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Seaweed Farming Methods

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The most important issues in global agriculture include climate change, soil degradation and scarcity of water resources, which call for research to investigate sustainable food production systems. Intercropping with legumes has been recognized for enhancing biodiversity and resource efficiency. On the other hand, land-based agriculture is still subject to stresses from environmental factors, demanding that these alternative farming methods be looked into. Effective growth of marine-based seaweed farming offers ecology as well as economic benefits without the use of either freshwater or synthetic fertilizers or even arable land. Seaweeds belong to the three groups Rhodophyta, Phaeophyta, and Chlorophyta, which are very rich in nutrients and have different applications in food, pharmaceuticals, biofuels, cosmetics, and fertilizers. Good growth of seaweed depends on optimizing conditions and different farming systems applied. Seaweed farming mitigates climate change by sequestering carbon dioxide and reducing ocean acidification while improving marine biodiversity.

Keywords: Climate change, Seaweed farming, Sustainable agriculture, Carbon sequestration, Ocean acidification.

Introduction

Global agriculture, which is the backbone of food security, faces an unprecedented crisis arising from the combined impact of climate change, soil degradation, growing population and water scarcity (Pattnayak et al., 2025; Pramanick et al., 2022; Mukesh et al., 2024; Ray et al., 2024; Maitra et al., 2024; Santosh et al., 2024). Worsened patterns of temperature, rainfall, and extreme weather events have disrupted traditional practices of farming, causing lower crop yields and posing a threat to the global food supply system (Hossain et al., 2022). The intense and frequent use of artificial fertilisers, monocropping, and irresponsible land use have further aggravated the problems of the environment, leading to soil infertility, loss of biodiversity, and oceans becoming acidic (Peera et al., 2020; Ray et al., 2021; Mwadalu et al., 2022; Mirriam et al., 2022; Sairam et at., 2024). To investigate alternative and sustainable food production systems with reduced environmental footprints, economic viability becomes a major concern due to the importance of the immediate problems. Among the sustainable agricultural approaches, such as intercropping and legume-based systems, intercropping became favourite much to the newer generation farmers (Maitra et al., 2000). Intercropping, growing two or more crops together promotes biodiversity, soil fertility, and resource efficiency making agriculture much more adaptable to environmental shocks. Among the species intercropped, legumes play a major role in nitrogen fixation and in reducing dependency on synthetic fertilizers and improving soil health (Sarkar et al., 2000). Though these land-based solutions promise sustainability in food production, they still remain vulnerable to the adverse effects of climate change, land degradation, and scarcity of water (Nduwimana et al., 2020; Bhattacharya et al., 2020; Tang et al., 2021; Haque et al., 2021; Krishna et al., 2024). Hence the increased interest in alternative farming methods that involve other modalities other than conventional terrestrial agriculture. Seaweed cultivation is one such potential alternative, a promising marine-based production technique that can provide a door for sustainable climate-resilient alternative. Seaweeds, or macroalgae, are among the rapidly growing maritime plants, which do not require fresh water, fertilizers, or arable land to come to grow. They enter into enormous value for climate change mitigation, absorbing huge amounts of CO2, reducing acidification of the oceans, and helping increase the health of marine ecosystems. Additionally, seaweed farming generates international interest because of the many applications of this growing resource in food, biofuels, pharmaceuticals, fertilizers, and animal feed to become an important environmental and economic resource. Important seaweed farming techniques have been developed to maximize productivity while environmentally and economically integrating sustainable practices. These range from traditional nearshore rope farming to modern offshore cultivation using integrated multi-trophic aquaculture (IMTA) systems. Of course, criteria such as seaweed species, environmental conditions, and market demand determine which of these farming methods will be used for a specific user. As the demand for sustainable, bio-based products grows, seaweed farming is emerging as a viable, environmentally friendly alternative that benefits marine diversity and provides livelihood possibilities for coastal people.

Seaweed Farming

Seaweeds are a diverse group of macroscopic, multicellular marine algae, with thousands of species represented. They are primarily classified into three main categories based on the chemical makeup of their photosynthetic pigments: Rhodophyta (red), Phaeophyta (brown), and Chlorophyta (green) (Dawczynski et al., 2007). The red and brown colours of Rhodophyceae and Phaeophyceae are due to pigments like phycoerythrin and fucoxanthin, while the green coloration in Chlorophyta arises from chlorophyll and related compounds (Khalid et al., 2018). Seaweeds find applications in various sectors, including pharmaceuticals, food production, cosmetics, and fertilizers, as well as in the extraction of industrial gums, among other uses. They are highly nutritious, containing significant amounts of protein, vitamins, minerals, fiber, and essential fatty acids (Ortiz et al., 2006). Seaweeds can be enjoyed in multiple forms, such as raw salads, cookies, condiments, and soups (Aguilera-Morales et al., 2005). Comprising about 80-90% water, their dry weight consists of 7-38% carbohydrates (50%), lipids (1-3%), and minerals (10-47%), along with a considerable amount of essential amino acids (García-Casal et al., 2007). The specific chemical composition of seaweeds can vary significantly among different species.

Sea weed farming

There are a lot of scopes and uses of sea weed, for which there is a need to harvest sea weed in large quantity. Sea weed farming bear a great role in achieving the sea weed demand.

Four important phases of sea weed farming:

1. Seeding
2. Growing phases
3. Harvesting
4. Processing

General condition required for sea weed farming:

- ***Location***
  - ✓ Grows well in tropical regions on coral reefs and on the rocky and sandy bottoms of marine waters in intertidal or sub tidal zones.
- ***Water quality:***
  - ✓ Clear, constant motion for continuous nutrient flow
  - ✓ Salinity: 28-34ppt, relatively salty, purely marine

- ✓ Depth: at least 30cm during low tide
- ✓ Temperature: 27° to 30°C
- ✓ Current: 5-10m per minute
- Land Quality: Substratum - Sandy/rocky

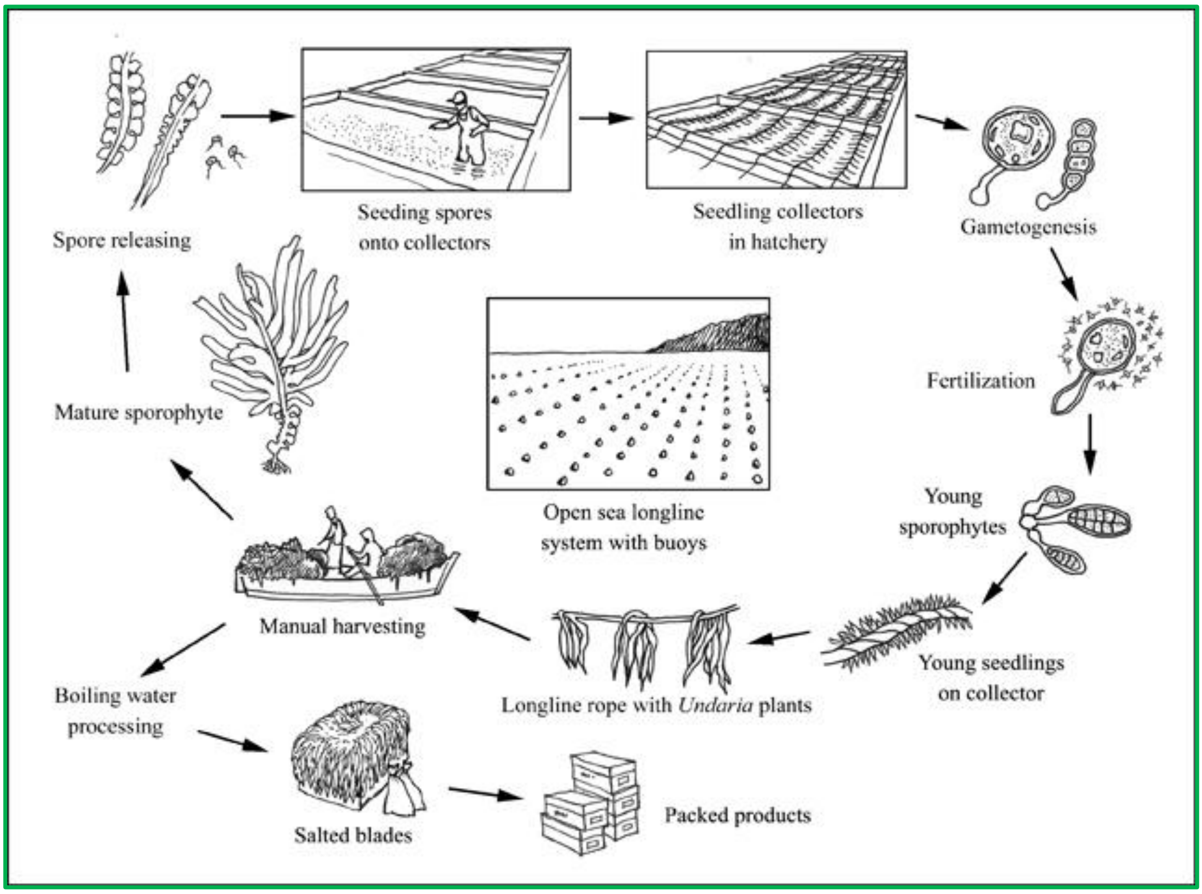

Fig-3: General process of sea weed farming

Preparation of planting materials

1) Cultivation Rope

2) Tying Materials (soft plastic rope)

3) Support Materials – bamboo, mangrove post, steel bar, Poly-propylene rope

4) Floater – Styrofoam (square or round shape), empty plastic bottles

Young branches of sea weeds are selected using sharp edge knife. Individual plants are tied to soft plastic rope and the plants should be immersed in seawater to prevent desiccation.

Sea Weed Culture Method

Different sea weed cultivation methods are seen depending on micro climate, (Nerisa et al.,1991)

1. Submerged System

- Rock or Stone Method
- Wood / Bamboo Stakes Method
- Net method
- Cage method
- Mono line method
- Off - bottom Mono line system
- Raft / Planting
- Frame Method

2. Floating Method

- Modified Floating Raft System
- Long Line
- Floating System

- Basket method

3. Species Cultured

- Species Cultured

Submerged system

Rock or Stone Method: Rock or Stone Method is ideal for rocky or hard bottom sites and with strong natural current. Propagules are tied to stones big enough not to be carried away by current.

Wood/Bamboo Stakes Method: Wood/Bamboo Stakes Method is good for soft, not sandy bottom & where there is availability of wood or bamboo. Propagules are tied to stakes driven into sea bottom. This method is inexpensive but labour intensive.

Net Method: Net Method can be used only in areas with moderate current. Propagules are tied to each intersection of the 20cm mesh net. Nets of 2.5cm x 2.5cm made of nylon/ropes and anchored to sea bottom by tying corners to stakes.

But, in this method, cost of input materials is high, vulnerable to strong waves, especially when net is loaded with mature seaweeds.

Cage Method: Cage Method is recommended only in areas with strong natural current. Propagules are placed in cages (1m wide x 0.5m deep x 3m long) covered with 3cm mesh nylon nets on all sides. Each cage is divided into 6 compartments of 2.5 to 5kg propagules each (not tied).

Monoline method &/or Off-bottom Monoline System: These methods are suitable for areas with shallow water (0.5m); soft or sand bottom; and moderate to strong current as lines could be oriented perpendicular to shore to reduce damage (e.g., uprooting stakes, propagule breakage) from strong currents and floating debris. Propagules are tied to monofilament nylon line or braided rope/nylon (2.5 to 10m long) at distances ranging from 5 to 25cm. The stakes are parallel to each other at 15 to 50cm spacing. Harvesting is done either by untying the lines with the plants intact or by removing the entire plant individually. The former is recommended because lines can be hung and drying is easier and cleaner.

Raft/Planting Frame: Raft/Planting frame method is suitable for areas with low water levels and moderate current. Propagules are tied to nylon lines which are tied to 2.5m x 2.5m frames. Frames are anchored. The frames are reusable. However, there is high initial investment although cheaper in the long run.

Floating Systems (Constant Level Systems)

Modified Floating Raft System**:** Modified floating raft system is used in areas with fluctuating water levels (1- 2m deep) to maintain constant sunlight without drying during low tides. Propagules are tied to nylon lines (1.6cm spacing attached to parallel poles. Poles tied to stakes tied to stakes anchored to reef bottom. There is higher yield in this system due to better gas exchange and photosynthetic rates & less plant sedimentation, sea urchin grazing damage, breakage and/or losses.

Long Line Floating System**:** Long line floating system is recommended for areas with usually high-water level. The environmental requirements are same as that of modified floating raft. Propagules are tied to 20m nylon lines whose ends are attached to 5m poles supported by 1m anchor stakes. Five floats on line at 4m intervals and lines at 2m apart. This method is less labour requiring and fewer poles breakage especially when the long lines sag due to heavy load of mature plants

Harvesting and post-harvest handling of sea weed

Seaweeds are harvested for drying after 40-60 days of culture. Generally, three ways of harvesting are employed:

1.) Individual plant is untied/cut
2.) Both ends of cultivation rope is untied
3.) Whole single bamboo raft is brought to shoreline

Post-harvest treatments of harvested sea weed are done to make sea weed clean and ready for its intended use or for its storage. Different factors like species handled, production scale, infrastructure availability on shore, specific industrial use, downstream processes affect the postharvest treatment procedures. The important factor affecting post-harvest care is, whether it will be used for raw industrial processing (e.g., phycocolloid extraction and biofuel), which require lower quality and less uniformity or for food or refined biochemical sector, that require strict care in postharvest processing. Cleaning is the most common pre-treatment done to remove impurities like and, salt other fauna other fouling variety, unwanted damaged parts etc. it is done either during or after harvest. Cleaning can be done either completely in sea water or sometimes with at least a final freshwater rinsing is done to remove salt if required. After cleaning other postharvest treatments like soaking, drying, freezing and thawing, enzymatic processing, fermentation, blanching and ensiling etc are done depending on the afterward requirement.

Conclusion

Seaweed farming is an eco-friendly alternative to traditional farming, which brings both environmental and economic benefits. It can combat climate change, soil degradation, and scarcity of water while improving global food security. Seaweeds absorb CO_2, reduce ocean acidification, and increase biodiversity within the ocean. Food, pharmaceuticals, biofuels, and fertilizers are all derived from seaweed, promoting a circular economy. Therefore, seaweed cultivation methods differ in the way they are submerged or floating to ensure productivity and sustainability. Above all, successful large-scale farming requires careful site selection, water quality, and post-harvest handling. More research and policy backing are required to enabling seaweed farming be integrated into the global food and industrial supply chains.

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