International Journal of Agriculture and Food Science Technology.
ISSN 2249-3050, Volume 4, Number 7 (2013), pp. 661-666

http://www.ripublication.com/ ijafst.htm

Agronomy and Cultivation Methods for Edible Seaweeds

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Abstract

Seaweeds, by all means, are "future plants"; they have been projected as the future viand for ever-increasing human populations, viable and sustainable source for biofuel without disturbing global food scenario, as potential candidates for carbon capture and sequestration that is considered as a practical remedy for global warming, and they have a number of pharmaceutical, industrial and biotechnological applications. However, information on its cultivation methods or life history remain obscure to a majority of marine botanists, especially in India. While life histories of seaweeds have traditionally been an exotic topic for specialists-language of which is ciphered with scientific jargons incomprehensible to general scientific audience, its agronomy had been a trade secret for coastal communities in East Asian countries, especially Japan, the Philippines and Indonesia. In this mini-review, an overview of major coastal and offshore seaweed mariculture techniques are presented with the aid of clear-to-understand illustrations.

1. Introduction

It was only a few decades ago that the concepts of modern agronomy have started to find applications in the field of seaweed farming (Doty, 1979; Santelices, 1999), however improvement of the existing farming methods have been very minimal for the last four decades or so. Manipulating factors contributing to the site fertility is often impractical due to the continuous nature of ocean. Therefore, we are limited to choose right, fertile site before the farming and continue until nutrients get exhausted, rather than attempting to alter site to make it more fertile. Current understanding of the farm fertility suggests far more viable factors than the four originally hypothesized; viz., temperature, water quality, water motion and light. These include additional abiotic factors such as availability of suitable substrata, pollution and eutrophication, and biotic factors such as biodiversity, presence or absence of grazing vectors, pathogens or epiphytes, and presence of invasive species. Recent findings suggest that role of biodiversity in providing stability for the established seaweed beds is much more than previously thought (Boyer, Kertesz, & Bruno, 2009; Stachowicz, Graham, Bracken, & Szoboszlai, 2008). Seaweedpolyculture is found to be significantly more productive than monoculture, perhaps due to factors such as facilitation and differential use of macrohabitats in heterogeneous environment. A small-scale experiment in which herbivore density have been manipulated in tide pool suggest that seaweed species evenness and primary productivity were increased by the presence of snails, as they preferentially consumed otherwise dominant less-productive seaweeds (Altieri et al., 2009). Another factor is UV-B irradiation that affects spatial and functional structure of seaweed communities in coastal environments (Bischof et al., 2007).

One significant difference from the land plants is that there is no alternative to the seeds in seaweeds, making its long term storage and propagation significantly complicated. Seaweeds have complicated life cycles and maintaining unialgal cultures in laboratories, although laborious, is often the method of choice. Some progresses have been made recently in these lines, such as development of vegetative propagation protocols from cells and protoplast and thereby using these as seed stock (Hernández-González, Buschmann, Cifuentes, Correa, & Westermeier, 2007; Polne-Fuller & Gibor, 1986) and selection of improved and/or disease resistant strains by selective breeding or hybridization by protoplast fusion (Cheney, 1990). Recent advances in seaweedmicropropagation techniques have been reviewed by (Reddy, Jha, Fujita, & Ohno, 2008). Selective breeding and genetic improvement of the cultivars for increased yield, flavor etc. have been successfully applied in several high-value seaweed genera, including *Saccharina*(Yan, Jianzhou, Xueyan, Tao, & Qingli, 2006), *Undaria* and *Porphyra*(Chaoyuan & Guangheng, 1987; Dai, Zhang, & Bao, 1993). Attempts by genetic engineering have also been done, whereby transferring biolistic gene to spores of several commercially important seaweed genera, taking advantage of the life cycle(Qin, Jiang, Yu, Li, & Sun, 2010).

2. Clonal Vs Non-clonal agronomy

In an agronomic point of view, there are two types of seaweeds; viz., clonal and non-clonal (Santelices, 1999). Clonal seaweeds have ability to propagate by fragmentation and therefore its cultivation is less laborious. Typically, these are farmed in one-step, i.e., tying fragments to the ropes and nets and its installation in the farm site. During each successive harvesting, a small piece of fragment is allowed to remain attached with the nets so that the thalli get regenerated in the next growth season. This farming method do not involve nursery-rearing of the seedlings and do not demand expensive infrastructural support or expertise and this might be the reason for its immense popularity in developing countries including China, the Philippines and Chile. Examples include *Eucheuma*, *Kappaphycus*, *Sargassum* and *Caulerpa*. In contrary, non-clonal (unitary) seaweeds do not have fragmentation ability and the only way to cultivate them is by completing the life cycle during each growth season. Farming is multistep and it typically involves *in-vitro* fertilization and nursery rearing of young seedlings on the nets, before its installation in farm sites. Examples include several high-value seaweeds such as *Porphyra*, *Gracillaria*, *Saccharina*, *Undaria*, *Monostroma* and *Ulva*. Cultivation techniques for clonal and non-clonal seaweeds are illustrated in Fig. 1.

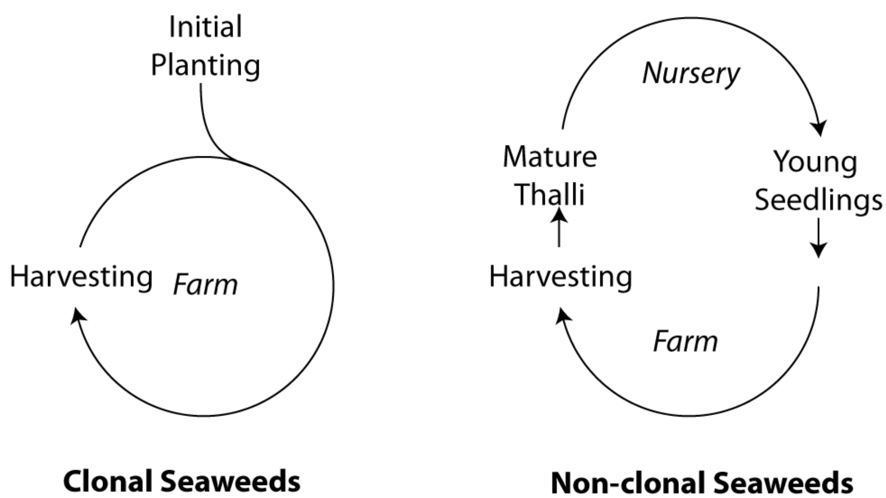

Fig. 1: Summary of farming method employed for clonal and non-clonal seaweeds.

3. Summary of Commercial Mariculture Methods

There are four basic types of agronomic methods widely employed in commercial seaweed cultivation; Floating raft method, Semi-floating raft method, Off-bottom (fixed bottom) method and Bottom planting method. In floating raft method (Fig. 2A), rafts are floated by means of buoys (styroform or even inflated PET bottles or coconut husks) installed in nearshore or offshore sites, such that they are floating all the time irrespective of the tides. The frame of the raft can be either synthetic material or wood, such as bamboo poles. Seaweed is cultivated in nets made of nylon or other materials (such as polyethylene or coir), which is interwoven in the raft frame. In this method, rafts are held in place via deadweight mooring, to prevent its drifting. A variant of this method is known as “longline method”, in which seaweeds are grown in the main rope that is floated via buoys installed at every 4-5 meters and ends fixed via deadweight mooring. Floating raft or longine is the method of choice for kelps (*Saccharina*, *Undaria*) and employed for Eucheumoidseaweeds (*Eucheuma* and *Kappaphycus*) and *Sargassum.*

In semi-floating raft method (Fig 2B), rafts with seaweed cultivation nets are attached with top ends of the poles. Bottom ends of the poles have a tripod-like structure and are free, not anchored into the shoal. As in the floating raft method, rafts are attached to an array of buoys such that the system gets floated during high tide. During low tides, tripod-like structure of the poles firmly touches the shoal and this makes raft with cultivation nets get exposed. This method is therefore a combination of floating raft and fixed net methods and guarantees good sunlight irradiance at all the times. This method is used extensively for the commercial farming of seaweeds that require periodic exposure to the air, such as *Porphyra*, *Monostroma* and *Ulva.*

In off-bottom method (Fig 2C), nets are hung between the poles that are fixed to the shoal. Poles of suitable heights are chosen so that at high tides, the nets are immersed, while at low tides, nets get exposed. As the nets are immersed in body of water at high tides, light irradiance is a limiting factor. This method therefore demands an appropriate site with sandy bottom and sufficient sunlight. As the farm being easily accessible at low tides, one potential problem is attack from intertidal epiphytes and grazers. Sites with minimal natural flora of these pests need to be chosen for the successful implementation. Seaweeds that require periodic drying such as *Porphyra*, *Monostroma* and *Ulva* are extensively cultivated by this low-cost method. In a variant of this method, nets are installed such a way to have subtidal environment; i.e., nets are lower than water level during low tides. This method has been widely used in developing countries to substitute more expensive floating-raft for the cultivation of Eucheumoidseaweeds.

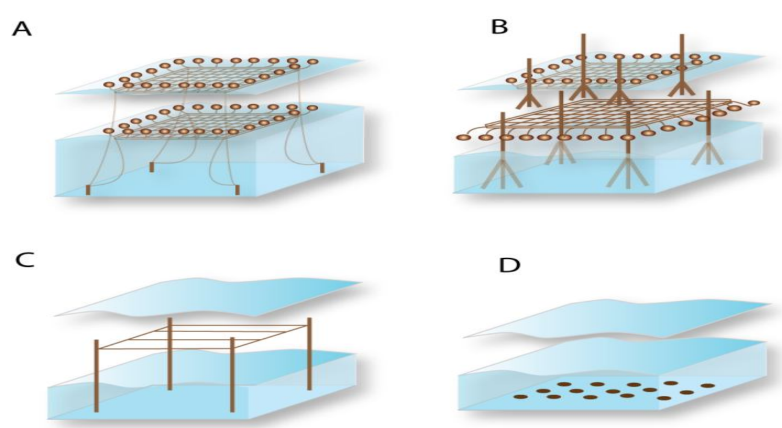

Fig. 2: Four basic types of seaweed agronomic methods. A. Floating raft in deep sea with deadweight mooring. Raft is floated all the time. B. Semi-floating raft in shallow water. Raft is floated at high tides but gets exposed during low tides. C. Off bottom in shallow water. Nets get immersed in high tide and exposed in low tide. D. Bottom planting in shallow water. Immersed at all the times. Water levels at high-tide are shown above low tide in all illustrations.

In bottom planting method (Fig 2D), seaweeds are cultivated on substratum placed directly on the shoal. This method is typically employed in areas where low level of water remains at low tides such that the planting can be performed without diving. Bottom planting assures immerse of seaweed at all the times and is performed for such benthic genera with thin corticated cylindrical thalli (*Gracillaria* and *Sarcodiotheca*) as well as those with creeping stolon (*Caulerpa*).

4. Conclusion

In India attempts have never been made to implement any of the modern seaweed mariculture practices reviewed herein for the commercial cultivation of seaweeds. With a coastline of more than 6000 km with nutrient-rich and comparatively unpolluted coastal habitats, India could tap into the potentials of sustainable seaweed mariculture to an extent to contribute in the national GDP- if agronomy methods effectively implemented. Seaweed agronomy remains one of the disciplines that need an immediate attention from local fishing communities, policy makers and scientists.

5. Acknowledgements

Research in this communication was supported by Department of Science and Technology (DST-Government of India) - INSPIRE Faculty Award. I thank Vice Chancellor, central University of Punjab for his support. This paper has been presented at 2ndInternational conference on Agriculture, Food Technologies and Environment” to be held at Jawaharlal Nehru University, New Delhi on 19th and 20th October, 2013.

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