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*Chapter 3*

# IMPACT OF SEAWEEDS IN AGRICULTURE

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## ABSTRACT

Seaweeds contain a considerable amount of micronutrients and plant growth hormones like auxins, gibberellins, cytokinins, and betaines etc. which are supposed to help plant growth and also in seed germination. The extracts of seaweeds have proved itself as a highly effective and eco-friendly pesticide against various crop pests. This chapter provides an overview of the varieties of seaweeds, their ecology and their utilization worldwide. The main concept of this chapter delves into the possible utilization of selected seaweeds in agriculture. The various forms of seaweeds such as seaweed extract (SWE), compost, mulch etc. and their applications as bio-stimulators, growth promoters, crop protection, soil conditioner, and stabilizer are discussed.

**Keywords:** micronutrients, growth hormones, SWE, mulch, biopesticides

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## Introduction

Seaweeds are a fascinating and diverse group of organisms living in the earth's oceans. They are found attached to rocks in the intertidal zone, washed up on the beach, as giant underwater forests and floating on the ocean's surface.

The seaweeds are either very tiny or quite large, growing up to 30 meters long. Although they have many plant-like features, the seaweeds are not true vascular plants; they are algae. They lack a specialized vascular system (an internal conducting system for fluids and nutrients), roots, stems, leaves, and enclosed reproductive structures like flowers and cones. Algae are a part of the Kingdom Protista, which means that they are neither plants nor animals.

All the parts of a seaweed are in contact with the water by which they are able to take up fluids, nutrients, and gases directly from the water, and do not need an internal conducting system. Like true plants, seaweeds are photosynthetic; they convert energy from sunlight into the materials needed for growth. Within their cells, seaweeds have the green pigment chlorophyll, which absorbs the sunlight they need for photosynthesis. Chlorophyll is also responsible for the green coloration of many types of seaweed. In addition to the chlorophyll, some seaweeds contain other light absorbing pigments. These pigments can be red, blue, brown or golden and are responsible for the beautiful coloration of red and brown algae. In addition, the pigments protect the seaweeds from UV radiation (Saranya 2013).

The Southern Coast of India bears luxuriant growth of seaweeds and more than 200 species of seaweeds have been found in this area. In the coastal waters, they grow almost like grass in large areas, extending over hundreds of kilometers. Indian seaweed industries depend on this coastline for the production of the phycocolloids agar, carrageenan, furcellaran, algin and many other commercially important products (Chapman 1980). The traditional uses of seaweed - as food, animal feed, and fertilizer supplements - remain important, but in most parts of the world, it is used as a raw material for certain chemical products that marine algae are now chiefly valued. The present chapter, whilst also considering the use of seaweeds in animal feedstuffs and fertilizers, deals principally with their positive impacts on agriculture.

Perhaps the longest established, most widespread and most proven use of seaweed is as a fertilizer. Wherever proximity to the coast has made access to the resource possible, seaweeds have been applied for many centuries to the land as direct and simple manure. Since 1950, the liquid seaweed products have enabled this practice to be extended, both geographically and in terms of specific uses (Blunden 1986).

Seaweeds contain reasonable quantities of nitrogen, phosphorous and potassium and they were extensively used, either directly or in the form of compost with cow dung as manure for vegetables in India. In seaweeds, the minerals and trace elements occur in water-soluble form and hence these could be easily taken up by plants (Booth 1966). The carbohydrates and other organic constituents of seaweeds are reported to increase the moisture holding capacity of soils. Seaweeds are a good source of potash and soda (Myklestad 1964).

The large brown algae, for example, *Macrocystis* and *Ascophyllum,* are the principal species used for manure. Their value as a fertilizer derives not so much from their nitrogen, phosphorus and potassium contents but rather from their unusual properties as a soil conditioner and growth promoter. The seaweed fertilizer has been demonstrated to produce positive effects additional to those to be expected from their content of N, K and P. For example, seaweeds and liquid seaweed manures appear to promote resistance to plant diseases and plant pests, induce the fruit setting and increase the germination rates (Crouch 1993).

## SEAWEED ECOLOGY

Seaweeds are subjected to harsh environmental conditions as they occupy very dynamic strata of the oceanic ecosystem. Because seaweeds absorb gases and nutrients from the surrounding water, they rely on the continual movement of water past them to avoid nutrient depletion. The constant motion of ocean water also subjects seaweeds to mechanical stress. Seaweeds cope with mechanical stress by having a strong holdfast, a flexible stripe, and blades, and bending towards the substrate as waves move over them (Kaliaperumal 1987). Intertidal seaweeds are subjected to the stresses associated with exposure to air and weather conditions. To survive in the intertidal zone, seaweeds must be able to tolerate or minimize the effects of evaporative water loss and temperature and salinity changes. When exposed to air, the seaweeds lose water through evaporation. Some seaweed can dry out almost completely when the tide is out, then take up water and fully recover when the tide brings water back to them. Seaweeds living in tide pools are exposed to changes in water temperature and salinity caused by the weather conditions (Costa Pierce 2002).

When the tide is out mobile intertidal animals must also try to minimize water loss. One way they do this is by seeking out a moist hiding place under some seaweed. The intertidal seaweeds provide shelter for the invertebrates and also act as a food source for grazing animals (Dhargalkar 2005).

## SEAWEED CLASSIFICATION

Seaweeds are classified into three major groups; the green algae (Chlorophyta), the brown algae (Phaeophyta), and the red algae (Rhodophyta) (Figure 1). The seaweeds are placed into one of these groups based on their pigments and coloration. The other features used to classify algae are; cell wall composition, reproductive characteristics, and the chemical nature of their photosynthetic products (oil and starch). Within each of the three major groups of algae, further classification is based on the characteristics such as plant structure, form, and shape (Dhargalkar 2004).

- Brown Algae (Phaeophyta)
- Green Algae (Chlorophyta)
- Red Algae (Rhodophyta)

Traditionally, the coastal communities worldwide have been using drift seaweed as soil amendment and fertilizer. This practice is, however, very limited among the farmers worldwide. Around 1.5 million metric tons of seaweeds are used as a nutritional supplement, fertilizer, and bio-stimulant (FAO 2006). Among the seaweeds classes listed above, brown seaweeds like *Fucus*, *Laminaria*, and *Sargassum* are mostly utilized in agriculture at coastline areas. Some of the commercial products available on the market are listed in Table 1.

**Table 1. Commercial seaweed products**

| **Type of seaweed** | **Product** | **Manufacturer** |
|---|---|---|
| *Ascophyllum nodosum* | Maxicorp | Brandon products |
| *Ecklonia maxima* | Kelpak | Kelp Products International |
| *Ascophyllum nodosum* | Algea | Seagro |
| *Durvillaea sp.* | Seasol | Seasol International |
| *Ascophyllum nodosum* | Stimplex | Acadian SeaPlant |
| *Ascophyllum nodosum* | Seacrop | Atlantic laboratories |
| *Ascophyllum nodosum* | Biovita | PI Industries Ltd. |

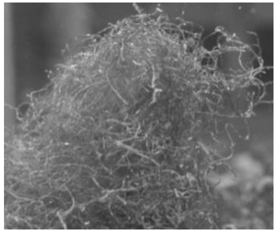
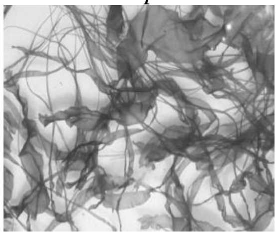
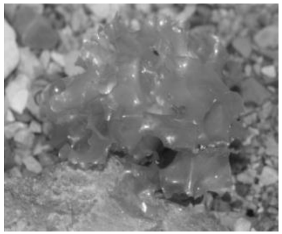
| **Brown Algae (Phaeophyta)** | **Green Algae (Chlorophyta)** | **Red Algae (Rhodophyta)** |
|---|---|---|
| <br>*Fucus vesiculosus* | <br>*Chaetomorpha linum* | <br>*Gracilaria edulis* |
| <br>*Laminaria digitata* | <br>*Ulva intestinalis* | <br>*Gelidiella acerosa* |
| <br>*Sargassum wightii* | <br>*Ulva lactuca* | <br>*Porphyra sp.* |

Figure 1. Varieties of seaweeds.

## UTILIZATION IN AGRICULTURE

Seaweeds have been used in agriculture in various forms owing to the advantages it holds in nature. Some of them are listed below:

**1. Enhance soil fertility**

Seaweeds are rich in beneficial trace minerals and essential nutrients required for the plant growth. In addition to these, the seaweeds have hormones that stimulate plant growth. When mixed with the soil, the nutrients enrich the fertility of the soil and improve the nature of the soil (Stephenson 1968).

**2. Improves root and shoot growth and development**

Seaweed fertilizer contains lots of ready to use micro-nutrients which can be readily absorbed by the plants without any further chemical decomposition. This enhances the root and shoots development in plants at a faster pace (Gayathri et al. 2013).

**3. Promotes the growth of symbiotic soil microbes**

The seaweeds serve as a suitable growth medium for beneficial microbes that in turn play an important role in nutrient recycle (Verkleij 1992).

**4. Increases nutrient uptake**

Seaweeds have the necessary micro-elements and nutrients which on absorption increases the nourishment of the plants (Pramanick 2013).

**5. Defensive against pests and diseases by crystal formation**

The pests are immediately repelled by two things – salt and sharp-edged materials. Seaweed has a natural salt content, which repels unwanted organisms, and within a few days of application, it dries and becomes quite crispy. Pests do not like “crispy” surfaces, as the sharp salty edges cut into the soft body tissue (Jayaraj2015).

**6. Triggers flowering and fruit yield**

Seaweeds are reported to contain the growth-promoting hormones like auxins and gibberellins, which triggers root and shoot formation.

*Better moisture retention

*Induces seedling germination

Seaweeds act as a source of bio-stimulants and organic matter, which led to their extensive use in agriculture (Sridhar 2011).

## BIOFERTILIZER

Seaweeds have been utilized as a bio-fertilizer over many years to enhance the fertility of the soil and improve the productivity of seasonal crops. Several approaches were followed to use the seaweeds as bio-fertilizers.

## SEAWEED EXTRACTS (SWE)

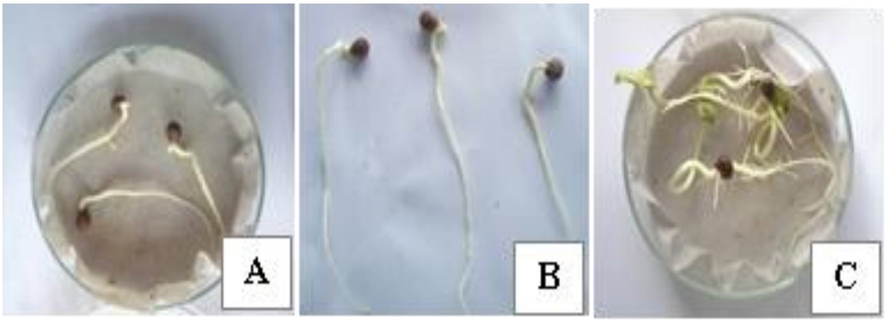



Figure 2. Germination of Okra seeds by three SWE.

(A) *Chaetomorpha linum.* (B)*Enteromorpha intestinalis.* (C) *Gracilaria edulis.*

The liquid extracts were widely used since 1950 and many commercial products are used worldwide currently. These liquid extracts were reported to improve the soil aeration and structure thereby makes the mineral nutrients available for the plants to a large extent (Zodape 2008). This may act as a stimulant, which increases the seed germination rate (Fig 2) and thereby supports shoot and root development. Seaweeds may improve the yield of flowers and fruits production by behaving like a chelator. Seaweed extracts were observed to be composed of many micro and macronutrients, which are essential for the growth of plants (Anantharaj 2001). Commonly used seaweed extracts were made from *Fucus sp., Ascophyllum nodosum, Laminaria, Turbinaria, and Sargassum spp* (Zodape 2001).

Various methods are available to prepare the seaweed extracts and widely categorized as physical and chemical methods. Physical methods include disruption using high pressure or milling whereas the chemical methods include heating seaweeds with various solvents to produce a 100% extract (Anantharaj and Venkatesalu 2001). The nutritive value of extracts may be enhanced by micronutrients addition, because the quality of extract may vary according to the place/season of collection and the process of extraction used.

Treatment with the SWE was observed to increase the photosynthetic pigments, protein, soluble sugars, starch, phenols, vitamin C, free amino acids, and the lipid content in crop plants like tomato, lady finger, fenugreek, mustard, maize, green gram and cluster bean (Mohanty et al. 2016). The presence of minerals, hydrophilic potash and other trace elements in SWE are readily absorbed by plants and regulate the deficiency of nutrients in plants. The non-toxic, non-polluting and biodegradable nature of the SWE makes it a desirable candidate for the agricultural application.

## Seaweed Mulch/Compost

There are certain drawbacks in the application of foliar spray viz. rain wash out, recurrent applications, low absorption rates by leaves etc. In this case, seaweeds are used in the form of compost in combination with cow dung or any organic matter in India (Kalimuthu et al. 1987). On applying to the soil as compost, the carbohydrates (e.g., laminarin, fucoidan, alginate etc.) and the other organic constituents of the seaweeds tend to increase the moisture-holding capacity of the soil. It was reported that 0.1 g of sodium alginate, when added to 100 g of soil, increased the water holding capacity by 11% (Stephenson 1968). Similarly, the decomposed brown seaweeds provide polyuronides such as alginates and fucoidans to the soil bacteria that dwell in the rhizosphere. These are hydrophilic polysaccharides, which absorb soil moisture, swell into a gel and provide better aeration to the soil (Myklestad 1964). The aeration improves the growth and activity of symbiotic soil bacteria, which can fix atmospheric nitrogen to the plants. The compost may serve as a soil conditioner by enhancing the capillary activity of the soil pores and sustained release fertilizer improving aggregation of the soil. The properties of the compost, which are responsible for improving the soil fertility, are biochemical composition, the pattern of mineralization and synchronization of minerals and nutrients with the demand for the crops.

## GROWTH STIMULATOR

Bio-stimulant (metabolic enhancer) is defined as a constituent other than the fertilizer that shall promote plant growth when applied in diluted proportion. The fertilizers supply the nutrients whereas the bio-stimulants induces root and shoot elongation, initiation of metabolic functions and alter cell division. The seaweed extract has to be diluted in the ratio of at least 1:1000 before applying as a foliar spray since the extract shall act as a bio-stimulant only at low concentration (Hattori 1999). A high concentration of the metabolic enhancers may be phytotoxic and may cause severe damage to plants.

Several researchers reported that the seaweeds contain plant hormones like auxin, cytokinin, gibberellic acid, betaines and sterols among which cytokinins are present in larger proportion when compared to other phytohormones. Cytokinins help in drawing the mineral and nutrients from the surrounding environment into the plant tissues and stimulate the plant growth (Mooney and Staden 1986). The cytokinins improve cell division and cell wall formation which are the prime factors to initiate growth in a plant. Cytokinins are important in seed germination by stimulating cell enlargement in cotyledons and initiate radical growth (Letham 1994). It influences the unloading of phloem into the cytoplasm, reduces leaf senescence and accelerates differentiation of the chloroplasts (Aldworth 1987). In plants, cytokinins are naturally secreted in the root and signal the plant to produce larger foliage. When given as a growth stimulant, the ratio of cytokinin to auxin should be balanced well. An increased level of cytokinins promotes the growth above the ground level only leaving the roots in an underdeveloped state.

Auxins are the second highest growth hormones present in the seaweed and are believed to kindle the root growth in various plants. Based on the quality and mass of the root, the nutrient uptake by the plant shall be determined. A denser root is articulated towards better absorption of nutrients as well as better support for the plant (Zhao 2010).

Sodium salts were believed to enhance the metabolism and synthesis of chlorophylls in plants (Khan 2009). The plants treated with seaweeds were observed to retain the chlorophyll content for a longer period of time when compared with the control crops. Certain seaweed extracts have betaines which greatly decreases the chlorophyll degradation and show longer photosynthetic retention. In few studies, the dry weight of root and shoot developed in seaweed treated plant measured greater than the untreated plants.

**Table 2. List of various types of pest attacking important agricultural crops**

| Agricultural crops | Crop plant | Pests |
|---|---|---|
| Cereals and millets | Paddy | *Scirpophaga incertulas, Orseolia oryzae, Spodoptera mauritia, Pelopidas mathias, Cnaphalocrocis mainsails, Melanitis ismene, Psalis pennatula, Hieroglyphus banian, Dicladispa armigera, Hydrellias asakii* |
| | *Sorghum* | *Atherigona varia soccata, Chilo partellus, Sesamia inferens, Helicoverpa armigera, Peregrinus maidis, Contarinia sorghicola,* |
| | **Maize** | *Atherigona orientalis, Cryptoblabes gnidiella, Myllocerus sp., Chilo partellus, Sesamia inferens, Pyrilla perpusilla, Helicoverpa armigera, Rhopalosiphum maidis, Calocoris angustatus, Peregrinus maidis* |
| | ***Pennisetum glaucum*** | *Atherigona approximate, Geromyia penniseti, Chilo partellus, Sesamia inferens, Nezara viridula* |
| | **Finger millet** | *Sesamia inferens, Calocoris angustatus, Rhopalosiphum maidis, Tetraneuranigri abdominalis,* ***Spodoptera exigua,****Chrotogonus trachypterus, Nephrosclerosis medinalis* |
| Pulses | *Cajanus cajan* | *Helicoverpa armigera,Lampides boeticus, Euchrysops cnejus, Exelastis atomosa, Maruca testulalis, Etiella zinckenella, Adisura atkinsoni, Melanagromyza obtuse, Aceria cajani* |
| | *Vigna mungo*, *Vigna radiate* | *Helicoverpa armigera, Empoasca kerri, Marucat estulalis, Riptortus pedestris, Etiellazincke nella, Coptosoma cribraria, Lampides boeticus, Bemisia tabaci, Euchrysops cnejus, Mylabris phalerata, Aphis craccivora* |
| | ***Vigna unguiculata*** | *Helicoverpa armigera, Empoasca kerri, Maruca vitrata, Riptortus pedestris, Etiella zinckenella, Lampides boeticus, Euchrysops cnejus, Aphis craccivora, Mylabris phalerata, Bemisia tabaci, Coptosoma cribraria* |
| | Soybean | *Spilosoma oblique, Aphis spp., Helicoverpa armigera, Apheliona maculosa, Spodoptera litura, Oberea (Obereopsis) brevis, Thrips tabaci, Melanagromyza sojae, Bemisia tabaci* |
| Oil seeds and cash crops | **Sun flower** | *Helicoverpa armigera, Spilosoma obliqua*, *Amrasca biguttula, Psittacula krameri, Spodoptera litura* |
| | Groundnut/Peanut | *Amsacta albistriga, Empoasca kerri, Aproaerema modicella, Scirtothrips dorsalis, Spilosoma (Diacrisia) oblique, Sphenoptera indica*, *Spodopteralitura, Helicoverpa armigera,Aphis craccivora* |
| | Cotton | *Helicoverpa armigera, Pectinophora gossypiella, Earias vittella, Pempherulus affinis, Sphennoptera gossypii, Spodoptera litura, Mylloecerus undecimpustulatus, Amrasca biguttula, Aphis gossypii* |
| | Sugar cane | *Chilo infuscatellus snellen, Chilo sacchariphagu sindicus, Scirpophaga excerptalis, Aleurolobus barodensis, Ceratovacuna lanigera, Saccharicoccus sacchari* |

Courtesy: http://agritech.tnau.ac.in/

## PEST MANAGEMENT

Almost 40% of crop production is destroyed by insects and pests throughout the world. More than 70,000 varieties of pests are available throughout the world and some of the pests which make damages to the prime crop plant around the globe are listed in Table 2. These pests are controlled by use of chemical pesticides (nearly 3 million tons/year) along with crop rotation and other biological methods (Pemsl 2006). The pest outbreaks may be due to change in the environmental condition which includes weak soil bases, change in the ecosystem and also due to native pests and pathogens. The use of chemical pesticides may destroy the beneficial organisms present in the agricultural land and on continual usage may develop resistant to the native pest. The pesticides or insecticides may also alter the physiology of the crop plants which in turn make the crop more susceptible to new pest varieties. When we observe the crop production, approx. 90% crops are newly introduced as hybrid variety in the agricultural land and these varieties do not have the natural resistance to the native pests which makes them a potent parasite (Patricia 1998).

Pests dwell in the soil where there is a high concentration of organic compounds. They tend to feed on the shoots and roots from the fresh seedling thereby disturbing the normal growth and development of a plant. Seedlings are least resistant towards pest attack and can cause enormous economic damage. The soil-borne pests can be controlled by prior treatment of seeds with pesticides and then planted. While using seaweed extracts, the seeds are soaked in the extract for a stipulated period of time and shade-dried before plantation. Seaweeds contain natural salt like sodium, chloride, and potassium which when applied on the seed get dried by the atmosphere. The dried salt gets converted into sharp crystals and prevents the slugs/pests from holding onto the plants. The reason is that the crystals tear away the soft tissues of the pests and makes significant damage. The extracts do not allow the pests to lay their eggs and hence reduces the chance of pest population explosion. It also restricts the movement of the pest in and around the area of application.

## STRESS MANAGEMENT

Drought, salinity, and temperature are some of the abiotic stresses, which tend to decrease the crop yield. The rhizosphere is an area around the root mass of plants which holds symbiotic bacteria and provides nutrient to the plant in drought condition. As discussed earlier, the plant growth hormones present in the seaweed compost develops a better environment for the soil microbes and increases the drought tolerance in many plants. The stronger root structure also supports the plant to resist against a certain type of epidemic diseases which outburst in stress conditions. The stress due to drought declines the chlorophyll content and nitrate reductase activity. The photosynthetic pigments are enhanced and few reports suggested about the faster recovery of crop plants like maize, ragi etc. by the application of SWE. SWE were found to induce the defensive enzymes (e.g., chitinase, flucanase, lipoxynase, peroxidase etc.) of plants, which reduces disease during stress conditions.

The SWE showed the presence of many bioactive substances which pertain to the antioxidant activity imparted by them. Under environmental stress condition, reactive oxygen species (ROS) are produced in the plants which should be neutralized by the antioxidants secreted within the plants. But this balance between ROS production and the quenching mechanism will be disturbed if the plant is under stress for a very long period of time. The plant hormones are also secreted in various environmental conditions and are seasonal dependent. The phytohormones mobilize from production site to action site and act as messengers that control various metabolic functions. The bioactive compounds and the phytohormones, which are available in the seaweeds, shall help the plant to recover from the environmental stress condition and enhance the stress tolerance capability (Gayathri et al. 2016).

## DISEASE MANAGEMENT

Many bacterial species, fungi, mycoplasma, and virus are known to produce severe diseases in the plants. Some of the major diseases caused by these microorganisms to crop plants are shown in Table 3. Reports say that SWE can increase the resistant towards diseases in plants (Pardee et al. 2004). Continuous applications of SWE to the plants may decrease the level of nematode attack. The secondary metabolites present in seaweeds shall be responsible for enhancing the defense mechanism of the host plants, controls the population of the parasites, and thus improves disease resistance. Certain seaweeds have also been reported to have antimicrobial activity against Gram positive and Gram negative organisms which may be attributed to the presence of acrylic acid like 1-aminocyclopropane-1-carboxylic acid.

**Table 3. Pictorial representation of various plant diseases and the responsible pathogens**

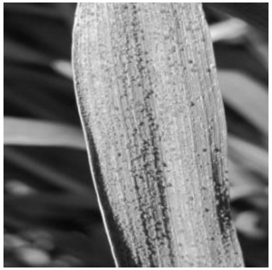
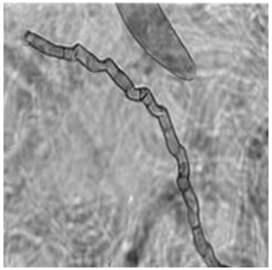
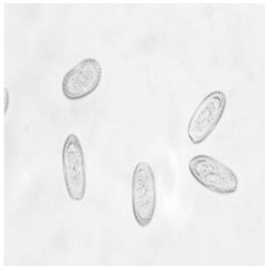
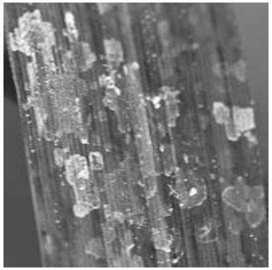
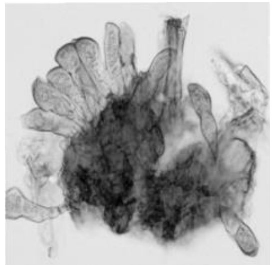
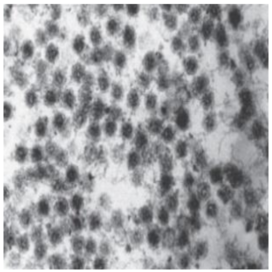
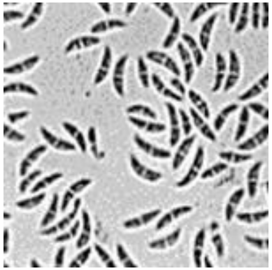
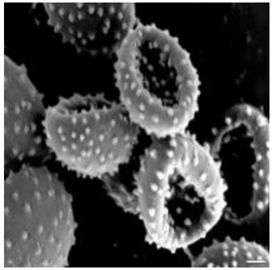
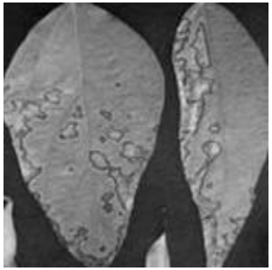
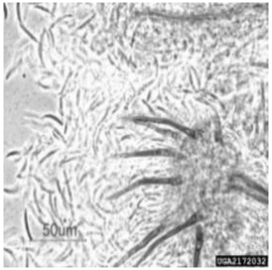
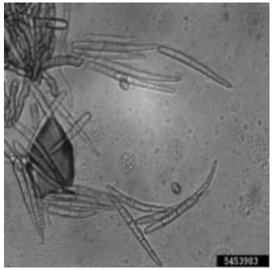
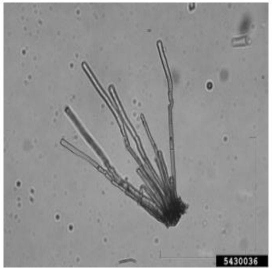
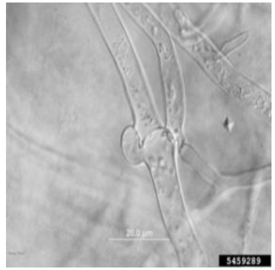
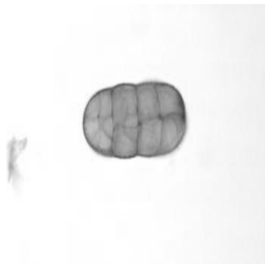
| **Disease** | **Organism** | **Disease** | **Organism** |
|---|---|---|---|
| Blast  | *Pyricularia oryzae*  | *Leaf rust*  | *Puccinia recondita*  |
| Brown spot  | *H. oryzae*  | *Stem Rust*  | *Puccinia graminis*  |

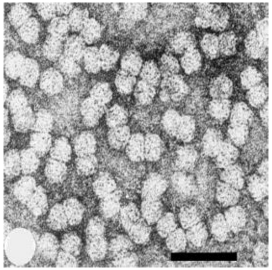
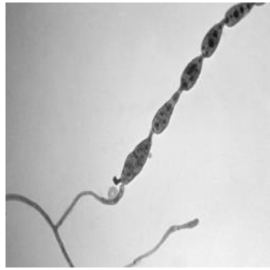
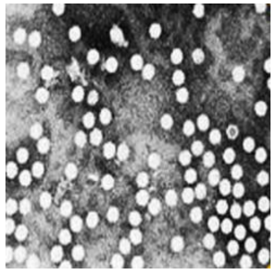
**Table 3. (Continued)**

| Disease | Organism | Disease | Organism |
|---|---|---|---|
| Leaf blight  | *Xanthomonas oryzae*  | *Yellow rust*  | *Puccinia striiformis*  |
| Ragged stunt virus  | *Rice ragged stunt virus*  | *Mildew*  | *Erysiphe graminis*  |

| **Disease** | **Organism** | **Disease** | **Organism** |
|---|---|---|---|
| Leaf scald  | *Microdochium oryzae*  | **Loose Smut**  | *Ustilago tritici*  |
| **Anthracnose/pod blight**  | *Colletotrichum truncatum*  | **Early leaf spot**  | *Cercospora arachidicola*  |

## Table 3. (Continued)

| Disease | Organism | Disease | Organism |
|---|---|---|---|
| **Purple seed stain**<br> | *Cercosporaki kuchii*<br> | *Stem rot*<br> | *Sclerotium rolfsii*<br> |
| **Charcoal rot**<br> | *Macrophomin aphaseolina*<br> | *Late leaf rot*<br> | *Phaeoisariopsispersonatum*<br> |

| **Disease** | **Organism** | **Disease** | **Organism** |
| --- | --- | --- | --- |
| Yellow mosaic<br> | MBYMV<br> | **Alternaria leaf disease**<br> | *Alternaria arachidis*<br> |
| **Banana Bract**<br> | Potyvirus<br> | **Bunchy Top**<br> | *Bunchy top virus*<br> |

Courtesy: http://agritech.tnau.ac.in/

The *A. nodosum* extract was reported to improve the disease resistant in capsicum plant due to the increased peroxidase activity and phytoalexin level. Cabbage seedlings treated with 1% SWE before inoculation decreased the incidence of a disease caused by *Phythium ultimum* (Walsh 2006). The extract of *Ascophyllum* species reduced the dollar spot disease caused by *Sclerotinia*, bacterial leaf spot caused by *Xanthomonas* and infection of *M. phaseolina* in the creeping bent grass, tomato and okra respectively (Jayaraj 2015).

The general mechanisms with which seaweeds impart disease resistance in plants are listed below:

- Improved vigor of the plant contributed by the robustness, increased photosynthesis, enhanced mobilization of the nutrients, improved regeneration and augmentation.
- Increased the presence of secondary metabolites like flavonoids, terpenoids, tannins, phenols, antioxidants and pigments.
- The signaling molecules may induce the systemic resistance in plants.
- Inhibition of microbial growth or killing of pathogen due to the antimicrobial agents present in the extract.
- Enhanced production of disease resistant enzymes and inducing the transcription of defense genes by the sugars and betaines in SWE.

## CONCLUSION

Seaweeds, unlike plants growing in soil, take up the majority of their nutrients from the medium they live in: the seawater. They absorb nutrients directly into their tissues. The ‘roots’ on seaweeds have the main function of anchoring the plant. There are over 79 minerals and trace elements in seaweed, and using seaweed is a superior way of bringing in copper, manganese, potassium, phosphorus, iron and zinc to the soil, plants, and animals in a plant-available form.

Liquid seaweed concentrate is used either as a soil conditioner or as a foliar fertilizer. It could be applied in a concentrated form or much diluted and can be easily mixed with other sprays. The use of liquid concentrate for soil conditioning gives quick results, but not necessarily long lasting. For barren soils, a seaweed meal might be more beneficial in the longer term. The cost of seaweed meal applications is considerably higher than for concentrate applications, and this is a point that must be considered for larger acreages.

This chapter dealt with all the beneficial applications of seaweeds for various agricultural practices.

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