(3) Net tube cultivation method: The net tube method is very useful because the seaweeds remain protected inside the tube and can withstand wave action. Upon subsequent growth of seaweed inside the nets, the branches come out from the net tubes and anchor very firmly which minimizes loss due to heavy wind and tidal action. Just like the mono-line method, approximately 50 kg of seeding materials can be put inside a 1000 feet long net tube. However, the net tubes are easily and quickly fouled by epibionts, that make them more susceptible to silt and mud accumulation. Thus, frequent cleaning is required for the tube net.

Management of seaweed farms

Once the seeded cultivation units (raft, mono-line or tube net) are deployed in the sea, they require periodic maintenance. Due to the heavy nutrient and freshwater influx, the cultivation units remain highly susceptible to biofouling. Sometimes a variety of endemic low-salinity tolerant seaweed species like *Acanthopora* spp., *Enteromorpha* spp. and *Gracilaria* spp. tend to compete with cultivated species and therefore must be cleaned periodically. *Kappaphycus alvarezii* always requires a salinity above 28 ppt for luxuriant growth.

Economics

Cost-benefit based on the experimental pilot scale farming of seaweed at Noliasahi (Odisha) is given below.

Input Cost			
Sl. No.	**Items**	**Quantity**	**Amount (INR)**
1	Seed material from Rameswaram to the site including transport	200 kg	4,000.00
2	Preparation of raft*	20 nos.	40,000.00
3		**Total Input cost (INR)**	**50,000.00**
Output cost			
	Items	**Production & value/ raft**	**Total Production & value**
4	Production from each raft during one culture cycle	100 kg/raft	2000 kg
5	Quantity with 35% moisture	35 kg/raft	700 kg
6	Value of dried seaweed per cycle	Rs. 1750/raft	35,000.00
7	Value of dried seaweed for 3 cycles in a year	Rs. 5250.00/ raft	105,000.00
8		**Profit per annum (INR)**	**55,000.00**

*in the case of the mono-line cultivation method, the input cost can be further reduced as it requires only ropes. About 10 bundles of good quality rope (500 feet length per bundle) costing approximately Rs. 20,000.00 are adequate to cover a seeding length of 5000 feet, which is equivalent to 20 rafts.

Opportunities and Challenges

(1) The encouraging results obtained, especially from Noliasahi of Gadakujanga (Jagatsingpur, Odisha) clearly indicate that the farming of seaweed (*Kappaphycus alvarezii*) is feasible in Odisha. In other places like Astarang and Chandrabhaga, low salinity tolerant species like *Enteromorpha* spp., *Gracilaria verrucosa* and *Acanthophora spicifera* could be explored for cultivation. The cultivation can be diversified including species like *Enteromorpha* spp., *Caulerpa* spp. and *Gracilaria* spp. which can be used for human and/or livestock consumption.

(2) The coastal areas along Odisha is mainly influenced by salinity, which is greatly affected by the heavy freshwater influx from the vast riverine systems in Odisha. However, due to the heavy nutrient influx, the coast provides a unique opportunity for seaweed cultivation for almost 5 months (from January to May), especially after monsoon due to cessation of cyclonic weather, storms and floods.

(3) The mono-line, net tube and raft cultivation techniques were found to give the best results under the conditions prevalent in Odisha and therefore, should be followed for seaweed farming along Odisha.

(4) The receding tidal areas like Chandipur and Balarampur in the Balasore district could be efficiently utilized for seaweed farming with certain structural modifications. Onshore collapsible seaweed farms can also be established on the seashore with a regular supply of seawater. Some of the river bar mouth areas having adequate influx of sea water provide ideal conditions for seaweed farming as the sand strips neutralize the heavy tidal action of the open sea. With proper dredging of the bar mouth connection to the sea and deployment of mechanical pumps to prevent salinity drops during low tide could give very encouraging results from such areas.

(5) Popularization of cultivation techniques and large-scale participation will open up new avenues for commercial-scale expansion of seaweed industry in Odisha.

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Seaweed farming in Odisha: Opportunities & Challenges

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Introduction

Odisha is bestowed with 8% of the coastline (480 km) and 4.5% of the continental shelf area (25,000 km^2) of India. With a mangrove wetland area of 215 km^2 and a heavy nutrient influx from three major, six medium and one minor river system, it represents one of the most productive marine ecosystems in India.Nearly 1.15 lakh families in Odisha depend on fishing as their livelihood. About 0.93 lakh families (80%) perform traditional fishing and 42% of total fishermen families live below the poverty line (BPL). The frequent cyclonic weather and storms in the Bay of Bengal along the Odisha coast and mandatory fishing bans for the conservation of wildlife greatly hamper the livelihood of fishermen. Therefore, it is necessary to develop alternative livelihood options not only to improve the socio-economic status of the fishermen but also to increase production from the marine ecosystem. One such alternative is seaweed farming. ICAR-CMFRI initiated the work to access the feasibility of and standardize the viable culture techniques for seaweed farming along the Odisha coast under the project funded by the Fisheries & Animal Resources Development Department, Government of Odisha.

Potential species for cultivation

Unlike southeast Asian countries, Indian seaweed industries rely heavily on wild harvests for phyco-colloid production. Seaweeds like *Gelidiella acerosa* and *Gracilaria edulis* are harvested for agar production. Some other potential agarophytes naturally found in India are *Gracilaria dura*, *Gracilaria salicornia*, *Gracilaria crassa* and *Gracilaria verucosa.* Seaweeds like *Sargassum* spp. and *Turbinaria* spp. are mostly harvested from nature for alginate production. In India, the carrageenan-yielding red seaweed *Kappaphycus alvarezii* is mostly preferred for cultivation due to its high growth rate and high production of carrageenan. It has myriads of applications that have a potential market and good global demand. Apart from this, some seaweeds, such as *Acanthophora spicifera, Ulva lactuca, Enteromorpha* spp. are used directly as food.

Site selection for seaweed cultivation

Site selection is one of the most important criteria that determines the success of seaweed farming. Shallow and wide nutrient rich coastal areas with moderate wave action are usually preferred for Seaweeds. The selected site should fulfill the ideal salinity and temperature requirements of the seaweed species. Certain species of seaweeds, like *Acanthophora spicifera*, *Gracilaria verrucosa* and *Enteromorpha* spp. can be cultivated in a wide salinity range of 15-45 ppt, while other species *viz. Kappaphycus alvarezii, Gracilaria edulis, Sargassum wightii, Turbinaria conoides, Ulva lactuca* etc., require a narrow salinity range of 25-35 ppt or higher for luxuriant growth. The culture site should be away from the navigational route and active fishing grounds of both the traditional and commercial fishermen to avoid multiuser conflict. ICAR-CMFRI has identified some potential sites for seaweed farming in Balasore, Jagatsinghpur, Puri and Ganjam districts of Odisha (Reference: MFIS No.246, 2020). The map below illustrates few such locations where the feasibility of seaweed farming has already been evaluated.

Seaweed seed material

The seaweeds can be cultivated by vegetative and reproductive propagation methods. Vegetative fragments are often used as seeding materials during cultivation. Once the cultivation is established, the remaining fragments of seaweed after harvesting are used as seeds for the next crop. However, to initiate the seaweed farming, these seeding materials can be obtained from Rameswaram (Tamilnadu), where they are being cultivated commercially. The freshly harvested seaweed seeding materials are packed in seawater-soaked gunny bags for transportation. Each 100 kg capacity gunny bag should carry nearly 25-35 kg of seaweed. Packing excess seaweed in a single bag can damage the seaweeds due to respiration and heat generation. Once packed, they should be transported immediately. It has been observed that the seaweed can tolerate this transportation stress for more than 50 hours. Upon arrival, the seed material should be acclimatized immediately in well oxygenated seawater with adequate salinity (28-35 ppt) supplemented with a photoperiod of 16:8 hours (Light: Dark cycle) using direct sunlight or artificial lighting to ease the transportation stress and help in acclimatization process.

Methods of seaweed cultivation

Seaweed can be cultivated mainly by following three methods: **(1) Raft cultivation method:** Seaweed rafts (Length×Breadth = 3×3 m) prepared with straight bamboo poles can be used for the cultivation of seaweed. Polyvinyl ropes (diameter: 10 mm) is tied between the two parallel side arms of the raft at an approximate

distance of 30 cm from each other to create a multi-line seeding surface within a limited space. Approximately 10 kg of seed material can be introduced into each raft for cultivation. The seaweed seeding materials are tied at 30 cm intervals to the main seeding rope using the rope-tying method or nylon zip-tying method for faster seeding. Unlike traditional rope-tying method, this innovative tying method considerably reduced the time and effort for seeding the rafts. Adequate allowance is provided at four corners of the raft to cope with the tidal fluctuations during low and high tides. **(2) Mono-line rope cultivation method:** As an alternative to raft cultivation

rope cultivation method can also be used for seaweed cultivation. The method further reduces the input cost, as unlike the raft cultivation method, it requires only ropes and fewer accessories. Parallel ropes 500-1000 feet long tied at both ends to the vertically driven bamboo poles are used for seeding the seaweeds. The ropes are supported with an adequate number of floats at regular intervals along the seeding rope to prevent the seaweeds from sinking too deep due to their own weight.

Bamboo supports are also provided perpendicular to the main ropes to prevent entangling with each other and damaging neighboring seaweeds. This also ensures adequate space for the growth of seaweed between the lines. Adequate allowance is provided at both ends of the mono-line to cope with the tidal fluctuations during low and high tides. The seeding material can be tied directly to the mono-lines using a rope-tying or a zip-lock-tying method or a net tube method. Approximately 50 kg of seeding material can be tied to a 1000 feet long mono-line.