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Seaweed Extract Based Biostimulants and their Role in Enhancing Crop Productivity

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Introduction

One of the significant difficulties in agriculture is the creation of sustainable and ecologically friendly solutions to satisfy the requirement to feed the expanding global population. In order to address these important concerns and offer more sustainable alternatives to conventional agricultural methods, plant-based biostimulants are regarded as the most creative and promising options.

Algal extracts function as biostimulants rather than fertilizers because they stimulate plant's defense and growth responses when applied. Algae are autotrophic photosynthetic creatures that can colonize extremely intricate environments. Algae have developed the ability to synthesize a wide variety of secondary metabolites because they are constantly exposed to abrupt changes in temperature, salinity, light intensity, and nutrient availability. These are primarily required to quickly respond to and adapt to abiotic stress. Algae extracts (AEs) are rich in macro- and micronutrients, a variety of bioactive substances and signalling molecules. As a result, they have long been regarded as a valuable source of nutrients that can benefit both humans and cultivated plants in a number of direct and indirect ways.

Seaweeds are macroalgae that are a crucial part of the marine and coastal ecosystems, adding to their rich biodiversity. Currently seaweed extracts (SE) are widely used as plant biostimulants which refers to "any substance or microorganism applied to plants with the aim of enhancing nutrition efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrients content." Seaweed extracts help promote plant growth, boost yields and raise plant's resistance to biotic and abiotic challenges. SE can be applied on soil and/or on plants as a foliar spray. They act positively on soil retention and remediation, they could be a source of nutrients and they may show hormonal effects.

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Methods of seaweed cultivation

Monocline farming:

Seedling materials are obtained from fragments of healthy mother plant's apical regions. Seedling material is inserted into the twists of nylon or plastic ropes (5 mm thick) at intervals of 5 cm. Ropes tied to poles fixed in the sea and the whole unit is submerged at 1-2 m depth. To keep the ropes from sagging, additional stakes are utilized. Periodic cleaning should be carried out, and harvested using scissors after two to three months, leaving the basal area on the ropes for regeneration.

Raft cultivation:

Cultivation on bamboo rafts of 2.5 x 2.5m with lines and plants submerged at 30cm in water. The raft is anchored either at the bottom with a stone or concrete block or it is tied to bamboo poles and positioned either parallel to or perpendicular to the water current. This approach is influenced by surface weather conditions. In locations with unfavourable tidal range and water depth, the raft approach is appropriate.

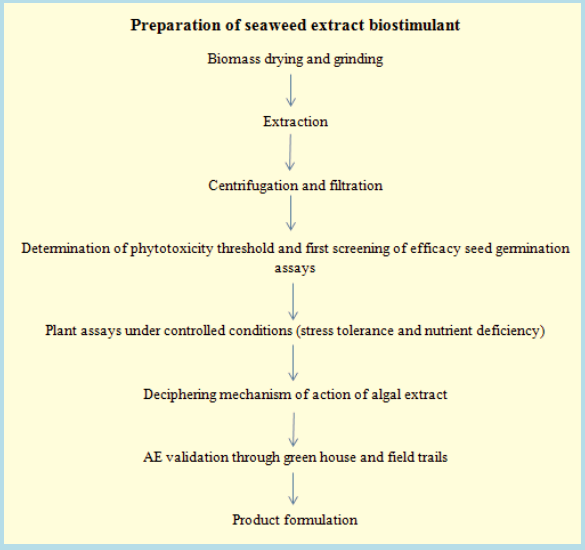
Net farming:

Coir nets of various sizes (1m x 1m) with a mesh of 7.5-15 cm are used. Seedlings inserted in the twists of coir ropes. Nets are tied to the poles which are already erected at the cultivation site and placed horizontally and kept in submerged position making sure that a depth of 0.5m even at the lowest tide. Plastic, aluminium or fiberglass floats are used and Periodical cleaning should be done.60-80 days culture was harvested using scissors leaving the basal portion for further growth

Monocline method

Raft method

Net method



Main Bioactive Compounds of seaweed

It is well known that algal extracts contain high amounts of macronutrients especially N, P, and K. AEs can promote plant growth because of a mixture of signaling molecules and metabolites such as phenolics, phytohormones, carbohydrates, betaines, amino acids, carotenoids, vitamins and polyamines. It has been long known that marine algae can have a high concentration of phenolics. These compounds usually accumulate under stress and have the ability to scavenge Reactive Oxygen Species (ROS), to chelate metal ions and to stabilize membranes and proteins. Phlorotannins are type of polyphenols commonly present in brown which are absent in terrestrial plants that is involved in the response to both biotic and abiotic stress. Brown seaweeds such as A. *nodosum*, F. *vesiculosus* and F. *serratus* are rich not only in phlorotannins but also in phloroglucinol, eckol, and dieckol. These substances are anticipated to detoxicate ROS more effectively because they contain more phenolic rings than other phenolics.

Effect of Seaweed Extracts on Plant Growth

Seaweed extracts have been extensively researched for potential application in crop production to increase biomass yield and produce quality over the years. These extracts have been demonstrated to have a favourable impact on seed germination and plant development throughout the whole growing cycle, including post-harvest (Ali O et al., 2019). By improving root size and density, seaweed products have been demonstrated to encourage higher germination rates and result in appreciable increase in seedling vigour.

Extracts of *A. nodosum* and *K. alvarezii* improved water uptake and nutrients, which ultimately led to the promotion of overall vigor and the growth of plants (Senthuran, S et al., 2019). The maize leaves applied with extracts of *A. nodosum* and *Laminaria spp* were able to absorb much more Zn, Fe, B, Cu, Mo, S, Mg, Ca, and Mn than the controls. A similar increase in potassium levels was also observed in the leaves of mustard treated with *E. maxima*. At the plant's vegetative stage, application of *A. nodosum* in tomato and sweet pepper led to the increased chlorophyll content of leaves which was probably due to inhibition of chlorophyll degradation caused partly by betaines present in the extract.

Effect of seaweed extracts on plants-Tolerance to abiotic stresses

Global climatic changes have significantly increased abiotic stresses on crops, which necessarily impede their growth, development, and yield and ultimately lower agricultural productivity globally. Abiotic stresses viz. drought (irregular and erratic

rainfall), salinity, excessive heat/extreme temperatures, and waterlogging are peculiar factors responsible for the poor productivity of most crop. Abiotic stresses are responsible for substantial losses of crops around the world. In addition to stresses caused by pests and diseases, various environmental stresses such as drought, high temperature, salt, and freezing conditions can reduce crop productivity. It is also estimated that by the year 2050, approximately 50% of arable lands will be plagued by high salt and drought conditions. These abiotic stresses can lead to the build-up of reactive oxygen species (ROS) which will ultimately cause damage to the plant system. *Kappaphycus alvarezzi* extract treatment on various wheat varieties under drought stress resulted in plants with increased root length, enhanced chlorophyll content and carotenoids, and tissue water content. The extract also caused a significant reduction in electrolyte leakage and lipid peroxidation, decreased Na+/K+ ratio, and increased Ca content, thereby reducing ionic disparity. Further, treated wheat plants accumulated osmoprotectants including proline, amino acids, and total protein.

Seaweed extracts also promote freezing tolerance in barley and *A. thaliana* with an increase in winter hardiness when treated with seaweed extract sprays (Ganesan, S et al., 2015). Seaweed extract induced attenuation of the harsh effects of drought, cold, and salinity stress has shown to be mediated through enhanced root morphology, a build-up of non-structural carbohydrates which improved storage of energy, enhanced metabolism, and water adjustments, as well as the build-up of proline. The enhancement and priming effects of seaweed extracts on the plant's defenses against both abiotic and biotic stresses can be attributed to the chemical composition of the extracts as well as its eliciting properties

Effect of algal extracts on plants -Tolerance to biotic stresses

Algal extracts also work as elicitors for plant defense mechanisms against pathogenic bacterial, fungal, and even viral infections, shielding crops from significant economic loss caused by diseases. It has been observed that extracts of different brown, red, and green macroalgae have strong eliciting effects against some harmful bacterial and fungal infections.

There are several fungal and bacterial diseases that are controlled by the application of seaweed extracts. The reduction of infection levels is due to a general improvement of vigor of seaweed extract treated plants, preformed resistance, induced systemic or systemic acquired resistance, or enhanced soil suppressiveness due to altered microbial dynamics

- A recent example of success against nematodes is the use of three microalgae (*Scenedesmus obliquus, Chlorella vulgaris* and *Anabaena oryzae*), alone or in combination, to control the root-knot nematode *Meloidogyne incognita*. All treatments significantly reduced the number of juveniles in soil and the triple mixture was the best at increasing total phenolic content and antioxidant amounts in plants (Hamouda, 2017).

Conclusions

It is obvious that seaweed extracts are continuously gaining more importance within the agricultural sector as excellent choice as organic fertilizers and supplemental fertilizer. Algal extracts gaining the farmer trust because of their applications in increasing agricultural crop productivity. However, gaps are still lingering. Moreover, it will be necessary to make clear at interactions of biomolecules and their molecular functions on the on plant physiology and phenology. Research and development, therefore, must retain in these directions to maximize the potential utility of algal biostimulants in sustainable agriculture.

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