



# Effect of Seaweed Extracts on Crop Growth and Soil: A Review

**Prasad B. Margal<sup>a++\*</sup>, Ritu S. Thakare<sup>a#</sup>,  
Bhimrao M. Kamble<sup>a#</sup>, Vijay S. Patil<sup>a#</sup>, Kranti B. Patil<sup>a#</sup>  
and Nihal S. Titirmare<sup>a++</sup>**

<sup>a</sup> Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri-413722, Maharashtra, India.

## **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## **ABSTRACT**

Seaweed is the common name for countless species of marine plants and algae that grow in the ocean. The seaweed cultivated by bamboo raft, tube mesh and stone method and harvested generally by acid, alkali and water extraction. However, the mostly commercially available in market, which is extracted by processing of bio refinery method. These seaweeds consist of 80-90% moisture. The dry seaweed extracts contains 50% carbohydrates, protein 10-47% with high proportions of essential amino acids, 1-3% lipids and 7-38% minerals. The essential nutrients contain in seaweeds are nitrogen, potassium, phosphorous, calcium, magnesium, sulphur, iron, sodium, zinc, and copper. Seaweed extracts are available in market viz, Sagarika, Kelp, Sea Secret, Sivarika, Solumax, Biovita etc. The soil application of liquid seaweed extracts through drip @ 0.5-1 L<sup>-1</sup> water and foliar @ 2-5 ml L<sup>-1</sup> of water at various critical growth stages of different crops. The application granules of seaweed were recommended @10-20 kg acre<sup>-1</sup> during sowing or

<sup>++</sup> Ph.D. Scholar;

<sup>#</sup> Professor;

<sup>\*</sup>Corresponding author: E-mail: [prasadmargal@gmail.com](mailto:prasadmargal@gmail.com);

standing crops. The application of seaweed extracts either through drip or direct application to soil at lower concentrations were positively impact on germination, shoot growth, root growth, nutrient use efficiency, soil properties, soil microbes, biotic stress, abiotic stress and crop yields.

**Keywords:** Seaweed extract; foliar spray; soil microbes; soil chemical properties; plant nutrients.

## 1. INTRODUCTION

“Seaweed extracts are the biostimulant extracted from seaweed (especially brown and red algae) that can promote crop growth, improve crop quality, enhance crop stress resistance and soil health. India’s coastline is 7517 km long and has an Exclusive Economic Zone (EEZ) of 2.17 million km<sup>2</sup> (equal to 66% of total mainland area). The Maharashtra also having 720 km seashore. The Central Salt and Marine Chemicals Research Institute explored the seaweed diversity of the Gujarat and Tamil Nadu coasts [1]. Around 700 species of marine algae are present and approximately 60 of them being commercially important in both the intertidal and deep-water regions of the Indian coast. Tamil nadu, Gujarat, Maharashtra, Goa, Lakshadweep, Andhra Pradesh, and Karnataka states are major seaweed extracts producers [2]. “The seaweed having three major types of species such as Phaeophyceae, Rhodophyta and Chlorophyta. The all commercial seaweed extract products are made from brown seaweeds (*Ascophyllum nodosum*, *Fucus*, *Laminaria*, *Sargassum* and *Turbinaria spp.* etc.) and red seaweeds viz, *Kappaphycus alvarezii*, *Hypnea musciformis*, *Sarconema filiforme*, *Gracilaria*

*edulis* etc”. [3,4]. Seaweeds consist of minerals viz., organic components, plant hormones and mixtures of different types of polysaccharides (laminarin, fucoidan and alginates), normally not found in terrestrial plants [5,6]. The optimum temperature between 25°C and 30°C and salinity should be from 2.7 to 3.5 % for optimum condition for seaweed cultivation [7]. The seaweed cultivated by bamboo raft method, tube net method and stone method etc. [8]. “Seaweeds are rich in valuable metabolites, such as natural pigments, proteins, lipids, minerals and cellulose which can be extracted and utilized through biorefinery processing methodologies” [9].

“Seaweed extracts act as chelates which enhances soil mineral element, nutrient-uptake in plant, soil structure and aeration properties of the soil, which ultimately promotes root growth” [10]. It also enhanced the adsorption of macronutrients including N, P, K, Ca, Mg, S [11] and micronutrients such as Zn, Mn and Fe [12,13]. “Seaweed is an excellent source of bioactive components with reported antimicrobial activity. Several scientific studies in vitro revealed the antimicrobial potential of seaweeds”.

**Table 1. Chemical composition of seaweed extracts**

Nutrients	Contents
Nitrogen (N)	0.18 %
Phosphorus (P <sub>2</sub> O <sub>5</sub> )	0.48 %
Potassium (K <sub>2</sub> O)	1.89 %
Calcium	0.11 %
Magnesium	0.01 %
Sodium	0.13 %
Iron	256.0 ppm
Zinc	11.87 ppm
Copper	15.62 ppm
Manganese	13.12 ppm

Manimaran, et al., 2018

## 2. EFFECT OF SEAWEED EXTRACTS ON CROP GROWTH ATTRIBUTES

The optimistic effects of seaweed extract on germination of different agricultural crops and its distinct concentration. The "*Cladophora rupestris* and *Ulva lactuca*" species used for seaweed extracts and the optimum concentration of seaweed extracts are surge the rate of germination for cereals and pulses. Advancement in germination percentage, shoot and root length as well as seedling vigour index of rice seeds were noted in lower concentrations of seaweed extracts. "The lower concentrations (5%) of seaweed saps (*Kappaphycus* and *Gracilaria* species) exhibited the higher rate of germination of maize seed, however the higher concentration (15%) of the seaweed extracts hinder the germination" [14]. "Application of *Kappaphycus* or *Gracilaria* seaweed sap at 15% concentration notably increased the germination in wheat. But, when the concentration is either below 2.5% or increased upto 20%, remarkably depletion in the germination" [15].

The higher concentrations of *Kappaphycus* or *Gracilaria* seaweed sap was decline in germination percentage might be cause of consist of high salts concentration at seaweed saps. Salt stress induced inhibition of seed germination, seedling growth and metabolic processes in maize [16] and wheat [17]. Germination percentage of different crops were escalated in lower concentrations might be due to IAA and IBA Gibberlins (A & B), micronutrients, vitamins and amino acids. The more concentrations of hormones and minerals had inhibited growth. "Marine algae *Enteromorpha intestinalis* species of seaweed extracts i.e. 60% seaweed liquid fertilizer was noticed 100% seed germination in soybean" [18]. The seaweed extracts persuade greater seedling growth at a lower concentration in arhar [19]. Higher germination percentage and seedling vigour of green gram and cowpea are due to application of seaweed extracts [20,5]. The increase in germination and seedling vigour at low concentrations of seaweed extracts could be due to presence of auxins, gibberellins, phenyl acetic acid [5] and micro-nutrients [14].

## 3. EFFECT OF SEAWEED EXTRACTS ON SHOOT GROWTH OF CROPS

The soil application of seaweed extract @ 12.5 kg ha<sup>-1</sup> along with the foliar spraying of seaweed

extract of *K. alvarezii* @ 0.5% twice at tillering and panicle initiation stage had significantly higher crop growth parameters of rice like plant height, LAI, DMP and yield parameters viz., number of grains panicle<sup>-1</sup>, panicle length, number of productive tillers m<sup>-2</sup> [21]. The application of coastal sediment with the foliar application of seaweed extract (*Euclima cottonii*) significantly affects growth parameters at all variety of shallots (*Allium ascalonium* L.). It was an evident that most of the applied coastal sediment and foliar seaweed extract greatly improved leaf length, number of leaf and number of tillers of shallots [22]. Application of seaweed extract showed maximum shoot lengths, fresh and dry weights, number of pods per plant, chlorophyll "a", chlorophyll "b", total chlorophyll, and carotenoids of "*Trigonella foenum graecum* L" [23]. The effect of different concentrations of commercial seaweed extract of "*Ascophyllum nodosum*" as a plant biostimulant on growth, yield and biochemical constituents of onion (*Allium cepa* L.) [24]. They concluded that seaweed liquid extracts play an important role for increasing plant height, leaf number, bulb diameter, protein content, sulphur content and chlorophyll and carotenoid contents of onion. Plant which received 0.55% concentration found superior to all treatments while the increased in concentration shows decreasing trends. The application of seaweed extract also increases higher leaf length in onion on sandy soil [25]. The *Ascophyllum nodosum* extract and its organic subfractions increment in more functional nodules might be the legume-rhizobia signaling processes as well as enhancement in growth of alfalfa plants [26].

The effects of foliar application of seaweed (*Sargassum crassifolium*) liquid extract (10%, 20%, 50% and 100%) on the leaf number, leaf area, plant height, shoot dry weight, root dry weight, number of flower and number of fruits etc. in the *Lycopersicon esculentum* and result showed that increased growth parameters as compare to other treatments. The treatment *Kappaphycus* extract @ 15% three foliar spray with recommended dose of fertilizers (RDF) registered higher yield attributes of rice crop such as number of panicles m<sup>-2</sup> (507.60), filled grains panicle<sup>-1</sup> (143.83), panicle length (28.97 cm) and 1000 grain weight (21.23 g) and followed by treatment *Gracilaria* sap @ 15% three foliar spray with RDF [27]. The highest number of panicles hill<sup>-1</sup> and number of effective grains panicle<sup>-1</sup> of rice was found in 15% *Kappaphycus* extract and it was statistically at par with 10 %

and 5% *Kappaphycus* extract sap concentrations [14]. The application of brown algal seaweed extracts boost growth of the crop and elevating number of functional nodules might be due to content of cytokinins [28]. Augmentation of plant height, number of pods plant<sup>-1</sup>, number of grains plant<sup>-1</sup>, number of branches plant<sup>-1</sup> of soybean was noted in treatment of 15% seaweed extract from *Kappaphycus alvarezii* [13].

#### 4. EFFECT OF SEAWEED EXTRACTS ON ROOT GROWTH OF CROPS

The soil application 12.5 and 25 kg ha<sup>-1</sup> with foliar spraying of seaweed extracts liquid 0.5 % (v/v) at tillering + panicle initiation stage have significant effect on the root length of rice crop [21]. "The effect of seaweed extracts on different cultivars of onion and they indicated that seaweed extracts application led to an increase in root length which can be ascribed to alginate oligosaccharide-induced expression of an auxin-related gene leading to higher auxin concentrations, thus promoting root formation and elongation" [29]. Mostly Marine algae loaded with auxins and its different compounds [30]. *Ecklonia maxima* species extract also content of auxins which is noticeable change was found in mung bean root. The seaweed extract also detected the indole compounds and IAA in Gas chromatography /mass spectroscopy method [30].

Seaweed products are inciting the root growth and development activity [31,32]. The root-growth invigorating effect was more notable when extracts were applied at an early growth stage in maize, and the response was similar to as that of auxin, an important root growth-promoting hormone [32]. Seaweed extracts applications minimises transplanting shock in seedlings of marigold, cabbage, and tomato by increasing root size and vigour [30]. Similarly, wheat plants treated with seaweed extracts Kelpak observed an increase in root: shoot dry mass ratio. The seaweed had a significant effect on root development [33]. Seaweed extracts were applied either roots or as a foliar spray to the plant excited to the root growth activity as reported by [34]. The concentration of kelp extract is a crucial factor in its effectiveness in tomato plants, the excessive concentrations (1:100 seaweed extract: water) inhibited root growth, however lesser concentration (1:600) stimulates the root activity [35]. Bio stimulants of

seaweed extracts having capacity of root development by improving lateral root formation and increasing total mass of the root system [36,37,38]. The seaweed extracts consist of endogenous auxins and root growth promoting substances were responsible for enhancement of root system [30].

#### 5. EFFECT OF SEAWEED EXTRACTS ON CROP YIELD

The significant effect of Sagarika seaweed granule and liquid extracts on rice crop in *Vertisols*. The highest yield (62.9 q ha<sup>-1</sup>) of rice was noted in the treatments of 100% RDF + seaweed granules @ 25 kg ha<sup>-1</sup> at 21 DAT + seaweed liquid @ 0.25% at 42 DAT. The addition of seaweed extracts with 75% RDF increased grain yield by 4.6, 7.9, 11.0, and 12.1% (highest) over the application of 75% RDF alone (52.58 q ha<sup>-1</sup>) [39]. The seaweed extracts fertilizer saving of 20% fertilizer with increase the rice yield. The treatment of chemical fertilizer, chemical fertilizer with 5% seaweed extract, and low chemical fertilizer with 5% seaweed extract had increased yield by 58.42%, 62.51%, and 62.06%, respectively over the control [40]. The true algae max (*Ulva lactuca*, *Jania rubens*, and *Pterocladia capillacea*) increased cucumber yield due to improving its chemical and physical traits related to immunity, productivity, and stress defence of cucumber [41]. Spraying of seaweed extract once at seedling, early elongation, and early mature stages increased the cane yield by 9.23, 9.01, and 3.33%, respectively [42].

The soil application of seaweed extract @ 12.5 kg ha<sup>-1</sup> along with the foliar spraying of seaweed extract liquid @0.5% twice at tillering and panicle initiation stage had significantly increased yield by 18 -20% [21]. The 18.0 percent increase in grain yield of rice was noted in treatment @15% *Kappaphycus* or *Gracilaria* extracts over the control [14]. Application of either 10% concentration of *Kappaphycus* or *Gracilaria* extracts of foliar spray along with 100% RDF was beneficial option to attain high yield and grain quality of rice in North Eastern region of India [43]. Application of biochar (2 and 5%) with the seaweed extracts (1 and 2 g L<sup>-1</sup>) gave positively enhanced plant growth, development, yield and the mineral composition of wheat plants cv. *Sakha 93* cultivated in sandy soil. The seaweed components providing an excellent source of bioactive compounds such as macro- and micronutrients,

essential fatty acids, amino acids, vitamins, cytokinins, auxins like growth promoting substances affecting cellular metabolism in treated plants leading to enhance growth and productivity [44].

The *Kappaphycus alvarezii* and *Gracilaria edulis* extract concentrations 7.5% and 5.0% foliar spray had improve 19.74% and 13.16% of grain yield of wheat, respectively. Similar results have been also noted in wheat with the application of *Kappaphycus alvarezii* seaweed extract [45]. The treatments RDF + *Kappaphycus alvarezii* @ 10 % and RDF + *Gracilaria edulis* @10% seaweed extracts were produced significantly superior tuber yield 32.88 t ha<sup>-1</sup> and 31.30 t ha<sup>-1</sup>, respectively over the control. Seaweed extracts foliar sprays were increased marketable yield of tuber and decline in non-marketable tuber yields of potato [46]. The increase in 47.52 and 42.52 grain yield of black gram due to application of @10% *Kappaphycus Alvarezii* and *Gracilaria edulis* extracts, respectively [47].

The application of seaweed extracts was significantly higher oil content, oil yield, K, Na and crude protein of sunflower seed. Application of @ 0.6 % *Gracilaria dendroides* and *Ulva lactuca spp* of seaweed extracts was noted higher oil content 34.05 and 30.55 percent in sunflower, respectively. The foliar spray of seaweed extract at 30 and 60 days of interval after planting of potato resulted higher tuber yield and quality parameters viz, nitrogen, total soluble solids and protein contents in potato tubers [48]. The application of seaweed extracts founded beneficial effect on growth, yield and quality of potato tubers [49]. The foliar applications of 15% and 12.5% seaweed extracts were noticed 57% and 46% increase in grain yield of soybean over to control [13]. Applications of @15% *Kappaphycus* extracts + RDF and @15% *Gracilaria* extracts + RDF had been recorded 38.97 and 33.58% higher grain yield of green gram, respectively as compared to the without application of seaweed extracts. The extracts of *Kappaphycus* and *Gracilaria* seaweed consist of micronutrients and growth hormone which is responsible for boosting the crop yield and enhancing quality of green gram in foliar application treatments [45]. Application of seaweed extract creates early growth and improved the yield contributing characters of legume crops as well as increase in 12-25% higher yield as compared to control [50].

## 6. EFFECT OF SEAWEED EXTRACTS ON SOIL PROPERTIES

### 6.1 Effect of Seaweed Extracts on Soil Microbial Activity

The application seaweed extract to tomato plantation significantly increased soil bacteria, this might be due to decompose the cellular matter and supply the soil carbon to microorganisms [51]. The increased number of 14 bacterial families in soils treated with seaweed extracts [26]. The application of seaweed extracts along with organic matter shown increase fungal families in soils [52].

Application of seaweeds and seaweed extracts activated growth of beneficial soil microbes and synthesis of soil aggregating agents which change in soil quality for sustainable growth of crops. The organic fractions (25% MeOH eluates) of red and green algae found that the substantially increase hyphal growth of arbuscular mycorrhiza(AM) fungi in vitro. The results also elucidated that 25% MeOH eluates of red and green algal extracts applied to roots of papaya (*Carica papaya Linn.*) and passion fruit (*Passiflora edulis Sims.*) enhanced mycorrhizal count as compare to control treatment [53]. Red and green algae present arbuscular mycorrhiza enhancing substances which play a role in mycorrhizal growth in higher plants. Marine brown seaweed [*Laminaria japonica Areschoug* and *Undaria pinnatifida (Harvey) Suringar*] extracts may be used as an enhancing the growth of AM fungus [53]. The higher in stimulated hyphal and elongation of arbuscular mycorrhizal (AM) fungi activity might be due to alginate oligosaccharides extracted from brown algae. Methanol extracts from brown algae augmented growth of arbuscular mycorrhiza fungi on trifoliolate orange, *Poncirus trifoliolate* (Linn.) Raf., seedlings [54]. Indigenous AM fungi intended a 27% growth in root colony and spore number was increased 21% over the control when liquid fertilizer containing tangle (*L. japonica*) extracts was given in a sprinkler system used in citrus orchard [55].

### 6.2 Effect of Seaweed Extracts on Soil Chemical Properties

Application of seaweed extract before sowing or even standing crop improves the soil chemical properties. This seaweed extract as manure provide essential nutrients to enhance crop

growth. Application of coastal sediment with foliar application of seaweed extract improved chemical properties *i.e.* pH and the availability of K, Ca, Mg and Na of peat soil [22]. During the decomposition of seaweed extract (*Sargassum horneri*) releases of nitrate, ammonium, total nitrogen, and phosphorus. Also chelate with major cations of  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ , and  $\text{K}^+$  to form aggregate with richer nutrients, improve the soil structure and ultimately boost the activity of soil microorganism. Therefore, seaweed extract supplement can potentially be a strategy of enhancing the level of N, P, and K contents in soil [40]. The soil application of seaweed extract @ 25 kg ha<sup>-1</sup> was noticed remarkable improvement in available nutrient status like N, P, K, Ca, Mg, S and micronutrients in soil [21].

Seaweed extracts (brown algae *Durvillaea potatorum* and *Ascophyllum nodosum*) increases available nitrogen content in soil [51]. Seaweed as a partial source of nitrogen (40–55%) used as organic fertilizer treatment for comparison in sweet corn. Soil electrical conductivity, potassium ( $\text{K}^+$ ), sulphate ( $\text{SO}_4^{2-}$ ), and active carbon (C) increased with seaweed addition relative to the organic fertilizer, where as potentially mineralizable N and pH decreased, with effects varying over time [56].

## 7. EFFECT OF SEAWEED EXTRACTS ON NUTRIENT UPTAKE BY CROPS

The effect of Sagarika seaweed granule and liquid extracts on rice crop in *Vertisols*. Application of 100% RDF along with the soil and foliar application of seaweed extract of granule (solid) and liquid formulations had maximum nutrient uptake of rice due to increasing nutrient use efficiency [39]. The bio stimulant prepared from seaweed extracts induced changes in the soil stoichiometry with a greater content of  $\text{NO}_3^-$  and a lower content of  $\text{PO}_4^{3-}$  without impacting the soil content of  $\text{NH}_4^+$  [57]. Spraying seaweed extracts to sugarcane crop once at seedling, early elongation, and early mature stages increased N, P, or K utilization efficiency as compared to without spraying seaweed [42]. The remarkably higher uptake of P and K in leaves of *amaranthus polygamous* noted in the foliar application of 10% seaweed extracts (*kappaphycus alvarezii*) combined with 50% chemical fertilizer treatments resulted higher values compared to that in chemical fertilizer alone in sodic soil [58]. Seaweed act as bio stimulant had a favourable effect on N uptake in

shoots, roots and whole plants of oilseed rape at the fruit development stage [59].

The application of biochar (2 and 5 %) with the seaweed extracts (1 and 2 g L<sup>-1</sup>) enhancing the use efficiency of nutrients in sandy soil [44]. The highest N, P and K uptake by rice grain and straw were recorded in the 15% *Kappaphycus sap.* + RDF and 15% *Gracilaria sap.* + RDF over the RDF and control treatment [60]. In addition, chemical components of brown seaweed extract are known to induce growth and root colonization of beneficial soil fungi [53]. Alginic acid, a major component of brown seaweed extracts, promoted hyphal growth and elongation of arbuscular mycorrhizal fungi [54], such proliferation of mycorrhizal fungi lead to an improvement in phosphorus nutrition of plants. Foliar spray of seaweed extract products *Ascophyllum nodosum* extract improved the Cu uptake in grapevine, probably by increased permeability of the cell membrane. Application of a commercial extract of *Ecklonia maxima* on lettuce grown under optimal conditions improved yield and Ca, K and Mg content in the leaves [11].

## 8. EFFECT OF SEAWEED EXTRACTS ON ABIOTIC AND BIOTIC STRESSES IN CROPS

Application of seaweed extract sprays of *Ascophyllum nodosum* (5 and 7 mL·L<sup>-1</sup> with 6 day intervals) on *Paspalum vaginatum* Salam' during prolonged irrigation intervals (2 and 6 day) and saline growing conditions (1 and 49.7 dS m<sup>-1</sup>) for 6 weeks. The results stated that the seaweed extracts increased turf quality, leaf photochemical efficiency, root length and dry weight, total non-structural carbohydrates, K, Ca, and proline in treated plants during prolonged irrigation intervals as well as saline shock conditions [61]. The seaweed extract could enhance the photosynthetic rates by reducing stomatal closure and increasing gas exchange, leading to improved growth during drought conditions [62]. The seaweed extract of *Ascophyllum nodosum* significantly delayed wilting, better water use efficiency, increased leaf water content and improved the recovery of drought wilted plants, as compared to controls [63].

The seaweed extract consist of bioactive element which enhance the performance of plants under abiotic stresses. Foliar applications of extracts have been shown to improve plant tolerance to

freezing temperature stress [12]. Application of an *Ascophyllum nodosum* extract formulation applied to grapes enhanced freezing tolerance might be due to lowering of osmotic potential in leaves. The average osmotic potential of seaweed extract treated grape plants was  $-1.57$  MPa correlated with  $-1.51$  MPa in the without treated plants of grape later 9 days of seaweed extract application to grape plants [64]. Aberrant changes in rainfall, higher concentration of salts in soil, and temperature extremes are responsible for decline the yield of main crops [65] and adversely effect on agricultural sector in a global. For example, soluble salt concentrations and limited rains are the mainly responsible for abiotic stresses in many areas of the world, with an estimated 50% of all cultivated lands are degrading due to salinization by 2050 [66]. The abiotic stresses had also causes secondary effects like oxidative stress, leading to an accumulation of reactive oxygen species (ROS) such as the superoxide anion ( $O_2^-$ ) and hydrogen peroxide [67]. These are known to damage DNA, lipids, carbohydrates, and proteins and also cause aberrant cell signaling [68]. *Ascophyllum* extracts *i.e.* Seasol (0.8%) sprayed on grape vines noted that the reduction in leaf osmotic potential, enhanced freezing tolerance in grape vine. The seaweed extract contain cytokinin is role in heat tolerance mechanism in creeping bent grass [69].

The seaweeds *viz.* *Sargassum polyphyllum*, *Turbinaria ornata*, *Gelidiopsis sp.*, *Padina tetrastomatica* and *Gracilaria corticata* as a stimulant to boost the growth of *Vigna radiata* (Mung) as well as its antagonistic activity against several fungal pathogens such as *Rhizoctonia solani*, *Alternaria solani* and *Sarocladium oryzae* [70]. Diseases of broccoli caused by *Albugo candida* and *Sclerotinia* were effective control with joint application of seaweed extract from *Ascophyllum nodosum* and *Durvillaea potatorum* [71]. This combination was also found effective against club root disease caused by *Plasmodiophora brassicae* [72]. Seaweeds are a good source of antioxidant polyphenols with bactericidal properties. The increase in superoxide dismutase (SOD) activity might be due to *Ascophyllum nodosum* and humic acid application in bentgrass (*Agrostis stolonifera*), which remarkably reduced dollar spot disease caused by *Sclerotinia homoeocarpa* [73]. The *ulva* extract extort the expression of the PR-10 gene required for active defence against diseases of pathogen attack. The cDNA array revealed that the seaweed extract caused

upregulation of 152 genes, mostly plant defence genes such as those involved in phytoalexin, PR proteins, cell wall proteins, and oxylipin pathways [74]. Soil application of liquid seaweed extracts to cabbage stimulated the growth and activity of microbes that were antagonistic to *Pythium ultimum*, a serious fungal pathogen that causes damping-off disease of seedlings [75]. Seaweed extracts was induced plant defence mechanism counter to pest and diseases of plants. The seaweed products enhancing plant defence mechanism for sustainable plant health as well as rhizosphere microbial community in soil [76].

## 9. CONCLUSION

Seaweed is the best biostimulant, good source of essential nutrients, excellent eco-friendly organic manure and alternative source for inorganic chemical fertilizer for sustaining the crop yield. Mostly Seaweed spp. *Ascophyllum*, *Fucus*, *Laminaria*, *Sargassum*, *Turbinaria*, *Kappaphycus*, *Sarconema*, *Gracilaria* etc are used for preparation of seaweed extracts which helps in enhancing cereal, pulses, vegetables, fruit crop growth, yield and quality. The seaweed extracts stimulating soil microbial activity as well as improved the soil fertility, quality, increasing the nutrient use efficiency and mitigating drought, salinity and chilling injury. Howerer, *Ulva*, *Durvillaea*, *Ascophyllum*, *Turbinaria*, *Gelidopsis Spp.* etc. creates disease resistance in crop.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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