material for alginate production.

The Gulf of Mannar and Palk Bay coasts are highly productive regions for commercially collecting agarophytes and alginophytes. A long and wide coral reef (140 km length), running along the southern side of the 20 islands of the Gulf of Munnar, supports luxuriant growth of seaweeds, especially *Sargassum* spp., *Turbinaria* spp. and *G. acerosa.* Similarly, the shallow and silty Palk Bay coast harbours rich growth of *Gracilaria salicornia* (C. Agardh) and *G. edulis.*

Harvesting techniques include cutting erect fronds from mono-specific patches of the targeted seaweed. Harvesting takes approximately 12 days per month during spring tides. In the Gulf of Mannar, 1555 fisherfolk from 14 coastal villages are known to harvest seaweeds, including 1270 women and 285 men.

Along the Palk Bay coast, 670 fisherfolk from 24 villages harvest seaweeds. Among them, 460 are women and 210 are men. In India, seaweed gathering is traditionally considered a job for women and teenagers. They earn an average annual income of US $1000.

Seaweed harvesting is seasonal work and helps people earn additional income for their families. Once the seaweed collection season ends, fisherfolk shift their efforts towards fishing and allied jobs. Harvested seaweeds are dried on the shore and sold to industry buyers. *Gelidiella acerosa* is USD $1800 per dry tonne; *Gracilaria spp, Sargassum* and *Turbinaria* value is approximately US $800 per dry tonne.

The harvested seaweeds are used to produce hydrocolloids, including agar and alginates, by 33 industrial firms. Harvesting of *Gelidiella acerosa* and *Gracilaria edulis* from 2005 to 2016 resulted in a gradual depletion of natural resources due to over-exploitation, whereas *Sargassum spp*. and *Turbinaria spp.* landings exhibited an irregular value trend.

Over-harvesting of seaweeds directly affects marine biodiversity, particularly in the abundance of motile invertebrates, fish and other animals occupying higher trophic levels (Migné et al. 2014; Phillippi et al. 2014).

Over-harvesting can negatively impact recruitment and reduce contributions to the marine carbon cycle (Levitt et al. 2002). Intertidal and subtidal seaweeds dominate the habitat and strongly influence community recruitment (Thompson et al., 2010).

6.2 Post-Harvest Handling of Seaweed

Seaweeds are ready for harvest in 45 days. The harvested seaweed rafts/ monolines must be placed over the tarpaulin sheets to avoid contamination by sand/silt. To limit contamination, drying gathered seaweeds on sand should be avoided. Seaweed harvested must be dried on raised drying platforms. Impurities such as stones, shells, and other foreign matter can be cleansed when drying. Harvested and dried seaweeds must be covered with tarpaulin sheets during rainy seasons. After drying, seaweeds can be put in sacks and stored in a clean, dry environment. Deep or wet seaweeds are shipped to industries for commercial use.

6.2.1 Storage and Transportation of Seaweed

The factors affecting seaweed during storage and transportation will be discussed here. They are as follows:

Personal health and hygiene - Personnel should be healthy when handling seaweed for human consumption. Personnel feeling ill and potentially contaminating the product should not be handling the seaweed. Personnel should maintain good hygiene while handling products and equipment and wash hands frequently.

Washing - Seaweed should be rinsed at harvest with filtered seawater to remove debris and marine life that could result in product deterioration.

Exposure - Seaweed should be covered to avoid excessive exposure to wind and sun and prevent premature drying, which could increase quality deterioration.

Storage - Seaweed should not be packed tightly into storage containers; it should be kept "fluffy" with room for air circulation.

Blanching - Seaweed should be stabilized by blanching or drying as soon as possible, ideally within 48 hours of harvest.

- Packaging and storage.
- Place the seaweed in the sack after drying.
- Never mix seaweed of different varieties in one sack.
- Weigh the sacked seaweed to keep a record and put markings on the sacks.
- Store seaweed in a dry, well-ventilated storage area [2].

Transport - Before delivery and selling, weigh the sacked seaweed and contact prospective buyers about the current buying price. Look for a buyer who is trustworthy and dependable. Avoid contact of dried seaweed with water (rain or seawater) during transport, as this reduces seaweed quality.

Besides, the faculty should also discuss the equipment and facilities required for storing and transporting seaweed and the measures to be taken during storage and transport to ensure the quality of the harvested seaweed. The correct practices of stacking, storing and transporting the harvested and dried seaweed are given in Figure 6.1.

(a) Well dried seaweed after 3-4 days of drying

(b) Removing debris (tie, rubbles etc.)

(c) Sacking dried seaweed

(d) Tying sack with seaweed properly

(e) Weighing at farmers sacks at farmers' site

(f) Proper warehousing while waiting for transport to market

Figure 6.1: Storage and transportation of seaweed

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Module 7

Products Derived from Seaweed & Market

At the end of this module, you will be able to understand-

- The different segments of the market.
- Companies marketing seaweeds.
- Different products possible from the processing of seaweed.
- Identification and generation of the market for seaweed.
- Calculate the benefit-cost ratio (BCR) for the seaweed cultivation operations.

7.1 Market Segmentation

India's seaweed market is segmented based on type, cultivation method, form, and application. The market is divided into brown, red, and green seaweeds. Based on the cultivation method, the market is divided into single rope floating raft method, fixed bottom long thread method, and integrated multi-trophic aquaculture. Based on form, the market is divided into liquid and dry. Based on application, the market is divided into human consumption and non-human consumption.

Aquagri Processing Pvt Ltd., Sea6 Energy, Tata Chemicals, Coromandel International Ltd., Mars Petcare Company, HiMedia Laboratories Pvt. Ltd, Snap Natural and Alginate Products Pvt. Ltd. are the key players operating in the India seaweed market.

The faculty should teach how to calculate the benefit-cost ratio for seaweed cultivation based on the economics discussed in earlier modules. BCR is a means of assessing the degree to which the benefit of a particular project exceeds the costs.

- **BCR<1:** the net present value of the project is negative and the internal rate of return (IRR) of the project is below the discount rate.
- **BCR=1:** the project will neither create nor destroy value. The project's net present value is zero, and the project's internal rate of return (IRR) is the same as the discount rate.
- **BCR>1:** the project will generate incremental value. The net value of the project exceeds zero, and the project's internal rate of return (IRR) is greater than the discount rate.

7.2 Identification and Generation of Market for Seaweed

The faculty should provide thorough insights into indigenous seaweed identification and market generation through effective research and development (R&D).

7.3 Products Derived from Seaweeds

7.3.1 Agar

Agar is the major cell-wall constituent of certain red algae, especially the members of *Gelidiaceae, Gelidiellaceae* and *Gracilariaceae.* It is extracted from *Gelidiella acerosa, Gracilaria edulis, G. crassa, G. foliifera, G. verrucosa* and species of *Gelidium, Pterocladia* and *Ahenfeltia*. Agar is used for gelling and thickening in the confectionery and bakery industries and as a stabilizer for the preparation of cheese and salad dressings. In the fish and meat processing industry, agar is applied for canned products as a protective coating against the effect of metal containers and against shaking while transporting these products. Agar is also a clarifying agent in wines, beer, and liquors. In the pharmaceutical industry, agar is used as a laxative for chronic constipation, a drug vehicle, and a medium for bacterial and fungal cultures. Agar is an ion exchanger and is used in the manufacture of ion exchange resins. In the cosmetic industry, agar is a constituent of skin creams and ointments. Agar is also a finishing and sizing agent in the paper and textile industries.

7.3.2 Carrageenan

Carrageenan is a sulphated galactan polymer obtained from various red seaweeds belonging to *Gigartinaceae, Solieriaceae* and *Hypneaceae.* It differs mainly from agar in its higher sulphated fraction and ash content. *Chondrus crisous, Gigartina stellata, Iridaea spp., Eucheuma spp*. and *Kappaphycus spp*. are the chief raw materials used to extract carrageenan. In the food industry, carrageenan is used in bakery, confectionery, and culinary purposes, especially in preparing condiment products, syrups, whipped creams, ice desserts, cheese, etc. Carrageenan is used to clarify beer, fruit juices, and other beverages. Carrageenan improves the quality of wheat flour in spaghetti and parotta making. The food sector accounts for nearly 70% of the world market for carrageenan. In the pharmaceutical industry, carrageenan is used as an emulsifier in cod liver oil and emulsions as granulation and binding agents to tablets, elixirs, cough syrups, etc. It is used extensively in ulcer therapy and for diseases of blood vessels. Carrageenan is applied as a stabilizer and thickening agent in toothpaste, skin ointments and solid air fresheners in cosmetics. In the textile industry, hot water extracts of carrageenan are used in printing designs with dye and act as finishing and sizing agents. Carrageenan, also called *Painter Moss*, has been used in paint manufacturing as a stabilizer for pigments. They are also good as film-forming agents.

Carrageenan, which is recognised by its distinctive gelling qualities, is used as an emulsifier and thickening in a wide range of consumer products, including toothpaste, cosmetics, and ice cream, as well as pet meals, drinks, pharmaceuticals, personal care items, and the dairy industry. This adaptable seaweed-derived product has become critical in various industries, and its use as an alternative to agar has considerably increased commercial potential for carrageenophytes, particularly post World War-II.

Chemically, carrageenan exhibits three major types, each associated with distinct seaweed species:

- Beta Carrageenan: Produced by Betaphycus gelatinae (also known as gelatinae in the trade).
- Biota Carrageenan: Produced by Eucheuma denticulatum (also known as spinosum in the marketplace).
- Kappa Carrageenan: Produced by various species of the Kappaphycus (trade name cottonii).

Using carrageenan as a substitute for agar has significantly increased the commercial viability of carrageenophytes, signalling a fundamental shift in the seaweed sector. Global red seaweed farming production has increased significantly over the years. In the year 2000, production stood at 2 million freight tonnes (fr. t), accounting for 21% of total cultivated seaweed production. By 2010, this amount had increased dramatically to approximately 9 million ft, accounting for 47% of total production. However, the increase in commercial farming practices, particularly in tropical waterways, has significantly contributed to the increased production of specialised carrageenophytes. *Kappaphycus* and *Eucheuma* combined production increased from 0.94 million fr. t in 2000, accounting for 48% of red seaweed farming, to an astonishing 5.6 million fr. t in 2010, accounting for 63% of overall production (Cai et al., 2013). This transformative shift underscores the dynamic nature of seaweed cultivation, with carrageenan-rich species playing a pivotal role in shaping the industry's landscape. The demand for carrageenan in diverse applications across various sectors has driven the expansion of carrageenophyte production, making it a cornerstone in the global seaweed market.

7.3.3 Algin

Algin or alginic acid is a membrane mucilage and a major constituent of all alginates. The various salts of alginic acid are termed "alginates" (for example, sodium alginate, calcium alginate, etc.). Algin is used as a collective name for alginic acid and alginates and as a trade name for "sodium alginate". Alginic acid and its salts with divalent and trivalent metal ions are generally insoluble in water, while alkali metal salts are water-soluble. Algin is obtained from brown seaweed species such as *Ecklonia, Macrocystis, Undaria, Laminaria* and *Durvillea* from temperate areas and *Turbinaria, Sargassum, Cystoseira* and *Hormophysa* from the topical areas. The industrial method for the manufacture of algin should be discussed here from ther references (Kaliaperumal and Ramalingam, 2000). In the pharmaceutical industry, algin is used as an emulsifier in watery emulsions with fats, oils and waxes, as filler in the manufacture of tablets, pills and as the 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, producing the feeling of saturation. Ammonium alginate wool is used as a filter for microorganisms in the laminar flow hood. In cosmetic, detergent and soap-making industries, alginates serve as thickening and dispersing agents in the production of ointments, creams, liquid emulsions, lotions and toothpaste paste, as well as an additive in hair dye, hair fixing tonics, shampoos, etc. due to the ability of alginates to form films. Alginates increase the consistency of shaving and creams; in dental technology, alginates are used to make denture mouldings and fixatives. In food technology, alginates improve baking properties, and they are constituents of baking emulsions. Alginates are used to make sugar glazing, egg, fruit, and other cream fillings and in confectionery to make imitation fruits. Jelly products are made with water and insoluble alginates (calcium alginates). In several countries, alginates are suggested as a gelating agent for marmalades and jams. Alginates are extensively used in dairy products such as cheese, creams, and milkshakes mixed in chocolates, puddings, cold-prepared pudding powder, soft cheese and custards. Alginates act as stabilizers in milk mixes and impart uniform viscosity and good whipping ability. In beverages, alginates are a clarifying agent for making wines and raw liquor of sugar and molasses. Alginates act as foam stabilizers in lager beer and malt beer. In the meat and sausage industry, meat and sausage products are given a longer shelf life with an alginate film. Artificial casings with an alginate base have been developed to make small sausages, particularly for vegetarians. An alginate gel is used for deep freezing of fish, meat, and poultry products, and this has been patented in many Western countries. Alginate filaments are used in the production of calcium alginate rayons. In ceramic and leather industries, the addition of alginate stabilizes the pigment and glazing suspensions for ceramic, porcelain, Chinaware, and leather goods. Alginates have extensive applications in the textile industry, particularly as a thickening agent for printing dyes and paints that prevent smudging and promote quick drying and evenness of prints.

7.3.4 Mannitol

Mannitol is an important sugar alcohol of the hexite series found in brown algae. Mannitol is a constituent of cell sap. It occurs also as mannitan. The chief raw materials for the extraction of mannitol are *Fucus vesiculosus, Laminaria hyperborea, Ecklonia radiata, Bifurcaria brassiformis, Sargassum spp*, and *Turbinaria* spp. In the extraction of mannitol, the dried brown seaweed materials are pre-treated with dilute HCl (10-15%). The aqueous acid extract, after neutralization, is evaporated to dryness. Mannitol and soluble polysaccharides are extracted from this mixture of salts with boiling methanol for 5 hours in the Hannen and Badum extractor. The solution containing the extracted material can stand for 24 hours at 5 °C, and the crystalline mannitol precipitate is filtered and dried before weighing. In the pharmacy, mannitol is used to produce tablets. Mannitol is also used for making diabetic food, chewing gum, etc. Mannitol is employed as dusting powder in the paint and varnish, leather and paper, pyrotechnics, and in making explosives. In organic synthesis and plastic production, mannitol is used as a plasticizer for the production of resins.

7.3.5 Iodine

Iodine is extracted in small quantities from brown seaweeds in Japan, Norway, and France and red seaweeds like Phyllophora nervosa in Russia. As seaweeds are a good source to meet the dietary requirement of iodine, goitre disease caused by iodine deficiency is less prevalent in countries where marine algae form part of the diet. The iodine occurs in seaweeds in readily available form, superior to the mineral iodine. Some species of seaweeds, especially red and brown varieties, can accumulate iodine and have a more concentrated source. *Laminaria, Phyllophora* and *Ecklonia* are the seaweeds from which iodine is extracted in Japan, Britain and other countries (Kaliaperumal et. al., 1987).

7.4 Product Forms of Seaweed

The Raw Dried Seaweeds (RDS) and Carrageenan, either semi-refined (SRC) or refined (RC), represent the seaweeds typically utilised in an industrial form. In contrast, raw fresh seaweed (RFS), seaweed chips, and seaweed noodles are typical of the seaweeds historically distributed in food forms. Seaweeds have only recently been used as components of pig and poultry feeds and fertilisers for agricultural crops.

Raw Fresh Seaweeds (RFS): The most fundamental type of seaweed is RFS. These seaweeds are delivered to wet markets as soon as they are harvested. RFS is offered raw as a primary element in fresh salads when consumed as food.

Seaweed-Enriched Food Products: Popular value-added seaweed products include seaweed chips and noodles. Both are prepared by cooking flour strips, salt, raw, dried seaweed, and other ingredients. Yet, the noodles appear considerably longer and thinner. Little packs of seaweed chips are sold and are largely marketed towards youngsters for use as snacks.

Raw Dried Seaweeds (RDS): RDS is what seaweed farmers often produce. These seaweeds must be dried before being sold in the marketplace. They serve as the main requirement of the carrageenan processing facilities because they are employed largely for extracting carrageenan.

Carrageenan refined (RC): RDS is changed into RC or SRC. RC is the name given to the pure hydrocolloid that is obtained by gel pressing or alcohol precipitation from raw, dried *Kappaphycus alvarezii, K. striatum, and E. denticulatum* seaweeds that are marketed as “cottonii” and “spinosum”, respectively. With all kinds of carrageenan, alcohol precipitation can be employed. However, the gel technique only works with kappa-carrageenan. Alcohol-precipitated RC is frequently used in relatively high-end applications like jams and meat products that demand the preservation of the true colour of ingredients or goods. As a result, it is more expensive than RC, which was gel-pressed.

Semi-Refined Carrageenan (SRC): SRC is a seaweed product produced from RDS in a way that is significantly faster, whether it is food grade or pet grade. Carrageenan is not extracted from seaweeds to make SRC; rather, insoluble residues are acquired by alkali processing. After that, the leftovers are dried, diced and ground into powder. Because of this, SRC is significantly less expensive than RC but is mainly used for kappa-carrageenan. The Philippines pioneered an energy-efficient method of producing semirefined carrageenan, which is increasingly replacing refined carrageenan in canned meat and pet meals. Industry dynamics: over the previous decade, the carrageenan industry has shifted, with a reduction in dairy applications (40 to 31%) and an increase in meat processing (33 to 41%) (Bixler and Porse, 2011).

Feeds, Growth Promoters, and Fertilizer: Sun-dried, powdered brown and green seaweeds are added to or utilised as ingredients in animal feed. An effective natural fertiliser for palay and other crops, as well as a pesticide and insecticide, *sargassum spp.* are carefully processed by water extraction and fermentation to generate coffee-brown liquid.

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Module 8

Seaweed Processing for Diversified Products

At the end of this module, you will be able to understand-

- Different processing technologies for seaweed with special reference to MUZE processing.
- Diversified products from seaweed.
- The different types of seaweed that could be used in human food products.

8.1 Single Stream and MUZE Processing of Seaweed

The most widely cultivated tropical red seaweeds are of the genera *Kappaphycus, Eucheuma, and Gracilaria,* which enter commerce as raw materials for hydrocolloid manufacture. Marine hydrocolloid applications have manifested market growth on the order of 2% per annum over the past two decades, so the markets for tropical red seaweeds have virtually reached a plateau. Innovation in tropical red seaweeds agronomy will be essential if biomass production is to achieve the qualities and quantities required. As the industry evolves markets beyond those for hydrocolloid raw material such as Multi-Stream, Zero-Effuent (MUZE) processing has been developed to produce plant bio stimulant products from *Kappaphycus* in India.

The traditional approach to extracting hydrocolloids from red seaweed has led to the unfortunate waste of non-hydrocolloid components. However, with the growing adoption of MUZE processing, tropical red seaweed biomass is now being utilized to produce a diverse array of products, minimizing waste. Comparison between the MUZE processing method and the conventional single stream method has been done below (Fig. 10):

Both single-stream and MUZE processing methods involve starting with fresh seaweed. However, in single-stream processing, the seaweeds are typically dried in sunlight, packed, and transported to remote factories for additional processing. On the other hand, MUZE processing begins near the farm sites, where live seaweeds undergo initial processing stages, thus creating added value in proximity to the farming communities.

In MUZE processing, the initial step typically involves extracting juice from seaweed and separating it from the seaweed pulp. This is achieved using equipment commonly found in the fruit and vegetable juice industries. The extracted juice is often concentrated under reduced pressure to minimize the transportation of low-solids liquid and to preserve the bioactive components present. Additionally, the juice may undergo fractionation to recover specific bioactive components like growth promoters and phycobiliproteins. The remaining pulp can be further processed, either in a wet or dry state, to produce hydrocolloids or other products such as ingredients for animal feed, employing various methods. Both the juice and pulp can then undergo a wide range of additional processing options. For instance, the juice, which is abundant in potassium compounds, can serve as a plant biostimulant or source for potash fertilizer.

In the single-stream processing method, the initial step involves cooking the raw, dried seaweeds in an alkali solution. This is followed by a series of processes that include recovery and dehydration. Refined hydrocolloids are typically dissolved, clarified, and extracted by precipitating them in alcohol or potassium prior to drying. Semi-refined hydrocolloids, on the other hand, are maintained in a gel-like state throughout the processing and are dried after undergoing a washing step. Once the hydrocolloids are produced through single-stream processing, they are milled into powder form and then blended into ingredient solutions to create final products.

In a well-designed MUZE processing system, the primary waste generated is typically water vapor, which is expelled during the liquid concentration and drying stages. The freshwater obtained during the juice concentration process can be recycled back into the processing system or can be marketed and sold as a separate product.

During single-stream processing, water vapor is also produced, but a significant amount of freshwater is often consumed throughout the processing, particularly when producing semi-refined carrageenan (SRC), which is the most widely produced carrageenan variant. The production of each tonne of SRC can generate several tonnes of alkaline wastewater with high chloride content, as well as high levels of biological oxygen demand (BOD) and chemical oxygen demand (COD). Additionally, waste solids can arise from the clarification process of both wastewater and refined carrageenan, leading to the substantial production of waste filter cake.

The initial phases of MUZE processing for red seaweeds yield intermediate products in the form of juice and dried pulp. These products serve as the foundation for subsequent processing, which results in a diverse range of final products. These include hydrocolloids, food and feed ingredients, agricultural bio stimulants, renewable chemicals, biofuels, and as a by-product of juice concentration, freshwater is also generated.

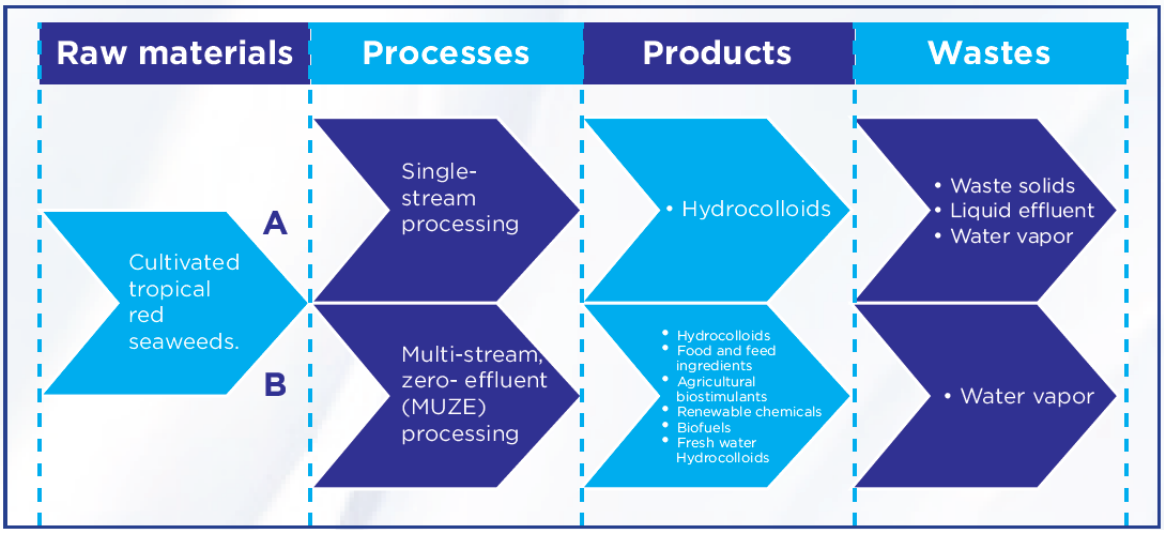

Fig. 8.1 Comparison of (A) single-stream processing as is prevalent for tropical red seaweed processing as of 2016 and (B) multi-stream, zero-effuent processing as it is being applied at present and developed for the future.

8.2 Product Diversification

The different products that could be derived from different types of seaweed, their utility, and applications.

8.2.1 Nutraceuticals

Ongoing efforts in developing a biorefinery approach aim to recover multiple products from fresh algal biomass, enhancing the sustainability and utility of seaweed farming. There are various health applications developed till date from seaweed. For example, recent studies highlight the potential of K. alvarezii in preventing diabetes. The dietary fibers derived from *K. alvarezii* exhibit remarkable properties as bioactive agents. Specifically, these fibers demonstrate a notable capacity to bind mutagenic amines. This quality holds substantial implications for pharmaceutical applications, hinting at the prospect of developing low-cost drugs in the near future. By binding mutagenic amines, these fibers may contribute to mitigating potential health risks associated with such compounds. Some of the patents developed by CSMCRI are given in Table 9. The faculty should discuss them in detail.

Table 8.1 Innovations developed by CSMCRI

Patent publication/ application number	Title
US Patent No. 6893479B2	Integrated method for production of carrageenan and liquid fertilizer.
US Patent No. 6858430B1	An improved process for cultivation of algae
US Patent No. 20050220975 A1	Low sodium salt of botanic origin.
US Patent No. 7067568B1	Process of preparation of biodegradable films from semirefined kappa-carrageenan.
PCT Publication No. EP2475776 A1	A process for integrated production of ethanol and seaweed sap from Kappaphycus alvarezii.
US Patent No. 8252359B2	Method for the preparation of refreshing drink and use thereof.
PCT Publication No. WO2014027368 A3	Process for improved seaweed biomass conversion for fuel intermediates and fertilizer.
PCT Publication No. WO2014167583 A1	K. alvarezii sap free of gibberellic acid (GA3) and its method of preparation.

Patent publication/ application number	Title
Patent Application No. US2015/ 0274942	Biodegradable hydrophobic composite materials and process for the preparation thereof (multifunctional hydrophobic ropes)
PCT Publication No. WO2015/ 087356 A1	A device for efficient and cost-effective seaweed harvesting for large-scale commercial applications

Besides, various seaweed-based nutraceutical products developed by ICAR-CMFRI are as follows:

- Green Algal extract to combat rheumatic arthritic pains
- Antidiabetic extract for use against Type II diabetes
- Antihypercholesterolemic extract for dyslipidemia
- Antihypothyroidism extract to combat hypothyroid disorders
- Antihypertensive extract for use against hypertension
- Antiosteoporotic extract to treat osteoporosis
- Immunoboost extract to boost innate immunity
- LivCure extract to combat non-alcoholic fatty liver disease
- Immunalgin extract to boost immunity and combating post-covid symptoms

8.2.2 Cosmetics

Seaweeds are often used as ingredients in the production of cosmetics. Seaweeds are either used as additives contributing to the organoleptic properties, used for stabilization and preservation of the product or as active ingredients that fulfils the cosmetic function and activity (Bedoux et al, 2014). The bioactive compounds present in seaweeds, including phenolic compounds, polysaccharides, pigments, PUFA, sterols, proteins, etc., can be used as active ingredients in cosmetic products (Pereira, 2018; Salehi et al, 2019). Seaweeds are major source of vitamins (A, B, C, D, and E) which are extensively used in skincare products (Jesumani et al, 2019).

Phlorotannins, the most important phenolic compound, is well known for applications such as anti-melanogenesis, and anti-ageing (Norzagaray-Valenzuela et al., 2017; Wang et al., 2019). Polysaccharides are used in cosmetics as a gelling agent, viscosity adjuster, thickener, and emulsifier Polysaccharides hydrates the skin, thus potentially protecting it from wrinkles (Kanlayavattanakul and Lourith, 2014). The natural pigments found in seaweeds have attracted much attention in the fields of cosmetics. Xanthophyll is used as a colour source for the cosmetics (Suseela Mathew and Ravishankar C.N.). Since seaweed contains a large number of different fatty acids, it provides a promising source of raw PUFAs for cosmetics production (Khotimchenko et al., 2002). Several fatty acids restore the permeability barrier and prevent scaly dermatitis and skin dehydration (Servel et al., 1994). Some of the PUFAs, such as linoleic acid and arachidonic acid are necessary for growth and protection of the skin (Mansour et al., 1999). It was also suggested that a lack of these fatty acids leads to cutaneous problems such as alopecia, peeling of the epidermis and eczema (Agatonovic-Kustrin and Morton, 2013). Seaweeds have amino acids, such as alanine, proline, arginine, serine, histidine, and tyrosine. *Palmaria* and *Porphyra* have the maximum amount of arginine, which is considered a natural moisturizing factor that can be used in cosmetic products (Jesumani et al., 2019).

8.2.3 Seaweed Biostimulants for Sustainable Agriculture

Unbalanced use of chemicals in farming harms soil, water, and the ecosystem, impacting plants, animals, and people. The growing population requires sustainable solutions like seaweed-based biostimulants to boost crop quality and yield. The use of Kapppahycus seaweed-based biostimulant has been recently reviewed and concise information on its beneficial effect on improving productivity of several crops, many under Indian conditions, have been documented (Trivedi *et al.* 2023). This has more relevance because of the impact of climate change being experienced currently. The seaweed-based biostimulants have an extremely low carbon footprint, which is as low as 73 and 119 kg CO_2 equivalents per kiloliter of *Gracilaria edulis*- and *Kapppahycus alvarezii* seaweed-based biostimulant production (Ghosh et al. 2015; Anand et al. 2018). Unlike traditional commercial fertilizers such as urea, muriate of potash, and diammonium phosphate, which have high carbon footprints (3253, 1435, and 515 per tonne, respectively), the combined utilization of seaweed biostimulants and reduced chemical fertilizer application has proven to conserve 12 and 35 kg CO_2 equivalents per tonne of sugarcane and rice, respectively (Gopalakrishnan and Ghosh, 2022). This approach exhibits significant promise in mitigating global climate change.

The sap derived from fresh *Kappaphycus alvarezii* as well as Gracilaria edulis are an effective biostimulant. They are inexpensive which makes it suitable for broad-acre crops and its price point makes it affordable and within the means of a small and marginal farmer. Multi-institutional multi-crop trials coordinated by CSIR-CSMCRI in collaboration with 43 State Agricultural Universities and ICAR Institutes across 20 states in India revealed that the biostimulant usage level of 2-15% results in an increase in crop yield production ranging up to 37% across crops over and above recommended fertilizer practices (Mantri et al., 2022; Bhushan et al. 2023). The trials carried out Pan-India affirmed that Kappaphycus biostimulant to be an excellent means to improve the yield of pulses and oilseeds, especially like soybean and blackgram whose yields were increased by over 20% in agro and demonstration trials (Figure). Several studies at molecular level through transcriptome analysis of roots and shoots of maize have now indicated that the seaweed biostimulant is capable of ameliorating soil moisture-stress (Kumar *et al*. 2020; Trivedi et al. 2021) and can reduce the diminution in crop yield under stress (Trivedi et al. 2018a, 2018b, 2022a). It has also been shown to stimulate soil microbes which may play a vital role in mineral cycling of soil nutrients making them more available to plants (Trivedi *et al.* 2022b). The soil microbes in moisture stress conditions was found to be maintained at par with that in normal irrigated conditions when the the *Kapppahycus* sap was applied. Studies have shown Gracilaria edulis (Singh et al. 2023) and Kappaphycus alvarezii and it to be effective in reducing the usage of chemical fertilizers by atleast 25% in crops (Sharma *et al*. 2015; Singh *et al.* 2016; Singh *et al*. 2018). While deciphering its scientific mode of action, the seaweed-biostimulants derived from *Kapppahycus* and Sargassum spp. Seaweeds were found to contain major and minor nutrients, phytohormones like indole-acetic acid, cytokinins, gibberellins and several bioactive compounds which can show bioactivity at extremely lower concentrations, some at even nano-molar levels (Vaghela et al. 2022, 2023a, b). It also contains quaternary ammonium compounds like glycine betaine, choline chloride which confers the ability of the plants to withstand abiotic stress like drought (Mondal et al. 2015). Likewise, biostimulant based on other seaweeds like Sargassum have also been found to give significantly higher performance on crops. Kappaphycus alvarezii as well as Sargassum- based biostimulants have been found to impart toleranc to soil fungal pathogens, thus warding off biotic stress (Agarwal et al. 2016, Agarwal 2021).

The Percentage increase in yield of various crops by foliar application of *Kappaphycus alvarezii*-based biostimulant as revealed from multi-institutional multi-crop trials in India is given in Figure 11 and 12.

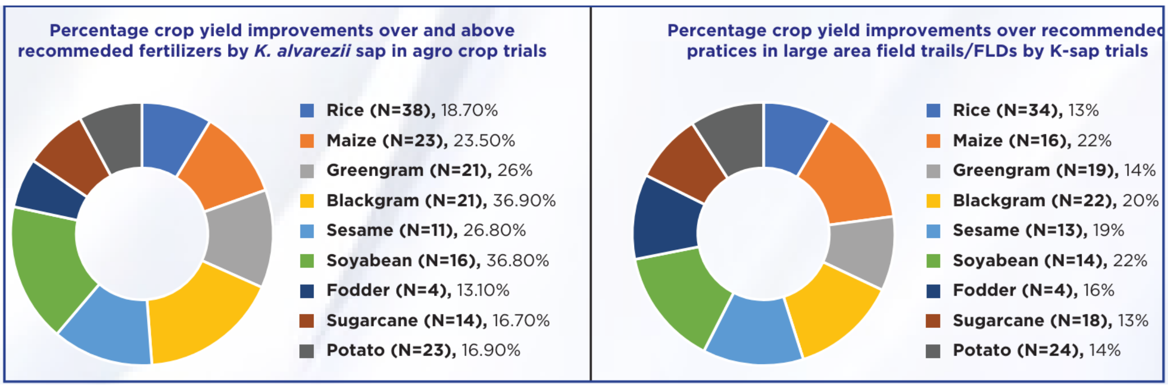

Fig. 8.2 Percentage increase in yield of various crops by foliar application of

Kappaphycus alvarezii-based bio stimulant as revealed from multi-institutional multi-crop trials in India (Source: Sustainability 2022, 14, 10416)

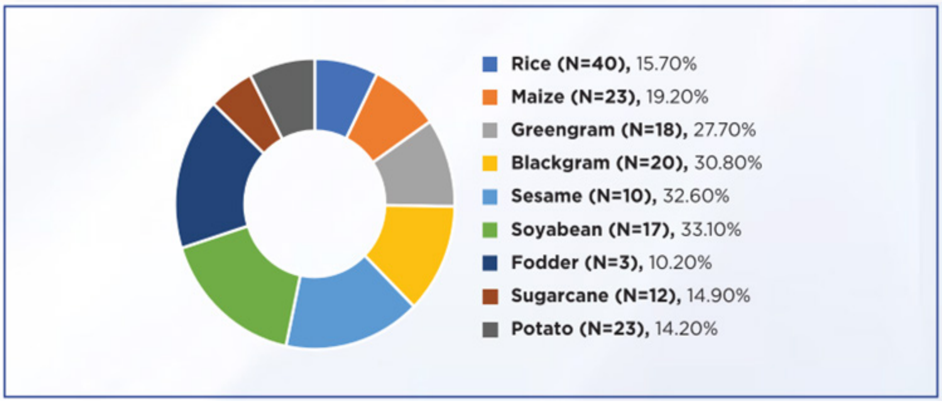

Fig. 8.3 Percentage increase in yield of various crops by foliar application of G. edulis based bio-stimulant (Source: Sustainability 2022, 14, 10416)

8.2.4 Seaweed Formulations for Productivity and Health of Dairy and Poultry Animals

CSIR-CSMCRI recently developed novel seaweed-based animal feed additive formulations to enhance productivity of animals, improving the quality of animal products and boosting immunity. Collaborative efforts by CSIR-CSMCRI, Bhavnagar in collaboration with ICAR Institutes (IVRI, CARI, and NDRI) and CSIR-IITR led to the development of these animal feed additives using seaweeds found to grow in Indian waters.

Seaweeds are rich sources of choline, glycine, betaine, nutrients along with biologically active compounds such as fucoidan, betaine, and glucans which are known to enhance immunity in animals. Polyphenols in the seaweed exhibit antioxidant and Reactive Oxygen Species (ROS) scavenging activity. Seaweed formulations were developed to harness the active ingredients for improving productivity, improved rumen function, boost immunity, and all-around health of animals (cattle and poultry).

The animal feed additive products have been engineered by blending selected cultivated seaweeds and naturally harvested seaweeds sustainably. Seaweed-based feed additives in nutrition are key to achieving maximum animal productivity and at the same time achieving optimal herd health and warding off health problems. The additives could boost immunity safely. The seaweed-based formulations were found to bestow the following properties:

- Improved performance of poultry (especially breast) and cattle
- Better Immuno-responsiveness (Cellular mediated and HA titer) in poultry and cattle
- Gut health (microbial & structural) in poultry
- Physio-biochemical characteristics of poultry meat
- Higher egg production and advancement in egg- laying age
- Higher Calcium and iron content in milk
- Better calcium retention leads to reduced chances of milk fever
- Reduced methane emission and higher energy use efficiency in ruminants
- Higher daily growth rate in cross bred calves

8.2.5 Seaweed derived packaging material

Synthetic plastic materials have been widely utilized since the 20th century due to their favorable properties and low production costs. However, the extensive use and improper disposal of these plastics have resulted in a significant increase in environmental pollution. In 2018 alone, global plastic waste reached a staggering 29.1 million tons, with over 99% of this waste originating from petroleum-based plastics. Unfortunately, these plastics derived from petrochemicals lack essential characteristics such as biodegradability, recyclability, biocompatibility, and reusability. Consequently, vast amounts of plastic waste accumulate on Earth, leading to severe environmental issues like soil contamination, marine pollution, air pollution, and the endangerment of various animal species.

The market value of biodegradable plastic materials has experienced significant growth in recent years. In 2021, the global market value of biodegradable plastics reached approximately 8 billion dollars. Projections indicate that this value is expected to triple by 2026, reaching around 23.3 billion dollars (Market Value of Biodegradable Plastics Worldwide, 2026). The United States has also witnessed a rise in the market value of biodegradable plastics, with the value reaching 822 million dollars in 2021. It is expected to further increase by 116% (reaching 1,774 million dollars) by 2026.

In recent times, there has been a growing interest in seaweed-based polysaccharides as a viable solution to meet the high demand for renewable materials. These polysaccharides, sourced from marine environments, have garnered attention for their diverse applications in biopackaging, food, biomedical, and agriculture sectors. They possess advantageous properties such as strong gelling ability, recyclability, thermal stability, and non-toxicity. Seaweed polysaccharides can undergo degradation through both enzymatic and non-enzymatic processes. However, one of the key challenges in utilizing biopolymers, including seaweed-based polysaccharides, for packaging purposes is their relatively limited mechanical strength and barrier properties compared to non-biodegradable alternatives. There are three types of seaweed polysaccharides, such as agar, alginate, and carrageenan that are commonly used as film-forming materials as compared to other seaweed polysaccharides like lam- inarin, fucoidan, and funoran. Alginate-based edible films have various applications in food packaging. These vary as per the additional components along with alginate according to the properties derived. Similarly, even carrageenan/furcellaran and agar-based edible films have found their applications in food packaging varying upon the additional compounds added and their properties. They are summarized in the table below:

8.2.6 Biofuels

Seaweeds are gaining increasing attention as a prospective feedstock for biofuels and are being considered as the most potentially significant future sources of sustainable biofuels. The worldwide interest in producing biofuels from seaweed biomass is because seaweeds are third-generation feedstock and have advantages such as the presence of high carbohydrate content which can be used for producing ethanol, absence or low lignin content, higher photosynthetic efficiency than terrestrial biomass, potential biomass yield per unit area is often higher than that of terrestrial plants, does not directly compete with human food supply, does not compete for arable land, does not require freshwater, does not require fertilizer, and the potential to obtain high-added value products i.e. cosmetics, drugs, pigments, biofertilizers, food additives, chemicals, etc.

Due to higher carbohydrate content, green seaweeds such as *Ulva lactuca* and *Enteromorpha intestinalis* are considered as viable feedstocks for the production of bioethanol (Ramachandra and Hebbale, 2020). The carbohydrates present in seaweeds are converted to bioethanol by appropriate microorganisms such as yeast or bacteria. Various processes involved in the production of ethanol include pretreatment, hydrolysis, and fermentation (Ramachandra and Hebbale, 2020). The techniques or pathways used generally in the fermentation of seaweed are separate hydrolysis and fermentation and simultaneous saccharification and fermentation (Offei et al., 2018). Seaweeds like *Ulva lactuca, Gracilaria verrucosa,* and *Kappaphycus alvarezii* have been utilized as the feedstock of bioethanol. Red seaweeds are mainly used for bioenergy production. The yield of bioethanol in red algae varies from 4% to 43 % (Andhikawati et al., 2020). Even though technologies are available for the conversion of seaweeds and seaweed phycocolloids to ethanol, currently the production is not cost-effective. Hence, the future of commercial-scale production of ethanol from seaweeds depends on the development of new processing technologies and the creation of an appropriate policy framework.

There is potential for ethanol production from red seaweeds, specifically from species like *K. alvarezii*. The authors highlight the growing market for bioethanol and the need to explore alternative biomass sources, such as marine macroalgae, due to limitations in agricultural land availability (Khambhaty et al). The substantial growth in the bioethanol market, which increased from less than one billion liters in 1975 to over 39 billion liters in 2006 and was estimated to reach 100 billion liters in 2015. The majority of bioethanol was traditionally produced through the fermentation of sugars derived from food crops like beets, corn, and sugarcane.

Due to limitations in available agricultural land, Khambhaty et al. proposed considering marine macroalgae as a potential biomass source for ethanol production. Marine macroalgae, such as red seaweeds like *Kappaphycus alvarezii*, are rich in carbohydrates and have low lignin content, making them suitable candidates. To prepare for fermentation, the seaweed biomass undergoes a process where SWC juice is extracted, and the remaining pulp is subjected to saccharification. This saccharification step involves treating the pulp with 0.9 N sulfuric acid at a temperature of 100°C. At a bench scale of 16 kg, this process yields approximately 30% in terms of saccharification. Next, the hydrolysate resulting from saccharification is neutralized using lime and undergoes desalination through electrodialysis. After this preparation, the hydrolysate is ready for fermentation in the presence of *Saccharomyces cerevisiae,* a type of yeast commonly used in ethanol production. During fermentation, about 80% of the reducing sugars present in the hydrolysate are converted into ethanol. The ethanol produced through this process has been successfully utilized as fuel for a petrol vehicle. Furthermore, additional fermentation trials using a marine yeast called Candida sp. have demonstrated its ability to function in high-salinity conditions and produce ethanol without requiring a desalting process.

Tan et al. showed that a combination of heterogeneous catalyzed hydrolysis and *Saccharomyces cerevisiae* fermentation can be employed to produce bioethanol from Kappaphycus biomass, specifically from a species known as *Eucheuma cottonii.* Their focus was on utilization of macroalgal biomass as an alternative source to lignocellulosic materials for bioethanol production. Amberlyst 15TM was used as a catalyst for carbohydrate hydrolysis from Kappaphycus extract to yield simple reducing sugars suitable for fermentation. Fermentation of the hydrolysate produced 0.33 grams per gram of bioethanol yield with an effciency of 65%.

8.2.7 Bioplastics

Seaweeds are sustainable alternatives for producing large-scale biopolymers. Polysaccharides such as alginate, carrageenan and agar isolated from seaweeds have been commonly used as precursors for edible film production (Mostafavi and Zaeim 2020). The film-forming biopolymers derived from seaweeds are non-toxic, easily degradable and biocompatible and show high rigidity and low deformability (Doh, 2020). The bioplastic films from seaweed exhibit relatively low water vapour barrier properties and mechanical strength in comparison to conventional non-renewable polymers. Hence, seaweed is generally mixed with other components to improve the properties of seaweed films. The edible film from seaweeds is used as sachets, pouches etc. in the food industry; as a wrapper for seasoning cube and chocolate; as interleaf for frozen foods; as material for the edible logo in bakeries products etc. Also, edible film is used in the pharmaceutical industry as functional strips such and in cosmetic and toiletries industries as a facial mask and bag for pre-portioned detergent (Siah et al, 2015).

8.2.8 Medical Textiles

Natural fibers, especially polysaccharides, have been considered as the most promising material for producing wound dressing products. Products based on alginate, a linear unbranched polysaccharide extracted from brown seaweed, are currently the most popular dressing products used in wound management since it has numerous advantages over traditional cotton-based products. The bandages based on alginate are more efficient than cellulose-based bandages, due to easy solubility and reduced wound curing rate (Qin 2008). Alginate is reported to have a high absorbency of exudates. Due to its gel-forming property, when alginate dressing comes into contact with the wound exudates, it absorbs the exudates and provides a desirable wound moist environment and allows the adequate exchange of water vapour and oxygen which is an important property for enhancing the wound healing. The gelling property of alginate also aids in painless removal of dressings. Alginate can absorb fluid 15 to 20 times its weight; hence alginate dressings can be used for moderate to heavy exudates.

8.3 Seaweed for Human Consumption

Seaweeds are not actually a sought-after vegetable to most westerners. However, the Orientals have been eating a variety of seaweeds for thousands of years. It is known that about 100,000 tonnes of seaweeds are eaten annually in Japan in the name of Nori, Kombu (konbu) and Wakame. Seaweeds are rich in protein, vitamins, amino acids, growth hormones, minerals, and other trace elements. Their methods of preparation are discussed below in detail:

8.3.1 Nori

Nori is the name of various edible products derived from *Porphyra* after processing. Nori is prepared by harvesting *Porphyra*, pounded washed with water, drained, chopped, and finally mixed with freshwater before being spread on bamboo mats for drying. When dried thin sheets of nori are obtained, these are pressed flat, stored, bundled and packed for marketing. Nori is used as a flavouring agent in soup, sauces, and broths or even soaked in soybean sauce ‘ and eaten with boiled rice. Nori is also used in well-known dishes - tempura and sushi. (Noda, H. 1993).

8.3.2 Kombu

Kombu is prepared from Laminaria. After harvesting and drying, Laminaria is separated from the stipe and holdfast for quality and sent to kombu factories. Kombu processing involves boiling the kelp in a green aniline dye solution, air drying, compressing in frames, and then cutting into blocks which are shredded. Kombu is used as soup stock, boiled vegetable, snack or seasoning for rice dishes (as curry leaves are used in India). (Jelena Milinovic *et al*., 2021).

8.3.3 Wakame

Wakame has become more popular in recent times. It is made from large brown seaweed *Undaria pinnatifida*. Undaria is processed as wakame by washing, desalting, and drying. Desalting is achieved by boiling with water. Wakame is popularly known in the forms of roasted or sugar candied products. (Martínez-Villaluenga C, et al., 2018).

8.3.4 Salad

The following seaweeds are used for making salads either singly or in combination of two or three seaweeds- *Caulerpa racemosa, C. sertularioides, Codium* spp, *Gracilaria verrucosa, G. eucheumoides, Hydroclathrus clathratus, Laurencia papillosa* and *Porphyra* spp. Fresh seaweeds are cleaned of sand, debris, attached stones etc. and then washed in freshwater. Chopped tomatoes, carrot, onion, chilli, and ginger are added and mixed. Salt is added to taste. (Chennubhotia et. al., 1981; Kaladharan and Kaliaperumal, 2000).

8.3.5 Seaweed Masala

Onion and green seaweed is cut and *(Ulva lactuca*) into pieces and garnish them in low fire with oil, mustard and curry leaves. When about to turn grey, add chilli powder, coriander powder, turmeric powder, salt, ginger, and tomato pieces and mix well. It can be eaten with rice and chapatis. (Chennubhotia et. al., 1981; Kaladharan and Kaliaperumal, 2000).

8.3.6 Seaweed pickle

Take cleaned fresh seaweed *(Gracilaria edulis)* and remove moisture with cloth. Cut into small pieces. Soak in vinegar for 2 days. Remove from vinegar, add gingelly oil, chilli powder, mustard, and fenugreek powder. Season with asafoetida. Add peeled garlic. Mix thoroughly and bottle. (Chennubhotia et. al., 1981; Kaladharan and Kaliaperumal, 2000).

8.3.7 Seaweed Wafer

Boil cleaned dried seaweed *(Gracilaria edulis)* in water. Filter through organdy cloth. Add rice paste, chilli paste and asafoetida powder. Add gingelly seed and cumin seed and mix well. Cook together. Dry the paste in open sun in small lumps on cloth. Store in airtight jar before serving fried in oil. (Chennubhotia et. al., 1981; Kaladharan and Kaliaperumal, 2000).

8.3.8 Seaweed Porridge

Boil dried cleaned seaweed (*Gracilaria edulis)* in water for 20 minutes. Grind it into a fine paste. Boil the paste in water. Add sugar and milk and mix thoroughly. Add cashew nut raisins and cardamom. Serve hot. (Chennubhotia et. al., 1981; Kaladharan and Kaliaperumal, 2000).

8.3.9 Seaweed Jam

Prepare sugar syrup. Add seaweed powder (*Ulva lactuca*) and boil for 15 minutes with stirring. Add edible colour and essence. Ready to serve. Some of the food stuff such as Ice-cream, Tomato sauce, Jams, Jelly, Marmalade, Blancmange (without corn flour) and Lime jelly requiring agar and their method of preparation are given by Thivy (1958, 1960).

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Appendix B

Expert Committee Office Memorandum

File No. Q-11050/3/2023-AGRICULTURE

NITI (National Institution for Transforming India) Aayog

(Agriculture & Allied Sectors Vertical)

NITI Aayog, Sansad Marg New Delhi – 110001

Date: 11th July 2023

OFFICE MEMORANDUM

Subject: Constitution of Expert Committee to review the Draft Policy on "Seaweed Value Chain Development in India" and draft curricula of certificate courses on seaweed cultivation -reg.

It has been decided with approval of the competent authority to set up an Expert Committee on the subject cited above with the following composition and ToRs.

2. The composition of the Expert Committee is as under:

1.	Dr. V.K. Saraswat, Hon'ble Member (S&T), NITI Aayog	Chairman
2.	Dr. J.K. Jena, Deputy Director General (Fisheries), ICAR	Co-Chairman
3.	Prof. Himanshu A. Pandya, Professor & Former VC, Gujarat University	Co-Chairman
4.	Ms. Neetu Kumari Prasad, Jt. Secretary, Dept. of Fisheries,	Member
5.	Shri Tanmay Kumar, Additional Secretary, MoEFCC	Member
6.	Shri. Dodda Venkata Swamy, Chairman, MPEDA	Member
7.	Dr. A. Gopalkrishnan, Director, ICAR-CMFRI	Member
8.	Dr. Kannan Srinivasan, Director, CSIR-CSMCRI	Member
9.	Dr. Dharani G, Scientist E, National Institute of Ocean Technology (NIOT)	Member
10.	Shri Rajesh Kumar, Additional Chief Secretary (Fisheries), Govt. of Maharashtra	Member
11.	Shri A. K. Rakesh, Additional Chief Secretary, Govt. of Gujarat	Member
12.	Ms. Salma K Fahim, Principal Secretary (Fisheries), Govt. of Karnataka	Member
13.	Shri. K S Srinivas, Principal Secretary (Fisheries), Govt. of Kerala	Member
14.	Shri Mangat Ram Sharma, Addl. Chief Secretary (Fisheries), Govt. of Tamil Nadu	Member
15.	Sri Gopal Krishna Dwivedi, Principal Secretary (Fisheries), Govt. of Andhra Pradesh	Member
16.	Shri Suresh Kumar Vashishth, Principal Secretary (Fisheries), Govt. of Odisha	Member
17.	Shri. Santhosh Kumar Reddy V, Secretary (Fisheries), Govt. of Lakshadweep	Member
18.	Ms. Nandini Paliwal, Secretary (Fisheries), Govt. of Andaman & Nicobar	Member
19.	Shri Shivkumar Suryanarayanan, Managing Director and Co-Founder, Sea6 Energy Pvt. Ltd.	Member
20.	Shri Ashwin Shroff, Executive Chairman, Excel Industries Pvt. Ltd.	Member
21.	Patricia Bianchi, Seaweed Account Manager, Aqua Stewardship Council	Member
22.	Dr. Neelam Patel, Senior Adviser (Agri), NITI Aayog	Member Secretary

3. The Terms of Reference (ToR) of the Expert Committee will be as follows:

    I. To review the draft policy on the development of seaweed value chain in India.

    II. To draft roadmap for the development of entire seaweed value chain -on-shore and off-shore.

    III. To develop any other necessary components for the policy framework of the seaweed value chain that may be required.

4. The Expert Committee may examine and address any other issues which are important though not specifically spelt out in the ToR. The Expert Committee may devise its own procedures for conducting its business / meetings / field visits / constitution of sub-groups, etc.

2. The Chairman of the Expert Committee may co-opt any other official / non-official expert / representative of any organization as a member(s), if required.

3. The Expert Committee will review the draft policy and curricula and finalize it within 60 days of its constitution.

4. Mr. Paremal Banafarr, Young Professional, W018, Fifth Floor, NITI Aayog, New Delhi, Telephone- 011-2304 2203 (L) - e-mail: paremal.banafarr@nic.in will be the nodal officer for this committee in NITI Aayog. Any further queries / correspondence in this regard may be made with him and the Member Secretary of the Committee.

Paremal Banafarr
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Distribution:

Chairman and all Members of Expert Committee

CEO, NITI Aayog

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Designed by:

सत्यमेव जयते

NITI Aayog