Chapter 12
Production, Maintenance and Benefits of Seaweeds in Tropical Regions

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Abstract The mariculture, a type of aquaculture, is the process in which the seaweeds, a type of macroalgae, are cultivated. The seaweed involves various medicinal, biological, and socio-economical applications. The seaweeds are autotrophic and can produce numerous compounds with many important aspects. It has been used for a long time as a nutrient, which is rich in protein, dietary fibres and lipids. Along with the bio-molecules, it has numerous bioactive compounds with multi-potential uses in various industries. The products of the seaweed cultivation majorly involve the consumption by human beings, whereas the other major impact of seaweeds has been observed in the maintenance of marine food chain and marine ecosystem. The seaweed cultivation has been seen majorly around the coastal regions but it does not denote that coastal areas are necessary for seaweed cultivation. This chapter provides information about different types of seaweeds, their characteristics, lifecycle, production, application and cultivation techniques of the seaweeds, particularly in tropical regions. The discussion continues to know about their nutritional values, followed by the details about the different regions and countries that fall under the tropical category, and the three major production methods of seaweed cultivation along with its advantages and disadvantages and the factors that can harm the seaweed cultivation have also been discussed in this chapter. The chapter also covers the threats and harm to the seaweeds as well as the factors that increase the growth of the seaweeds.

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12.1 Introduction

Seaweeds are also known as marine algae which are distributed along the coasts from tropical to the polar region. It has been receiving much interest in the present era due to its potentialities. It is very nutritive as well as with numerous medicinal properties. This chapter provides information about different types of seaweeds, their characteristics, lifecycle, production, application and cultivation techniques, particularly in tropical regions.

12.2 Aquaculture

Aquaculture, which is also referred to as fish farming, is being practised all over the globe in the naturally occurring freshwater lakes to artificially built tanks (Food and Agricultural Organisations of the United Nations 2021). The aquaculture products are mainly used for consumption by human beings in the day-to-day diet. The aquaculture involves different stages beginning with hatchery, in which the eggs of respective fishes hatch artificially in a hood or cabinet. The hatchery stage is followed by feeding the hatched ones with appropriate nutrients and food till it attains the matured form. The matured or adult fish is taken for farming purposes, which is the third stage. The fishes, once matured and attain the stage to harvest in the farm, is then packaged and transported for various purposes (Crespi and Coche 2008).

Aquaculture may be regarded as one of the most prominent and efficient culturing since the benefits are considerably higher. Approximately around 50% of the global fish is consumed for dietary purposes (Food and Agricultural Organisations of the United Nations 2021). India ranks second in aquaculture among the worldwide nations and Andhra Pradesh ranks first among the states of India. Aquaculture falls into various categories like mariculture that uses seawater, fish farming that is performed with either seawater or freshwater, the algal culture that cultivates the algae, integrated multi-trophic aquaculture involving the combination of different tropical levels, inland pond culturing and open-net pen and cage systems that use the artificially constructed ponds and cages, re-circulating system culturing that involves the recirculation of water constantly, and flow through methods, in which the fish is stocked in a lengthier unit (Mirzoyan et al. 2010).

12.2.1 Seaweed

Seaweed is a macroalga, which may be red, brown, black or green in colour and are grown in the seawater and seashores (Townsend and David 2012). Seaweed is also referred to as sea vegetables and is a rich source of nutrients. The red algae fall under Rhodophyta division and it includes species like *Palmaria palmata, Gelidium amansii, Chondrus crispus, Porphyra* species, etc., the brown algae include Phaeophyceae class and the most common brown algae includes kelps and *Fucus* (Sheath and Robert 1984). The sea lettuce, which is *Ulva* spp., is being grouped under the green algae or Chlorophyta seaweeds. The marine environment is being enriched with macroalgae, which approximately involves 1800 different species of brown algae, 6200 species of red algae and 1800 green algal species. Among these vast species, brown algae are the larger ones (Cribb 1953).

12.2.2 Red Seaweeds

The red algae have the pigments phycoerythrin and phycocyanin, which may be responsible for the red colour (Kadam et al. 2013). In addition to these pigments, chlorophyll is also present in the red algae. Among these three pigments, phycocyanin is the most important (Cian et al. 2014). These compounds are widely used as a natural dye in milk products, soft drinks and also in cosmetic materials including eyeliner, lipstick, etc. In addition to this, the compounds also have potential health benefits with antioxidant, antimicrobial, anti-inflammatory, hepato- and neuroprotective properties (Sekar and Chandramohan 2008).

The red algae also contain polyunsaturated fatty acid, particularly eicosapentaenoic acid and arachidonic acid (Kumari et al. 2013). It is also having rich amounts of phenolic compounds, which is having more potent antioxidant properties. This seaweed produces polysaccharides including agar and carrageenans (Usov 2011). The agar is an important component of the cell wall. The unique property of the agar is the capability to form reversible gels; hence, it has wide uses in food additives (Imeson 2009; Liu et al. 2020). It also has many biological activities including antioxidant, antimicrobial, anti-inflammatory, immunomodulatory, anticancer and hepatoprotective properties (Jin et al. 2017; Mazumder et al. 2002; Bhattarai and Kashyap 2016; Coura et al. 2015; Higashimura et al. 2013; Liu et al. 2017). The agar is used as stabilizing as well as a gelling agent in the food industry, cosmetics industry and pharmaceutical industry (Freile-Pelegrín and Murano 2005; Marinho-Soriano and Bourret 2005; Villanueva et al. 2010; Ganesan et al. 2020a, b).

Another important compound isolated from the red seaweeds is carrageenan. Much red seaweed produces more concentrations of carrageenan and is called carrageenan producers (carrageenophytes, Pereira and Mesquita 2003). It has been widely used in the pharmaceutical industry because of its antioxidant, antimicrobial, anticancer, anti-inflammatory, immunomodulatory and neuroprotective activity (Chattopadhyay et al. 2008; Souza et al. 2018 Vanderlei et al. 2011; Talarico et al. 2004; Yuan et al. 2006; Liu et al. 2013; Poupard et al. 2017; Sattanathan et al. 2020a, b). In the plant, the carrageenans stimulate defence mechanisms particularly against various viruses, increase the growth of the plant and also maintain abiotic stresses (Mercier et al. 2001; Sangha et al. 2011; Ghannam et al. 2013; Shukla et al. 2016).

12.2.3 Brown Seaweeds

The brown algae have the pigment fucoxanthin, which may be responsible for the brown colour, and the chlorophylls are also present (Chandini et al. 2008). The concentration of fucoxanthin may differ in different species of brown seaweed. Several studies suggest that fucoxanthin have antioxidant, anticancer and anti-obesity activities (Yan et al. 1999; Maeda et al. 2005; Pigmen et al. 2014). Myristic acid and palmitic acid are the saturated fatty acids present in large quantities in brown seaweed. In polyunsaturated fatty acids, the brown seaweeds contain arachidonic acid, linolenic acid and eicosapentaenoic acid (Khotimchenko 1998; Graeve et al. 2002). Plastoquinones and chromanols and chromenes are meroditerpenoids (phenolic compounds) present in the brown seaweeds (Reddy and Urban 2009). These phenolic compounds have potent antiviral (particularly HIV), antibacterial, anti-diabetic, anti-obesity and neuroprotective activity (Artan et al. 2008; Kim and Kong 2010; Murray et al. 2018).

Alginate is the most important polysaccharide in brown seaweeds and it has been found in the cell walls of the brown seaweed (Andrade et al. 2004). It has been used widely in the food industry, textile industry, cosmetic industry and also in the pharmaceutical industry (Wiltshire et al. 2015). It also controls glucose and cholesterol in the blood due to its dietary fibre character (Wolf et al. 2002). Laminarin is another polysaccharide present in brown seaweeds (Kadam et al. 2015). The concentration varies depending on the temperature and salinity of the water (Rioux et al. 2010). It can be used to activate macrophages leading to immunostimulatory, wound healing and anticancer activities (Kadam et al. 2015) and it also influences the metabolism in the intestine (Déville et al. 2007). Because of its fibre nature, it helps to reduce the cholesterol and triglycerides in the liver; hence it also controls blood pressure. The cell walls of the brown seaweed contain fucose-containing sulphated polysaccharides called fucoidans (Imbs et al. 2014). *Undaria pinnatifida* is rich in fucoidan. This can be used as a good anticoagulant agent; it also exhibits antiviral and antioxidant properties (Mandal et al. 2007; Chandía and Matsuhiro 2008). It is used to moisturize the skin; hence it has anti-ageing properties (Wijesinghe et al. 2012).

12.2.4 Green Seaweeds

The green seaweeds contain only chlorophylls and carotenoids. It contains polyunsaturated fatty acids including linoleic acid, palmitolinolenic and palmitidonic polyunsaturated fatty acids (Khotimchenko 1993; Khotimchenko et al. 2002; Kumari et al. 2010). The green seaweeds are rich in sulphated polysaccharides called ulvans. It is water-soluble and its concentration ranges between 18–29% (85–84). Ulvans are not digestible by humans, but they can act as dietary fibre. It is used in biomedical fields particularly in tissue engineering and drug delivery (Alves et al. 2013; Wijesekara et al. 2011; Venkatesan et al. 2015; Cunha and Grenha 2016). These compounds have potent antioxidant, antimicrobial, anti-tumour and hypolipidemic activity (Alves et al. 2013).

12.3 Physical Characteristics of Seaweed

The seaweeds contain various parts such as conceptacles which contain the reproductive structures of the algae with a receptacle, a swollen tip of the fertile frond. The algae are attached firmly to the substratum or any surface with the help of a hapteron, which is also referred to as holdfast (Dayton 1985; Graham 2004). The hapteron extends to a stripe that is tough and flexible and elevates the algae above the surface and along with lamina (also named as a blade) it helps to withstand the wavy action. Apart from these parts, seaweeds also possess mid-rid, which is the central vein of the lamina and air bladders that are capable of keeping the lamina buoyant and near the surface of the water for the purpose of photosynthesis in an efficient manner. The lamina contains the midrib medulla at the centre and the cortex cells as an extension from the midrib medulla. It is then covered by the epidermis layer.

12.4 Lifecycle of Seaweed

The life span of seaweed varies, some are annual and some of them have a longer life span of 6–10 years. Seaweed reproduction happens via its spores. The male and female reproductive cells, i.e. zoospore matures into male gametophyte and antheridia followed by female gametophyte respectively. The male gametophyte matures to sperm and the female gametophyte matures to egg followed by the fusion of egg and sperm forming the zygote. The zygote grows into sporophytes and matures as seaweed (Fig. 12.1).

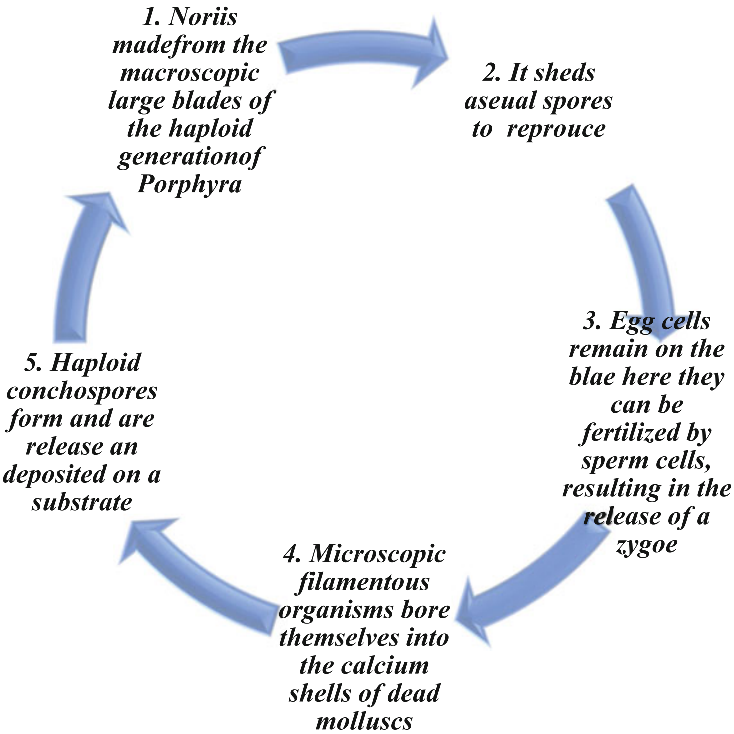

Fig. 12.1 Reproduction in seaweed

12.5 Seaweeds: Production

The production of seaweed is being elevated by about 5.7% approximately every year globally, according to Fisheries and Aquaculture (FAO). According to FAO, Asian countries are predominant in seaweed culturing accounting for about 99.05% in quantity and 99.36% in quality (Fisheries and Aquaculture 2014). Around 98% of the seaweed harvested worldwide, and five genera of seaweed were found to be predominantly harvested, namely *Saccharina*, *Undaria*, *Porphyra*, *Eucheuma*/*Kappaphycus* and *Gracilaria* (Suo and Wang 1992; Pereira and Yarish 2008).

12.6 Nutritional Content in Seaweed

Seaweed has been found to have various beneficial properties for humankind, with a wide range of nutrients like minerals, vitamins, proteins, carbohydrates and fibres (Paul et al. 2007). Since ancient times, seaweeds have been cultivated and consumed by humans and as feed for live stocks. It has been reported that *Pyropia* spp., (Nori) has 1.5 times higher vitamin C content than oranges. All the seaweeds categorized under the Phaeophyceae family have a sufficient amount of vitamin B (Salehi et al. 2019). Depending upon the species, the carbohydrate content might vary from 20% to 76% (dry weight). Seaweeds have a higher amount of carbohydrate which is stored in the form of functional and structural polysaccharides (Holdt and Kraan 2011). The composition of fat varies remarkably between different types of seaweeds. The polyunsaturated fatty acids and lipid content of seaweeds are reported to increase during the cold and summer season, respectively (Rajapakse and Kim 2011). Seaweeds are also a vital source of iron.

The iron content of *Sargassum* spp. seaweeds is 156.9 mg/100 g of dry weight and it also aids in the absorption of iron from a rice meal. The iron content of *Sargassum* spp. may vary from 81 to 290 mg/100 g of dry weight and the maximum content is recorded during the month of July (Cherry et al. 2019). Genus *Gracilaria* (red algae) is the most cultivated seaweed which is a great source of both insoluble and soluble dietary fibres. The insoluble dietary fibre helps in improving gastrointestinal and cardiovascular function. Soluble fibre aids in the reduction of cholesterol and glycaemia (Rosemary et al. 2019).

The brown algae rank in the topmost as a good source of iodine. The fat content of the seaweed has been found to be lower when compared to the other nutrients, whereas the protein and calcium contents range from higher to lower and are species-specific in nature. The brown algae have lower protein content, which accounts for only up to 15%, whereas the red algae and green algae have higher protein content ranging up to 30% (Kolanjinathan et al. 2014). Another *Ulva* species, called *Ulva lactuca,* green algae has been found to have a high protein and carbohydrate content but a lesser fat content (Rasyid 2017).

Fucoidan derived from *Undaria pinnatifida* were reported to have greater anti-diabetic and anticancer effects. Koh et al. (2020) reported that fucoidan had prominent activity on amyloglucosidase, α- amylase and α-glucosidase. Lu et al. (2018) demonstrated that fucoidan obtained from *U. pinnatifida* significantly exhibited proliferation inhibition in breast cancer cells. Traditionally, brown seaweeds are used in thyroid goitres treatment (Salehi et al. 2019). Fucoxanthin derived from *Sargassum horneri* was found to be effective in reversing the cognitive impairment caused by scopolamine in mice (Lin et al. 2016). Ulvan, fucoidan and S-heterogalactan have displayed strong antioxidant activity against the 1,1-diphenyl-2-picrylhydrazyl (DPPH) (De Jesus Raposo et al. 2015; Le et al. 2019; Zhao et al. 2018). Sulphated polysaccharide (fucoidan) derived from *Turbinaria decurrens* and *Dictyota bartayesiana* displayed maximum antiretroviral activity (Sanniyasi et al. 2019).

Almost all the seaweeds contain nutrients such as vitamins (A, B1, B2, C, E and K), calcium, folate, potassium, iron, manganese and copper. *Himanthalia elongate,* a brown seaweed, which is commonly referred to as rockweed, has been ranked top among the seaweeds with higher fibre content. It has a total fibre content of about 9.8 g/100 g net weight, whereas other brown algae, *Ascophyllum nodosum* contains 8.8 g/100 g net weight fibres ranking it into the second position. The various mineral composition of seaweeds has been given in Table 12.1 (Mac Artain et al. 2007).

Table 12.1 Mineral composition of some economically important seaweed

Seaweed	Ca	K	Mg	Na	Cu	Fe	Iodine	Zn
Ascophyllum nodosum	575.0	765.0	225.0	1173.8	0.8	14.9	18.2	–
Laminaria digitata	364.7	2013.2	403.5	624.6	0.3	45.6	70.0	1.6
Himanthalia elongata	30.0	1351.4	90.1	600.6	0.1	5.0	10.7	1.7
Undaria pinnatifida	112.3	62.4	78.7	448.7	0.2	3.9	3.9	0.3
Porphyra umbilicalis	34.2	302.2	108.3	119.7	0.1	5.2	1.3	0.7
Palmari apalmata	148.8	1169.6	97.6	255.2	0.4	12.8	10.2	0.3
Chondrus crispus	373.8	827.5	573.8	1572.5	0.1	6.6	6.1	–
Ulva spp.	325.0	245.0	465.0	340.0	0.3	15.3	1.6	0.9
Enteromorpha spp.	104.0	351.1	455.1	52.0	0.1	22.2	97.9	1.2

Ca calcium, *K* potassium, *Mg* magnesium, *Na* sodium, *Cu* copper, *Fe* iron, *Zn* zinc.

12.7 Applications of Seaweed

The seaweed varieties are involved in various applications environmentally and biologically (Fig. 12.2). The environmental applications include the protection of coastlines against soil erosion (Dayton 1985) as well as the significant contribution towards the aquatic carbon cycle (Thiel et al. 2007; Ugarte and Sharp 2011). The marine food chain is being maintained and balanced mainly by seaweeds. The nutritional contents and energy are directly provided to the marine animals by eating the seaweeds directly or indirectly after being decomposed into small particles. The coastal animals have their shelter and habitat in the beds of seaweed for their whole life or for the part of their life. Seaweeds serve as nurseries for the species that are commercial in nature like rock lobster, abalone, etc.

Seaweed has been widely used in the treatment and management of human diseases as they were found to have some medicinal properties. The seaweed has the capacity of reducing the cholesterol levels of plasma that paves the way for using the seaweed in the management of cardiovascular disease, which is mainly caused due to high cholesterol levels (Imenez-Escrig and Sanchez-Muniz 2000). The seaweeds were also found to have antimicrobial, antifungal and anti-inflammatory properties. Erythema, a disease caused mainly due to increased flow in superficial capillary blood, may be suppressed by seaweeds, *Undaria pinnatifida*, a brown seaweed, and *Ulva linza,* green seaweed. Another clinical condition that may be controlled by these two seaweeds is oedema (Mohammed et al. 2008).

The hyperglycaemic condition may be effectively suppressed by a type of brown algae, *Pelvetia babingtonii,* as it has the potential to inhibit α-glucosidase activity (Ohta et al. 2002; Smit Albertus 2004). Seaweeds can also be used against cancer, diabetes and also against certain viral infections. The antagonistic compounds present in algae have made them capable of functioning as antibiotics, which can be used against infections by bacteria, viruses and fungi (Hoppe 1979). Extracts of red seaweeds like *Solieria robusta*, brown algae like *Lyengaria stellata*, *Colpomenia sinuosa*, *Spatoglossum asperum* and green algae like *Caulerpa racemose* have exhibited hypolipidemic activities. Serum total cholesterol levels, triglyceride ranges

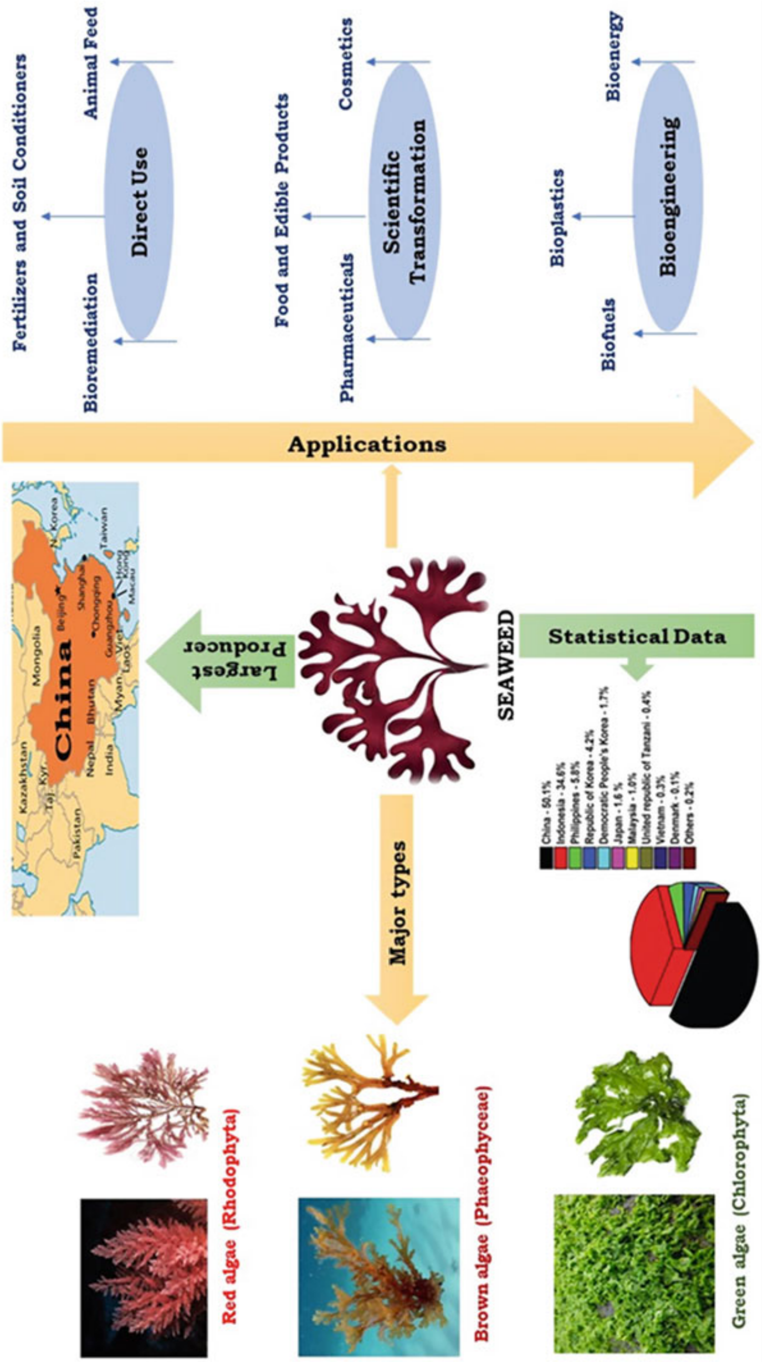

Fig. 12.2 Facts about the seaweeds

and low-density lipoprotein levels decline in the animal models after the treatment with these algal extracts (Ara et al. 2002; Smit Albertus 2004).

Seaweed has an important role in improving thyroid function as they are the rich source of iodine (Lazarus and Smyth 2008; Smyth et al. 2016; Smyth 2021). Gut health can also be improved by the seaweed intake as they possess carrageenan, agars, fucoidans, which act as prebiotics, non-digestible fibres and also the sulphated polysaccharides increase the beneficial bacteria growth in the gut as well as the short-term fatty acids that paves a way for healthy gut lining (Cherry et al. 2019; Zaporozhets et al. 2014). Fucoxanthin is present in the brown algae that have a role in managing the blood glucose level (Peng et al. 2011; Airanthi et al. 2011; Mise et al. 2011; Heo et al. 2010).

12.8 Tropical Regions in the World

Geographically, the Equator that is considered as the line through the centre of our planet falls at zero degree latitude, dividing the earth into Northern and Southern hemispheres. The regions that are found around the Equator are referred to as tropical regions. Approximately around 40% of the total surface area on Earth and 36% of the landmass together comprises tropical regions in the world (National Geographic Encyclopaedia 2017). India, an Asian country in the southern part of the continent, falls almost in the tropical region, whereas all the other countries in Southeast Asia fall in the tropical regions totally (Morgan 2011). The list of tropical countries in the world has been given in Table 12.2.

12.9 Tropical Marine Life

Ocean majorly influences the tropical marine climate. The tropical marine climate is commonly observed in the islands and the regions around coastal areas that are located 10°–20° either north or south to the Equator. The main seasons in the tropical marine climate are wet season and dry season, with the temperature ranging between 68 ° F and 95 ° F. The rainfall measures over 39–59 in. annually. The wind blows and passes through the warm seas and retains its moisture throughout the year. The countries like Brazil, Madagascar and Queensland, etc., are majorly in the tropical waters and exhibit this kind of moisture winds throughout (Filho and Walter Leal 2017; Wilson and Mark 2016).

Table 12.2 List of tropical countries across the world

Continent	Country
North America	Mexico
Central America	All of Central America
North and Central America	All of the Caribbean islands
South America	Colombia
South America	Ecuador
South America	Peru
South America	Bolivia
South America	Colombia
South America	Venezuela
South America	Guyana
South America	Suriname
South America	French Guiana
North America	Chile
North America	Argentina
North America	Paraguay
North America	Brazil
Western Asia	Yemen
Western Asia	Parts of Saudi Arabia
Asia	Oman
Asia	United Arab Emirates
Australia	Australia
Oceania	Micronesia
Oceania	The Marshall Islands
Oceania	Kiribati

12.10 Seaweed Cultivation in Tropical Regions

The artificial method of cultivating the seaweed is called as mariculture method. Seaweed cultivation has reached 27% of the total marine aquaculture production with the production of about 27.3 million tons annually in the year 2014 and the growth rate has been estimated to be 8% per year from 2014. The favourable climatic conditions for seaweed cultivation have been listed in the following paragraph.

The temperature of the water, in which the seaweed has to be cultivated, should be optimum between 25 °C and 30 °C, in order to have the best growth. The salt content in the water, which is denoted by the term "salinity", should be ideally more than or equal to 28 ppt (parts per thousand). The movement in the water that indicates the speed and direction of the water is known as water current and the moderate range is considered for better seaweed growth as the strong water current can wash away the seaweeds. There are various methods available for cultivating seaweeds and three of them are majorly used. Those methods are discussed as follows.

12.10.1 Off-Bottom Method

The off-bottom method is also referred to as the fixed bottom method. This method involves the placement of wood stakes at 20–25 cm apart from each other, into the bottom of the sea in the straight line in different rows. The preferred diameter of the stakes is between 5 and 10 cm and the ideal length is 1–1.5 m. Approximately about 500 centimetres of the stake is buried in the soil or sand in order to stand strong against the water currents safely. The following Fig. 12.3 shows the diagrammatic representation of the off-bottom method of seaweed cultivation.

A polypropylene rope of about 5 m in length has been stretched strongly in between the two stakes. The preferred thickness of the polypropylene rope is about 3 mm. Thirty pieces of polypropylene strings, known as raffia, are attached to the rope. The seaweed, which is to be planted, should be approximately about 150 g in weight to be tied to the raffia or polypropylene strings. The polypropylene rope should be suspended at the height of 20–30 cm above the sea bottom in order to protect the seaweed that grows from being blended into the sand and at the same time, 20–30 cm underneath the surface of the water in order to avoid the direct exposure of seaweeds to the sunlight as the seaweed would be killed when exposed directly to the sunlight. The stakes are preferred to be sharper at the ends to penetrate the sand or soil in which they are placed. The most preferred stakes are mangrove or bush timber that can withstand the seawater for a longer period without rotting.

The major advantages of the off-bottom method of seaweed cultivation are that it is simpler to construct as well as easier to manage. It is economically low and the farm may be easier to reach the low tide areas. Although there are advantages, it also has few disadvantages like locating a good area for farming is being difficult and the rough weather can damage the seaweeds as the farm cannot be moved when it is in unfavourable conditions. The grazer fishes, which can damage the seaweeds, are easier to be found around the crops and a drying rack needs to be constructed separately.

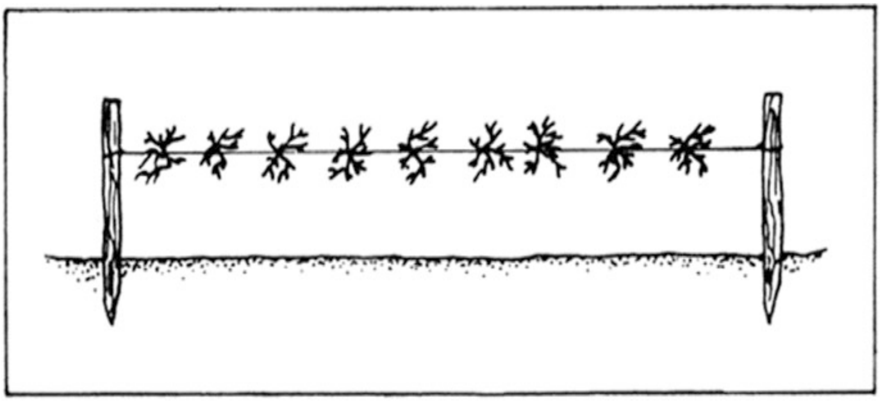

Fig. 12.3 Off-bottom method

12.10.2 Raft Method

The raft method is also named the floating method. As the name implies, seaweed cultivation by using this method involves the floating of seaweed by attaching them to a floating device that can move along the tides of the seawater accordingly. The floating device may be the simple frame that is made up of wood (mangrove), bamboos or bush timber which are readily resistible to the seawater for a longer period of time. The method involves the seaweed placement attached to the floating device to be underneath the surface of the water at least 50 cm. The preferred length of the floating device is 2.5 m that is made into a square and the ropes to be tied into the square frame in definite rows. The ropes of ideal size are 3 mm and these ropes can make up to 15 rows with 10–15 cm distance in between each of them. As with the off-bottom method, raffia is tied to the ropes and about 15 pieces of the crops are tied to the single row. Figure 12.4 shows the model of the floating method of cultivation of seaweed.

Like the off-bottom method, the floating method also has its own advantages and disadvantages. The advantages include the convenient utilization of the shallow and deep waters for the cultivation and the sandy sea bottom is not necessary for seaweed growth. Moreover, the floating rafts are easier to move to the various places and the planting can be done on the shore and rafts can be moved after that into the seawater conveniently. No drying rack is needed to be constructed separately and the seaweed growth has been observed to grow faster in the floating or raft method of cultivation. Even though, it has these advantages; it is difficult to find bamboo or other floating materials to construct the frames that are resistant to seawater for a longer duration.

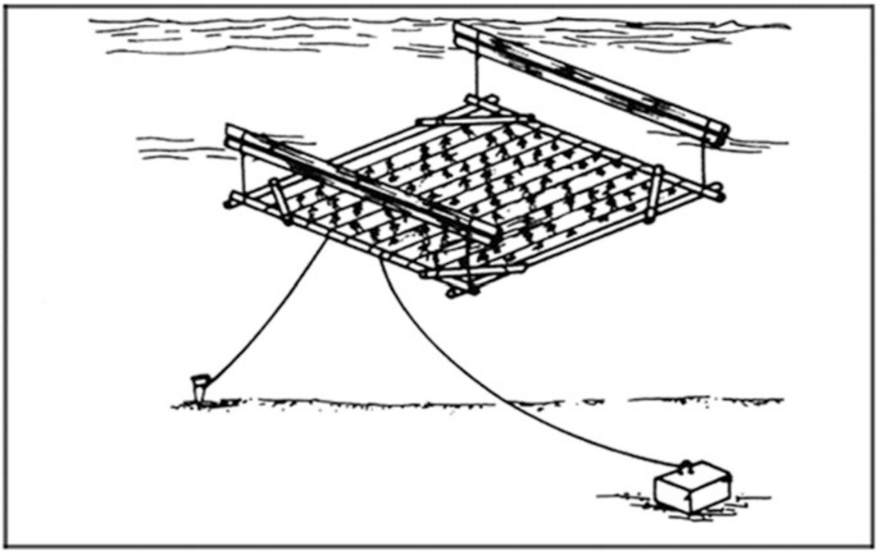

Fig. 12.4 Raft method

Rough weather may not favour the framework and the frames may break or sink into the seawater during the rough weather. The sea carriage like boats may damage the rafts and the frames cannot be handled single-handed.

12.10.3 Long Line Method

The long line method is another way of cultivating the seaweed and it shares a lot of similarities with the floating method. The long line method involves the hanging of seaweeds to be cultivated to the rope that is suspended by the floating materials. The rope diameter is preferably 10–15 mm, which is tied to the floating materials that are about 4–5 m in length. The raffia holds the seaweed like that of the other two methods. The seaweed attachment to the raffia can be done in two ways.

The first method involves the attachment of 0.5–1 m rope to the mainline and the raffia are to be attached to the additional ropes. The second way involves the attachment of raffia directly to the main lines. Figure 12.5 shows the long line method of seaweed cultivation. The seaweeds should be hanged to the mainlines in a way such that they are capable of receiving sufficient sunlight. The better distance is that the suspension should be made 0.5 m underneath the water surface.

As with all the other methods, the long line method also has its own advantages and disadvantages. The advantages include the convenience of setting up the long line almost anywhere compatible and the growth of seaweeds are faster. The long lines can be moved to other areas if necessary, during unfavourable climatic conditions. Even though it has these positive sides, the negative side involves the economy, since the ropes for long lines are costlier. The harvesting and plantation on the shore are not easier and the floaters are costlier than the other methods. Like the floating method, the long line method can also be damaged by the sea carriage like motor-driven boats that disturbs the water current.

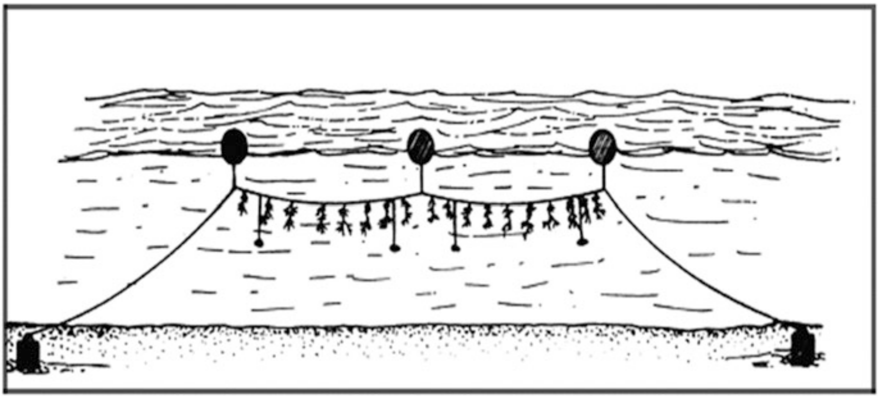

Fig. 12.5 Long line method

12.11 Harm to Seaweed

Although the seaweed can be cultivated and maintained by various methods, they have certain harm created naturally as well as artificially. Those harmful factors are discussed as follows.

12.11.1 Natural Predators

The natural predators are none other than the grazers of the seaweed. The seaweed grazers majorly involve the rabbit fish and puffer fish. The other aquatic animals like sea urchins and sea turtles also damage the seaweed plants and the rabbit fishes are also the major destructors of seaweeds. But the rabbit fish lives around the coral heads majorly and it is better to cultivate the seaweed farms away from the coral head areas (Fig. 12.6a, b).

The rabbit fish is not a major problem during the summer season or during the warmer climatic conditions. The unused stakes of wood or other rubbish materials are the home of rabbit fish and the other predators, and hence it is better to keep the seaweed cultivation region neat and clean.

12.11.2 Diseases

There are no specific diseases that affect seaweeds and one of the conditions is whitening of the branches, which may be a fungal infection. The discolouration of the branches makes them appear white or pink in colour.

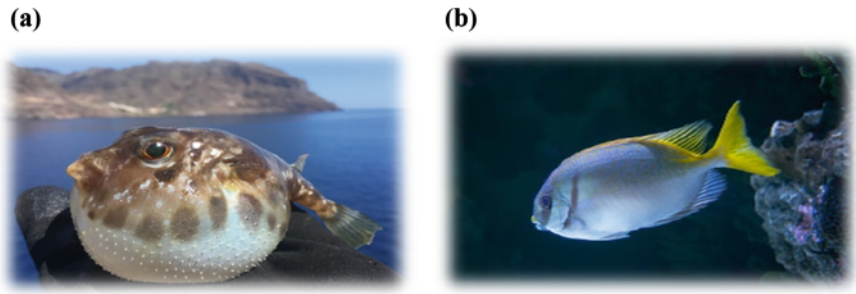

Fig. 12.6 (**a**) Puffer fish, (**b**) rabbit fish

12.11.3 Weather

The bad weather or climatic condition includes the rough water currents and heavy rainfall, as well as the cyclones that occur during the summer season are more dangerous. Since natural disasters like cyclones and heavy rainfall cannot be avoided or prevented, safety measures may be taken in order to reduce the destruction or loss. Harvesting the seaweeds before the period of the expected cyclones and can be protected from wind and rain by placing them on the shore. In the seaweed cultivation of *Kappaphycus alvarezii* in Saugi Island during the rainy season and dry season, the rainy season was found to favour its cultivation and enhance its production (Ali et al. 2017).

In Tanzania for the marine algae environment, the temperature of seawater at its surface is about 24.3–29.7 °C. The nutrients of seawater are found to vary during different seasons. In most temperate areas, the NO_3^- level of seawater in its surface undergoes a strong seasonal cycle because of seasonal thermoclines and it is found that in winter NO_3^- levels are maximum about 5–20 micromolar based on the geographical location, whereas in spring the rise in temperature results in the minimal level of NO_3^- due to the thermocline forms (Roleda and Hurd 2019). The damaged seaweeds must be replaced by the new seaweeds and the tangled lines may be entangled and secured further.

12.11.4 Factors That Increase the Seaweed Growth

The fertilizers with phosphate content can be preferred while the urea and KCl can be avoided. Maximization of the depth of water in the pond and minimizing the water exchange percentage can help in the seaweed production efficiency. Increasing the pH of the soil and lowering the Fe level in the water can influence the positive growth of seaweed. Reducing the epiphyte population by improvising the density of milkfish also aids in the development of seaweed (Mustafa and Sammut 2010). The nitrate concentration in the rainy season of seaweed cultivation was about 1.12–2.17 ppm whereas during the dry season it was about 1.24–1.96 ppm. The pH of the water during the rainy season was about 7.68–8.14 and during the dry season 8.25–8.39 (Ali et al. 2017). In common the factors like change in temperature, dissolved oxygen and phytoplankton production contribute to the alteration in pH of the water (Chen and Durbin 1994). The physical-chemical and biological factors are assumed to affect the absorption rate of nutrients (Harrison and Hurd 2001). Knowledge about the nutrients like nitrogen, phosphorous and carbon requirements for the seaweeds are a must for its cultivation (Hurd et al. 2014). When there is a higher requirement of nutrients more than its supply, then the nutrient starts to limit the growth of the seaweed, which is known as limiting (Harrison and Hurd 2001). *Fucus vesiculosus* Linnaeus during the limitation in nitrogen content it was to increase the uptake of phosphate (Perini and Bracken 2014).

12.12 Conclusion

The technologies for cultivating seaweeds have developed an interest for the past decades because of their nutritional and medicinal importance. Recent research urged to increase the production of more seaweed due to its high demands in the market. Hence, it is highly essential to optimize the new cultivation techniques with eco-friendly by multi-disciplinary approach with healthy and cost-efficient.

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