Review Article

Effect of Seaweed Extracts in Fruit Crops: A Review

ABSTRACT

Seaweed or Marine macro-algae are often regarded as an underutilized bioresource, many have been used as a source of food, raw materials for industry, and therapeutic and botanical purposes for decades. Moreover, several plant growth-stimulating compounds found in seaweed and products derived from seaweed have made them popular supplements to crop production systems. This article provides an in-depth analysis of how different seaweed species and seaweed products affect plant growth and development of fruit crops. They also increase the biochemical components of plants and have ability to alleviate abiotic stress.

Keywords: Seaweed; plant growth-stimulating compounds; plant growth and development; biochemical components, abiotic stress

1. INTRODUCTION

Due to the rising need for food and fiber per unit of land area, chemical fertilizers are becoming increasingly popular to increase yields from small plots of land. Chemical fertilizers pose major health risks and harm the environment when they are used in excess. Because of this, research in this area is heavily focused on finding and evaluating the efficacy and efficiency of new products. One such approach is the use of biostimulants that can enhance the effectiveness of conventional mineral fertilizers [1]. Biostimulants are loosely defined as non-fertilizer products which have beneficial effects on plant growth and didn't contain any chemicals or synthetic plant growth regulators [2]. Nearly 10,000 different species of macroalgae (seaweeds) exist and account for 10% of marine productivity globally. Seaweeds are quintessential members of inshore, marine ecosystems as they provide shelter and food to numerous marine biota and can even contribute to the modification of physicochemical properties of seawater. Only a small part of all seaweed species is used extensively in agriculture as mulches, manures, and modified extracts, as well as food and supplements for humans and animals [3,4,5].
The earliest evidence of the use of seaweed by humans' dates back 15,000 years and was discovered in organic remains excavated from prehistoric sites in Monte Verde, Southern Chile, where an ancient migratory population of maritime origin had been established [6]. Seaweeds have been utilized by humans for a variety of purposes, including food, medicine, agriculture, cosmetic items, colouring pigments, and textiles, according to the available resources, which range from ancient scriptures and folklore to anthropological studies. Various seaweeds have found their places in diverse cultures throughout the globe [7]. Deity Ukimochi, the Goddess of food, is depicted to be associated with seaweed in Japanese mythology [8]. The most famous author of Roman agriculture, Columella, described how roots were to be wrapped in "seaweed" (genus not specified) to preserve the greenness of the seedlings, demonstrating that the ancient Romans were aware of the fertilizing properties of seaweeds [9]. In the British Isles, including Scotland and Ireland, different seaweeds have been used as manure more recently [10]. Seaweeds are macroscopic marine algae. They serve as human food, livestock feed, a source

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of numerous fine chemicals, and a replacement for chemical fertilizer. In addition, it is employed to produce a variety of industrial goods, including agar and alginate [11]. Natural seaweeds have begun to take the place of synthetic fertilizers in recent years. Several commercial seaweed extract products are available for use in fruit crops [12] (Table 1). Because they contain numerous growth regulators, including cytokinins [13], auxins [14], gibberellins [15], and various macro and micronutrients required for plant growth and development, seaweed extracts are marketed as liquid fertilizers and bio-stimulants. Additionally, it facilitates the development of advantageous soil microbes [16], builds environmental stress tolerance [17], increases nutrient uptake from soil [18], and improves antioxidant characteristics [19]. Numerous studies have shown that applying seaweed extract to plants has a wide range of advantageous effects, including promoting early seed germination and establishment, increasing crop performance and yield, boosting resistance to biotic and abiotic stress, and extending the post-harvest shelf life of perishable goods [20,21,22] (Fig. 1). In this review we reported the effect of seaweed extracts as plant biostimulants in fruit crops and the possible modes of action including the chemical components that may be responsible for causing plants to respond physiologically to treatment.

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Table 1. Commercial seaweed products used in fruit crops

2.

Product name	**Seaweed name**
Acadian	*Ascophyllum nodosum*
Acid Buf	*Lithothamnium calcareum*
Agri-A-Mic	*Ascophyllum nodosum*
Bio-Genesis™ High Tide™	*Ascophyllum nodosum*
Biovita	*Ascophyllum nodosum*
Emerald RMA	Red marine algae
Fartumm	Unspecified
Guarantee	*Ascophyllum nodosum*
Goeman GA 14	*Ascophyllum nodosum*
Kelp Meal	*Ascophyllum nodosum*
Kelpak	*Ecklonia maxima*
Kelpro	*Ascophyllum nodosum*
Maxicrop	*Ascophyllum nodosum*
Profert, Seasol	*Durvillea potatorum*
Soluble Seaweed Extract	*Ascophyllum nodosum*
Simplex, Tasco	*Ascophyllum nodosum*

METHODS OF SEAWEED FARMING IN INDIA

2.1 Floating bamboo raft method

The principal structure for cultivation is an 8–10 cm wide by 3–3 m long bamboo raft. To keep it intact, the angular pieces are diagonally fastened with the aid of support bamboos (about 120 cm long). To fix the rafts and keep them buoyant, an anchor is attached around each group of rafts. To reduce grazing and prevent debris drift, bottom netting is offered. Total 20 plantings of about 100–150 g fresh weight each are planted on polypropylene ropes (3 mm) at regular intervals by raffia or braider. The seeded ropes are fastened to opposing bamboo at both ends, 15 cm apart and parallel to each other. Each raft with 20 such ropes thus will have an initial seeding weight of 60 kg fresh weight (Fig. 2a). The seeding is carried out onshore and seeded rafts are transplanted into the open sea subsequently. After 45 days, harvesting is often done. It is advised to use this technique in locations with calm water currents, such as the North Ramanathapuram district of Tamil Nadu [23].

2.2 Longline or monoline method

There are a few similarities between this modified form of traditional off-bottom farming and the raft approach. Between anchors, seedlings weighing between 100 and 150 g are tied to a rope with raffia or braider. The main rope has a diameter of 6 to 8 mm and is roughly 20 meters long. The longline ropes are kept afloat in water with the help of floats tied at regular intervals and anchoring is done on both ends. The timber of casuarina, eucalyptus, bamboo, etc. is used for anchoring. In a square pattern, poles are erected at 3-m intervals, and 12-mm polypropylene rope is linked in any two parallel directions (depending upon tidal current). The 3 mm seeded ropes are then tied at intervals of 10 cm. It is important to take precautions to guarantee that the seaweed is always submerged (0.5 m below the surface) and gets enough sunshine (Fig. 2b). To prevent seedling loss that can occur if ropes are seeded on the coast and dragged into the sea, seeding in this situation is typically done in the water itself. This farming method is especially advised in regions with low grazer densities and moderate wave action. In Tamil Nadu's South Ramanathapuram, Pudukkottai, and Tuticorin districts, it is widely practiced [24.]

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2.3 Tube net method

Higher wave action may result in crop loss at the preharvest stage, when seeding is at its heaviest, or drifting of germlings during the early growth phase. So, the tube net method has a lot of potential [25]. The tube nets (15-cm diameter; mesh size of 2.0 cm) of 25-m length are held floating in the water column below the surface with an appropriate number and size of floats at regular intervals. Anchor stones (about 30 kg) are used at each end to hold the tube nets steady in the water column; if required, additional anchors of appropriate size and weight can be fixed intermediately. The seed material of 20 kg fresh weight is loaded into the tubes with the aid of a 1.0- or 1.5 m long plastic pipe acting as a funnel or a hopper. For effective seeding, the pipe diameter should be a bit less than that of the tube network. Once the plastic pipe is installed, the entire tube is dragged downward until the plastic pipe's mouth protrudes from the tube. To load the seedling material into the tube sequentially and without gaps between the seedlings, the tube net is carefully pushed down from the bottom of the plastic pipe. This procedure is repeated until algal biomass has been planted throughout the entire tube net. The tubes are closed at both ends with rope to prevent material from being lost (Fig. 2c). Recently, a mechanical harvester was created and put through testing to harvest the biomass from the tubes [26].

3. GROWTH STIMULATORY FACTORS IN SEAWEED EXTRACTS AND THEIR METHODS OF ACTION

The use of seaweed formulations as biostimulants in crop production is well recognized, and seaweed products demonstrate growth-stimulating properties. Biostimulants, also known as "metabolic enhancers," are substances that "boost plant development when administered in tiny doses, rather than fertilizers" [27]. Seaweed components such as macro- and microelement nutrients, amino acids, vitamins, cytokinins, auxins, and abscisic acid (ABA)-like growth substances affect cellular metabolism in treated plants leading to enhanced growth and crop yield [28,29,30,31,32,33]. At low concentrations (diluted as 1:1000 or higher), seaweed extracts are bioactive [34]. It is conceivable that the numerous chemical components of seaweed extracts exhibit synergistic activity, even though many of these components' actions and modes of action are still unknown [35,36].

4. EFFECTS ON ABIOTIC STRESS ALLEVIATION IN FRUIT CROPS

Abiotic stressors like drought, salinity, and temperature extremes can lower the yield of important crops and restrict agricultural production globally [37]. For instance, drought and salinity are both spreading in many parts of the world, with 50% of all arable lands likely becoming salinized by 2050 [38]. Many abiotic variables, including temperature, salt, and drought, manifest as osmotic stress and have downstream consequences that include oxidative stress, which results in an accumulation of reactive oxygen species (ROS), including hydrogen peroxide (H2O2) and the superoxide anion (O2 • −) [39]. These are recognized to cause harm to proteins, lipids, carbohydrates, and DNA as well as to produce abnormal cell signalling [40].

Plants perform better under abiotic stressors due to bioactive chemicals found in seaweed extracts. Spraying extracts on plants has been found to increase their resistance to the stress caused by freezing temperatures [41]. Applying an *A. nodosum* extract formulation specifically improved the ability of grapes to withstand freezing because it reduced the leaves' osmotic potential, which is a crucial sign of osmotic tolerance. After nine days of seaweed extract treatment, the average osmotic potential of the treated plants was -1.57 MPa as opposed to -1.51 MPa in the untreated controls [42]. Spinelli et al. (2010) [43] examined the impact of another commercial seaweed extract, named Actiwave® on the vegetative and productive performance of strawberry plants grown on an iron-deficient substrate. They observed that vegetative growth, chlorophyll content, stomatal density, and photosynthetic rate were increased after biostimulant application. Fruit production and weight were also enhanced. Nutrient uptake might have been positively influenced by the more developed root system of treated plants. Treatment also contrasted the negative effects of iron chlorosis and this could be linked to betaine contained in this product. Two seaweed-based plant biostimulants containing *Ascophyllum nodosum* named Super Fifty® and Acadian were applied respectively on strawberry and was associated with a significant improvement in yield and root dry weight, despite the adverse salinity condition [44].

5. EFFECT ON PLANT METABOLISM AND PHYSIOLOGY OF FRUIT CROPS

One of the characteristic impacts of seaweed extract treatment is an increase in the chlorophyll content in the treated plants; this result has been seen in a variety of crops, including grapevine and strawberry [45,46,47,48].

Under nutrient-deprived conditions, the application of a commercial seaweed extract to apple trees of the variety Fuji reduced the problem of alternate bearing, but not under normal nutrient management conditions [49]. Application of plant growth regulators such as gibberellin, auxin, and cytokinin can decrease alternate bearing. Accordingly, it would seem that the influence of commercial seaweed extracts prepared from *A. nodosum* on alternate bearing under nutrient-deprived conditions may be caused, at least in part, by the presence of a hormone or a signalling molecule in the extract. However, it is challenging to explain why the commercial *A. nodosum* extract only reduces alternate bearing in conditions of inadequate nutrition [50,51].

6. EFFECT ON GROWTH AND YIELD OF FRUIT CROPS

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In many crop plants, seaweed concentrate induces early flowering and fruit set [52,53,54]. For example, Roshdy (2014) [55] recommended the use of potassium silicate in combination with seaweed extract both applied four times at 0.05 % in the Grand Naine variety of bananas for higher bunch weight, average hand weight, finger weight, finger length, and finger diameter. Foliar application of seaweed extracts at 0.2% recorded maximum no. of fruits/tree, fruit weight, and yield/tree in valencia orange [56]. Seaweed extract had a higher amount of essential nutrients, amino acids, vitamins, antioxidants, and natural hormones [57]. The hormonal components found in the extracts, particularly cytokinins, are assumed to be responsible for the increased yield in plants treated with seaweed [58,59,60]. High amounts of cytokinins in reproductive organs may be related to nutrient mobilization, whereas cytokinins in vegetative plant organs are involved with nutrient partitioning. Fruit ripening generally causes an increase in the transport of nutrient resources within the developing plant [61,62]. and the fruits can serve as strong sinks for nutrients [63]. According to Norrie and Keathley (2006) [64]. over three years, *A. nodosum* extracts consistently increased the production of "Thompson seedless" grapes (*Vitis vinifera* L.). They noticed that the *A. nodosum*-treated plants always outperformed (in terms of berries per bunch, berry size, berry weight, rachis length, and the number of primary bunches per plant) the controls maintained under the regular crop management program. This led to improved fruit size (13% increase), weight (39% increase), and yields (60.4% increase over the control).

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7. EFFECT ON QUALITY AND SHELF LIFE OF FRUIT CROPS

A. nodosum extract increased olives' productivity, quality, and nutrient status [65]. Foliar spray of *A. nodosum* extracts along with root application of nitrogen and boron improved K, Fe, and Cu concentrations in the leaves with a concomitant decrease of Mn. The seaweed extract treatment caused changes in the fatty acid profile of the olive oil; there was a significant improvement in the concentration of linolenic and oleic acid and a considerable decrease in palmitoleic, stearic, and linoleic acid. In addition to increasing productivity and quality, using seaweed extract prolonged the shelf life of pears and avocados [66,67]. Additionally, post-harvest treatments have been employed with seaweed extracts. When held at room temperature or in cold storage, post-harvest treatment of navel oranges with seaweed extract including a combination of Sargassum, laminaria, and *A. nodosum* extracts dramatically increased post-harvest shelf-life and quality [68].

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8. CONCLUSION AND PROSPECTS

Seaweeds and seaweed products are increasingly used in crop production. However, it is currently uncertain what mechanism(s) seaweed extract uses to cause its physiological effects. To better understand the mechanisms of action of the seaweed-induced growth response and stress reduction, it is possible to examine the effects of seaweed extracts and components on the entire genome/transcriptome of plants. This is possible because the genomes of many plants have now either been fully sequenced or are almost there. For instance, using model plants like Arabidopsis thaliana and Medicago truncatula might help elucidate the molecular mechanism(s) underlying the effects of seaweed extracts [69]. Climate change is likely to be to blame for the recent challenges to food production brought on by the rising incidence of biotic and abiotic stresses, which will further diminish yields and/or have an effect on crops in the twenty-first century (IPCC 2007) [70]. Therefore, it should be a top priority to research to create sustainable means of reducing these strains. Recent research has demonstrated that seaweed extracts made from different starting raw materials, and by different procedures are attributed to several beneficial effects such as increased nutrient uptake, abiotic stress tolerances, and improvement in the growth, yield, and quality of fruit crops. Seaweed extracts are also regarded as an organic agricultural input due to their safety for both human and animal health as well as the environment.

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