Chapter 9
Epiphytism in Seaweed Farming: Causes, Status, and Implications

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Contents

Abstract An epiphyte is a nonparasitic plant that dwells on another plant and has been well studied in terrestrial plants. However, in the marine ecosystem, these epiphytes thrive on algal thallus for their support and growth, and their infestation has a prime economic impediment in commercial cultivation. They usually belong to various groups, namely, bacteria, fungi, algae, ascidians, bryozoans, sponges, protozoa, molluscs, crustaceans, and other marine sessile organisms. The seaweed farming industry is currently growing at ca. 9% per annum, with global production of 31.2 million wet tons worth US$ 11.7 billion. The first report of an epiphytic outbreak in commercial farms of *Kappaphycus* in the 1970s caught the attention of

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several researchers on this devastating epiphyte which causes retarded growth and significant loss of stocking biomass, ultimately leading to the production of inferior quality of raw material. High-density planting in commercial farms is often responsible for recurring epiphytic infestations. Nevertheless, it is almost certain that the entire crop collapses due to epiphyte outbreak in a short span of time. Therefore, the lack of reliable global statistics exerts trade deficit in commercial seaweed farming. This chapter highlights the causes of epiphytic infestations, the current status of outbreaks, methods to control epiphytes, and its economic implications.

Keywords Seaweed · Epiphytes · Control strategies · Seaweed farming · Economic implications

9.1 Introduction

Seaweeds are marine macrophyte algae. They are exceptionally diverse in their forms and functions, are renewable in nature, and provide inimitable prospects for its utilization as a source of nutrition, food, cosmetics, fertilizer, medicinal, nutraceuticals, pharmaceutical, biofuels, personal care, and allied industries. Commercial harvesting of seaweeds has reached a new milestone with 31.2 million tonnes year^{-1} production (95% accounts to farming) with a market value of over US$ 11.7 billion (FAO 2018). About 221 species of seaweed are being utilized commercially. Of these, about 145 species are used for food, while nearly 110 species are exploited for phycocolloid extraction. Almost all of the seaweed production (94%) is produced through aquaculture practice, while harvesting from the wild stocks is minuscule.

Asian countries alone account for over 99% of global seaweed production. The highest proportion of tonnage is constituted by food alga, namely, *Porphyra* (Nori), *Laminaria* (Kombu), and *Undaria* (Wakame), followed by seaweeds for phycocolloid extraction. As seaweed farming has been gaining impetus globally, including outside Asia, the problems faced by this industry need to be addressed; one of the several issues is an epiphytic infestation. The first report of an epiphytic outbreak in commercial farms of *Kappaphycus* in the 1970s caught the attention of several researchers on this devastating epiphytes which causes retarded growth and significant loss of stocking biomass ultimately leading to the production of inferior quality of raw material. It is also a major, worldwide problem in *Gracilaria* cultivation as well (Fig. 9.1). The epiphytic infestation has severely reduced the productivity and cost efficiency in tank cultivation systems (Fletcher 1995). Seaweed in their natural ecosystem acts as a primary producer and provides food to consumers. With this primary role in the marine ecosystem, seaweed provides shelters and habitat to many organisms including the plants and animals. The organisms which colonize the seaweeds can be called as epibiotic communities or epibionts or even referred as epiphytes (Peteiro and Freire 2013) although this word is not clearly defined (Steel

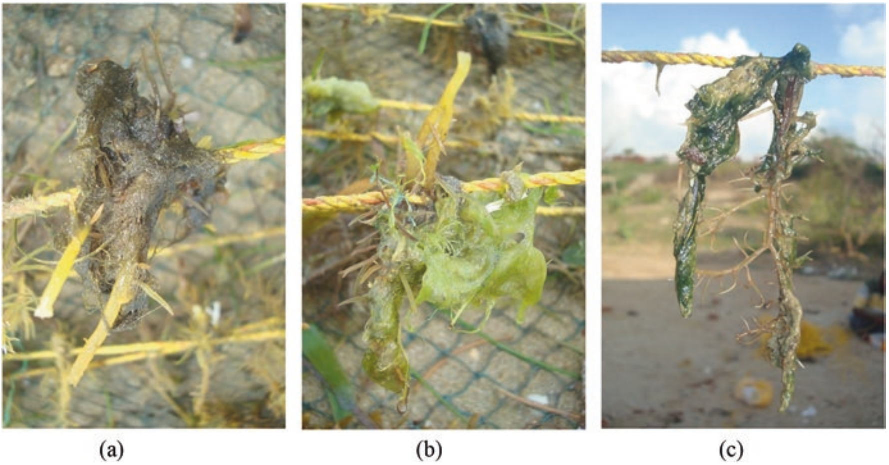

Fig. 9.1 Various forms of epiphytic infestation recorded during *Gracilaria edulis* farming. (**a**) Red algal type (**b**) Green algal type (**c**) Blue-green algal type

and Wilson 2003) and the phenomenon is referred as epiphytism. Epiphytism is common in marine habitat (Ingle et al. 2018), and there are various types of epiphytes from microalgae, other seaweeds to invertebrates and animals from the class of gastropod, and many small crustaceans such as amphipods and isopods associated with seaweeds. With this, there are various kinds of microorganisms from bacterial, fungal, and viral species (Gachon et al. 2010) associated with seaweeds. Almost all of these microorganisms (Goecke et al. 2013, 2010) and epibiotic communities (Wahl 1989) get suitable place, habitat, food source, as well as protection from their predators and other environmental stresses.

All these epibiotic communities of seaweed can show positive as well as negative mechanism. The positive interaction however is not so well studied, but few species particularly grazers can control the epiphytic algal species. In the cultivation of seaweeds, the decrease or increase of these communities can impact on the production. The abundance and species biodiversity of epibiotic communities are dependent on crop species morphology, season, etc. There are some other important factors in defining the epifaunal assemblages apart from the algal host such as epiphytic load and height on the shore (Cacabelos et al. 2010). In many places, the seaweeds are non-native species which can show variation in acceptance of them by native epibiotic communities (Cacabelos et al. 2010), due to their metabolites as deterrents against consumers (Paul and Fenical 1986). The physiological tolerance of these animals and the variations in the habitat environment determine the distributional pattern and abundance of this epifauna related to specific marine macrophyte (Lancellotti et al. 1993). Basically, the majority of epiphytic algae species are facultative in nature and are usually found associated with more than one species (Wahl and Mark 1999), while others are known obligate epiphytes which grow on specific single host species.

Almost all epibiotic organisms are generally deposited on the thallus part of cultivated seaweeds. In case of the epiphytic seaweeds and seaweed, crops are generally competitors of each other for the resources such as sunlight and nutrient (Kersen et al. 2007) which can make host seaweed weak, resulting in bacterial infection. The abundance of epiphytic species is determined by few abiotic factors, for instance, the direction of water movement and the availability of nutrients. Their spatial distribution is dependent on their ability to dryness or removal capacity of moisture during low tides (Molina-montenegro et al. 2005). The higher level of sunlight, high temperature, and strong desiccation at the time of low tides make the intertidal zone a stressful habitat (Bertness and Leonard 1997). The species which have the capability to keep themselves alive in such adverse conditions can impact on other species (Bertness et al. 1999; Molina-montenegro et al. 2005). Few seaweed species show tolerance to such environment and can provide shelter to various organisms such as other seaweeds and small crustaceans (Bertness et al. 1999).

The upsurge in the amount of nutrient load shows a gradual increase in the number of epiphytic seaweeds and invertebrates which are dependent on the seaweeds. However, intraspecific competition is also possible in the invertebrates for light, space, and food (Lobban and Harrison 2000; Kersen et al. 2007). The complex structure of seaweed can provide larger surface results in the diverse assemblages of invertebrates associated with that seaweed (Chemello and Milazzo 2002). The spatial variability of epifauna within the same environments might vary from a few days to several months. The small spatial scale of observation shows that the seaweed is a highly appropriate habitation for an extensive variety of faunal organisms (Chemello and Milazzo 2002), but this depends on many factors such as life cycle of epibiotic organisms, the architecture, and chemical defense of host seaweeds (Duffy and Hay 1994).

9.2 Classification of Epiphytes

Linskens (Linskens 1963) classified the epiphytes in two types on the basis of their attachment to host seaweed. The holo-epiphytes attach to the outermost layer of their seaweed host, while amphi-epiphytes acutely anchor inside the host seaweed tissue. This classification is complimentary compared to the classification given by Leonardi et al. (2006), which is based on the level of host penetration and classified in five types as per their interaction with macroalgae. Leonardi classified the epiphytes in five categories as shown in Table 9.1.

These epiphytes can be other algae, bacteria, fungi, etc. which cover the parts of seaweed densely as per their requirement and possibility of spreading. Both these classifications are related with the interaction of seaweed with epiphytes particularly epiphytic algae, and no mention about microorganisms are given separately and even no discussion on the animal's association to the seaweed. Ingle et al. (2018) defined the term pests in macroalgae cultivation, and on the basis of negative

Table 9.1 Classification of marine epiphytes in five different types

Type	Attachment characteristics	Damage possibility
1	Weak attachment to the host surface	No damage to host tissue
2	Strong attachment to the host surface	No damage to host tissue
3	Bleach the deck lamella, and outer layer of the host wall is penetrated	No damage to cortical cell
4	The deck lamella and outer layer of the host cell wall	Disturb the cortical tissue
5	The cortex is penetrated to reach the deep medullary tissue	Damage to host due to penetration up to medulla of host seaweed

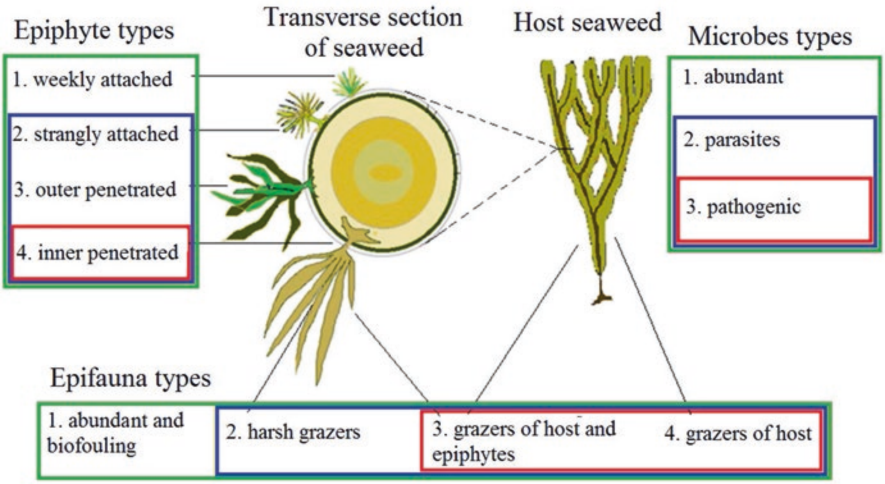

Fig. 9.2 Classification of marine pests into three main groups, plants, animals, and microorganisms, which are further categorized into subtypes which negatively interact with seaweed and might be responsible for direct or indirect harm or injuries. (Modified from Ingle et al. 2018)

interaction of epibiotic communities with crop seaweed, pests are classified in various categories as shown in Fig. 9.2.

9.3 Microorganisms and Seaweed

In the marine environment, seaweed deals with all types of microorganisms including the viruses and fungal species but mostly with bacteria. Although there is a limited study on the seaweed interaction with viruses and fungi, it is found that up to half of natural seaweed is infected by viruses (Cock et al. 2010) which denotes that viruses can strongly influence the seaweed lifestyle as well (Egan et al. 2013) (Table 9.2). In case of fungal species, only a few fungal species are yet known, but

Table 9.2 Key research works on the epiphytes in different geographical regions

Sl no.	Authors	Work done	Epiphytic composition	Area
1	Sand-Jensen and Borum (1984)	Epiphyte and photosynthesis	*Lobelia dortmanna* L., epiphytic diatoms	Denmark
2	Kitayama and Garrigue (1998)	Microscopic multicellular algae	*Plzaeophila deidroides* (Chlorophyceae, Phaeophilales), *Feldinannia irregularis*, *Feldrnaniiizia indica* (Phaeophyceae, Ectocarpales), *Stylonema alsidii* (Rhodophyceae, Porphyridiales)	Japan
3	Muñoz and Fotedar (2010)	Epiphytism of *Gracilaria cliftonii*	*Hypnea episcopalism*, *Ceramium puberulum*, *C. minuta*, *C. pusillum*, *C. isogonum*, *Polysiphoniaforfex*, *P. spinosissima*, *Laurencia clavata*, *Ulva lactuca*, *Champia parvula*, etc.	Western Australia
4	Vairappan (2006)	Epiphytic algae on *Kappaphycus alvarezii*	*Neosiphonia savatieri* followed by *Neosiphonia apiculata*, *Centroceros* sp., *Ceramium* sp., *Acanthophora* sp.	Malaysia
5	Rindi and Guiry (2004)	Spatiotemporal variability and composition of the epiphytic macroalgal assemblage of *Fucus vesiculosus*	*Polysiphonia lanosa*, *Elachista fucicola*, *Porphyra umbilicalis*, *Ulva compressa*, and *Spongonema tomentosum*	Western Ireland
6	Totti et al. (2009)	Function of the host thallus morphology in structuring the epiphytic diatom communities	*Epiphytic diatoms*	Iceland
7	Tujula et al. (2010)	Bacterial epiphytes on *Ulva*	Members of the *Alphaproteobacteria*, *Gammaproteobacteria*, and the *Bacteroidetes*	Australia
8	Ganesan et al. (2011)	Culture of *Gracilaria edulis* in open sea by rafting method	*Chaetomorpha linum*, *Enteromorpha compressa*, *Cladophora fascicularis*, *Ulva lactuca*, *Enteromorpha intestinalis*	Southeastern coast of India
9	Burke et al. (2011)	Epiphytes on *Ulva*	*Various epiphytic bacteria species*	Bare Islands, Australia

(continued)

Table 9.2 (continued)

Sl no.	Authors	Work done	Epiphytic composition	Area
10	Ganesan et al. (2014)	Epiphytism differences in *Gelidiella acerosa* in floating rafts and concrete blocks	*Caulerpa racemosa*, *C. linum*, *C. peltata*, *Acetabularia* sp., *L. Majuscula*, *P. tetrastromatica*, *Dictyota* sp., *Cladophora* sp., *Gracilaria cylindrica*, *H. pannosa*, *H. valentiae*, *J. adhaerens*	Thonithurai coast and Ervadi coast of Gulf of Mannar, India
11	Veeragurunathan et al. (2015)	Seasonality (epiphyte and epifaunal assemblages) on *Gracilaria dura*	*Chaetomorpha crassa*, *Enteromorpha intestinalis*, *Ulva reticulata*, *Hydroclathrus clathratus*, *Padina gymnospora*, *Sargassum palgiophyllum*, *Acanthophora spicifera*, *Hypnea pannosa*	Palk Bay, southeast coast of India
12	Lim et al. (2016)	Defense-related transcripts of an agarophyte, *Gracilaria chang*	*Epiphytic bacteria*	Malaysia
13	Werner et al. (2016)	Food web structure in climate change	*Interaction with grazing and epiphytes in changing seasons*	Baltic Sea
14	Anderson and Martone (2014)	Biomechanical consequences in epiphytism	*Soranthera ulvoidea*	Canada

majority of fungi are from *Ascomycota* (Loque et al. 2010; Zuccaro et al. 2008). But compared to these, the bacterial-seaweed interaction is well studied because it is one of the dominant groups, and seaweed can come under pressure due to a higher number of bacterial communities.

Many times this interaction is positive and beneficial for both. Seaweed provides favorable habitat to bacterial colonies to grow and reproduce on its surface (Englebert et al. 2008). With this, bacterial colonies get nutrients and food source from biochemical activities in the seaweed. For example, seaweed is marine photosynthetic organisms which produce oxygen is a good source of oxygen for bacteria associated to seaweed. But this interaction is not one way as for the growth and development of seaweeds, and few bacterial species are important. These symbiotic bacteria can enhance seaweed growth (Singh et al. 2011), protect seaweed from harmful bacterial and fungal species by producing certain chemicals (Lemos et al. 1985), and also help in reproduction (Joint et al. 2007). But with such positive interaction, there is negative interaction too, in which few bacterial species are responsible for many seaweed diseases (Goecke et al. 2010).

The physical association of bacteria with seaweed is generally in different ways such as tightly attached and not directly attached, and a few show syntrophic associations (Goecke et al. 2013). Bacteria can harm seaweeds by producing a chemical which is toxic (Berland et al. 1972), injuring them by degrading their cell walls

(Goecke et al. 2010). Few bacterial species can produce biofilm in the seaweed crop surrounding or on the water surface which is an intricate three-dimensional cluster in nature, responsible for both direct and indirect harms by reducing the essential light penetration (Wahl et al. 2010) and gaseous exchange. Biofilm can impact negatively on the reproduction of seaweed and also in the natural environment by enhancing the attachment of spores which later results in damage.

9.4 Epiphytic Algae

The epiphytic algae on seaweed crop can be microalgae or most specifically macroalgae or other seaweed species which are not part of cultivation. It can impacts on the host seaweed as a reduction of the growth rate of the crop, a decrease of reproduction output, or even whole or partial mortality of host seaweed (Davis et al. 1989) which can further results in quality and quantity of production or yield of the crop (Table 9.3). Generally, the ephemeral epiphytes can be seen at the host tips, while large-sized epiphytes can be found attached to the basal disk (Arrontes 1990). The overall coverage of epiphytes on these seaweed crops increases as per availability and nutrients and with the age of host seaweed. The structure of epiphytic communities depends on the position of the thallus of seaweed (Longtin et al. 2009).

9.5 Epifaunal Communities

The epifaunal species assemblage undergoes frequent temporal fluctuation because of several environmental (abiotic) factors like availability of light, temperature, abundance of epiphytes, and pressure of predation (Jones and Thornber 2010). Fluctuations in these features can influence the pattern of abundance at different spatial and temporal scales for the epifaunal community. Many of these epifaunal species such as amphipods, isopods, and even smaller gastropods live in the epiphytic algae (Orav-kotta and Kotta 2004) and can use that as a food source (Leonardi et al. 2006). In this way more dense epiphytic algae host more epifaunal communities by creating a suitable environment.

In the seaweed assemblages, amphipod crustaceans are very much common which are particularly the mesograzers and impact adversely on the seaweed (Poore et al. 2012). In all ecosystems, herbivory is a key process which transfers the primary production to further consumers in ecosystem level with impact on structure and productivity of vegetated habitat (Poore et al. 2012). Similarly as herbivores control the growth of producers in the ecosystem, they are controlled by the predators, but in this natural phenomenon, the seaweed can get harm indirectly (Ingle et al. 2018). The amphipod crustaceans are important for predatory fishes and other invertebrates as a food source (Table 9.3).

Table 9.3 Key research works on the epifaunal composition in different geographical regions

SL	Authors	Work done	Epifaunal composition	Area
1	Norton and Benson (1983)	Faunal association of the brown seaweed *Sargassum muticum* (Yendo)	Ampithoe mea, Aoroides columbiae, *Caprella laeviuscula*, *Ischyoceras anguipes*, and *Lacuna variegata*	Washington, USA
2	Sarma and Ganapati (1972)	Association of faunal species with algae at the intertidal region of Visakhapatnam	A diverse group of Mollusca, Foraminifera, Polychaeta, Nematoda, Amphipoda, and Isopoda are associated with seaweeds	Visakhapatnam, India
3	Joseph (1978)	Ecological perspective on the faunal species associated with economically important seaweeds of South India	Porifera, Bryozoa, Polychaeta, Amphipods, Isopods, Ostracoda, Harpacticoida, Tanaidacea, Gastropoda, Bivalvia, Echinodermata, and the algivorous gastropods are *Turbo intercostalis* Menker, *Pyrene versicolor* Sowerby, *Aplysia lineolata* Adams and Reeve, *Pyrene zebra* Gray, *Trochus radiatus* Gmelin	Gulf of Mannar and Palk Bay and the adjacent groups of island
4	James et al. (1986)	Fauna associated with the cultured seaweed *Gracilaria edulis*	Fish and crab fauna	Coastal waters of Gulf of Mannar and the Palk Bay
5	Taylor and Cole (1994)	Mobile epifauna on subtidal brown seaweeds *Carpophyllum plumosum* var. *Capillifolium* and *Cystophora retroflexa*	Isopods and amphipods were the most dominant animals (2000 individuals per algal wet weight)	Northeastern New Zealand
6	Viejo (1999)	Mobile epifauna inhabiting the invasive *Sargassum muticum* and two local seaweeds *Fucus vesiculosus* L. and *Cystoseira nodicaulis*	Gastropods, gammarid amphipods, and isopods accounted for 90–95% of the total number of invertebrates. *Fucus* had the lowest number of taxa in comparison with *Sargassum* “tidepool”	Northern Spain
7	Norderhaug et al. (2002)	Mobility patterns of holdfast fauna in kelp	A total of 59,664 individuals from 116 species/taxa of kelp-associated fauna were recorded	Norway

(continued)

Table 9.3 (continued)

SL	Authors	Work done	Epifaunal composition	Area
8	Anandavelu et al. (2013)	Epifaunal assemblage on morphologically distinct intertidal seaweeds of Kodiyaghat, India	The epifaunal communities mainly include *Amphipoda*, *Polychaeta*, *Mysida* *Mollusca*, *Brachyura*, *Isopoda*, *Pycnogonida* followed by other fauna *Echinodermata*, *Nemertea*, and *Sipuncula*	South Andaman, India
9	Veeragurunathan et al. (2015)	Epifaunal pattern study	15 epifauna species were observed including maxillopod, decapods, gastropod, polychaetes, anthozoa, ophiuroidea, isopods, ascidiacea, ectoprocta, and several fish species	Thonithurai Southeast coast of India

9.6 Problems/Diseases Caused by Epiphytes and Their Potential Control Strategies

Due to the rapid developments in the seaweed-based farming activities, there is also an increase in the epiphytic diseases/menace worldwide. The epiphytic invasion causes significant damages for the local farmers as it drastically affects the growth of field-grown algal species and ultimately hampers the farming activity in several cases. As with any agronomical practice, several approaches are being utilized and developed to control the epiphytes growth on seaweed, although several strategies have been suggested to control the unsolicited growth of epiphytes and have been used in controlling them in *Gracilaria* farming (Fletcher 1995). However, some of these strategies can be used only in the cultivation tanks, and its application in an open ocean farming is highly challenging. Here we discuss about some major control strategies against seaweed epiphytes.

9.6.1 Chemical Method

The epiphytes can be removed by employing chemical procedures such as by chlorine or copper rinsing or by altering the pH. Some other preventive chemicals like sodium hypochlorite have been largely used to pre-treat the seawater, tanks, and equipment (Ugarte and Santelices 1992). However, if the contamination already starts spreading, the host material is often immersed in an appropriate toxicant and has been proven to be highly useful. Ugarte and Santelices (1992) have successfully demonstrated that immersing *Ectocarpus* and *Enteromorpha* species in 4–6% commercial hypochlorite solution for 6–10 h killed 80% of epiphytes. However, in the case of *Gracilaria*, it caused minor injuries until the thiosulfate was used, and the repetitive treatment led to enhanced yield of *Gracilaria*. Similarly, the usage of 100 g/l of copper solution significantly reduces the growth of *Enteromorpha* within a week without affecting the growth of *Gracilaria* (Haglund and Pedersén 1992). Several researchers have reported that by controlling the pH level, the epiphytes can be repressed (Friedlander 1991), particularly at the high pH level (Haglund and Pedersén 1992).

Considerable interest has been shown by the researchers to optimize the nutrient regimes in order to control the growth of epiphytes. It has been proven that incessant or higher supply of nutrients is not only extravagant but could also favor the unsolicited growth of epiphytic species (Pickering et al. 1993). By following a vigilant supervision of the nitrogen inputs, mainly by decreasing the nitrogen supply, the uncontrolled loads of epiphyte can be prohibited (Pickering et al. 1993). Contrarily, high levels of ammonia (>0.5 mmol/l) have been also proven to be lethal for several epiphytes (Friedlander et al. 1991).

9.6.2 Physical Method

Epiphytes can be physically removed by using the manual methods like mechanical brushing and rapid water movement. In certain cases, sand shifting has been implemented as an effective approach to maintain epiphyte-free *Gracilaria* culture (Doty 1980). Moreover, the strategy to control epiphytic growth in seaweed cultivation system includes the direct physical elimination of the host epiphytes. For the removal of diatoms, water jets are very useful and are usually used against the host material post-harvest. However, for the majority of the macroalgal species especially those affected by a special type of filament known as rhizoidal filaments can deeply penetrate and thus requires manual hand removal, which is a labor-intensive process and is unfeasible for huge culture units and may also cause damage to the host (Ugarte and Santelices 1992). Due to this problem, many farmers favor to employ some other precautionary procedures and recommend good husbandry to tackle the occurrence of epiphytism and fouling.

In tank cultivation systems, it must be confirmed that the source of seawater is devoid of impurities (Ugarte and Santelices 1992) or the seawater is routinely exchanged. For instance, filtration of seawater using diatomaceous earth or filter cartridges and sand is often utilized for blocking the entry of epiphytic organisms. Additionally, some other precautionary procedures have been also implemented to reduce the contamination, for instance, by adjusting the abiotic factors in favor of the host species. The usage of UV light has also been endorsed for tank culture system. The reduction in irradiance levels has also been successfully demonstrated to reduce the level of epiphytism in seaweed cultivation (Friedlander 1992).

9.6.3 Biological Method

The rapid prevalence of epiphytism in seaweed mariculture has enticed special attention to develop resistant strains and to utilize existing knowledge to control epiphytism in seaweed farming (e.g., Santelices and Ugarte 1990; Fletcher 1995). Acadian marine plant extract powder (AMPEP) is a commercial extract obtained from the brown alga, *Ascophyllum nodosum*. It harbors some major macronutrients such as total nitrogen N (0.8–1.5%), phosphoric acid P_2O_5 (1–2%), and soluble potash K_2O (17–22%), which has been proven to augment the overall growth and development of eucheumatoids (Hurtado et al. 2013). Furthermore, promising results have been obtained in in vitro and field trials using AMPEP extract against epiphytes and pathogen. In addition, it has been linked to increase the rate of growth and carrageenan production (Loureiro et al. 2012). Interestingly, studies have also shown that soaking the algal seedlings in AMPEP, before planting, could efficiently improve the daily growth rate and productivity of both varieties of *Kappaphycus*. It has been also utilized to check or diminish the influence of *Neosiphonia* infection on commercial farming regions (Borlongan et al. 2011). However, more field trials with extracts from other algal species might lead to discovery of some new and potential anti-epiphytic compounds.

Maintaining an optimal density of host plants has been suggested by the phycologist to prevent epiphytes from colonizing. Grazers have been effectively utilized to control epiphyte growth. *Gammarus lawrencianus* and *Idotea baltica* are the two crustacean species which have been successfully demonstrated to selectively graze on *Ectocarpus* spp. and *Enteromorpha* spp. which epiphytically grow on the surface of *Chondrus crispus* (Shacklock and Doyle 1983). Similarly, the epiphyte growth on *Fucus* is controlled by *Idotea* which is often seen during the high nutrient load conditions (Worm et al. 2000; Orav-Kotta and Kotta 2004). Sporadic feeding by herbivores could also be beneficial for seaweeds and communities sometimes (Hay et al. 2004). The mesograzers which are the filamentous epiphytes are usually removed manually from a host. This manual removal of epiphytes allows the absorption of higher amount of light and enhances nutrient absorption by the host plant (Duffy and Hay 1990). The epiphytes associated with pond-grown seaweed species have been effectively controlled by fish such as milkfish (*Chanos chanos*) and *Tilapia mossambica* (Shang 1976).

9.7 Conclusion and Perspectives

Seaweed farming, or seagriculture, is anticipated to offer sustainable seaweed biomass, thereby enabling the rapid expansion of marine bioeconomy. But, with the increase in activities related to seaweed farming, there has been reportedly higher occurrence of epiphytic filamentous algae (EFA) disease in several parts of the world. Similar to land-based crop, the cultivation of macroalgae is also prone to diseases and infestations. This epiphytic infiltration significantly affects the algal growth and thus the local farmers and has even totally collapsed the farming activity in several parts of the globe. Moreover, because of the fragility of the marine environment, it is impractical to utilize chemical methods to control the epiphytes. In this regard, marine integrated pest management (MIPM) approach appears to be the best available option for the sustainable seagriculture. On the other hand, AMPEP (Acadian marine plant extract powder) has also been proven to be highly potential in minimizing or controlling the growth of epiphytes and the respective diseases caused by them.

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