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MARINE MACROALGAE: PLANT GROWTH STIMULATORS

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ABSTRACT

The modern agricultural sector is mainly dependent on synthetic fertilizer for enhancing the growth of crop improvements but a burden of inorganic and chemical-based fertilizer currently created a serious threat to human health as well as the soil environment. Fertilizer research is therefore focusing on an alternative to chemical fertilizer by exploiting natural sources such as marine macroalgae or seaweed. The use of seaweed will be an eco-friendlier approach to sustainable agriculture. Marine macroalgae or seaweed widely applicable in plant growth enhancements due to the presence of biological active phycocompounds such as proteins, phenolic compounds, amino acids, polysaccharides, plant-growth-promoting hormones, and some growth factors, etc. Several research studies have been carried out on the applicability of seaweed or the effect of marine algae or its components on plants and its quality. These types of constituents play their role in improving the morphological as well as biochemical characteristics of plants. The present review study focuses on the applicability of marine macroalgae as a biofertilizer or plant growth stimulator in agricultural applications. This study further helps to improve the nutritional quality of crops which prove to be useful in further investigations and applications.

KEYWORDS: *Seaweed, Marine Macroalgae, Biofertilizer, Growth stimulator, Agriculture*

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1. INTRODUCTION

Generally, soils rarely have adequate essential micro and macronutrients for plant growth development. Therefore, fertilizers are necessary to apply soil for increasing crop productivity in terms of yield and quality.[1, 2] Fertilizer can be defined as any component or material which is added to the soil to fill adequacy of plant nutrients and enhance a number of the plant growth characteristics. It can be classified into two different groups: One is organic or natural fertilizer and another is Inorganic or synthetic fertilizer.[3] Chemical fertilizer contains inorganic chemical components like triple superphosphate, potassium chloride, nitrogen, urea, anhydrous ammonia, etc. These types of chemical constituents or artificial fertilizers are mostly non-biodegradable.[3, 4]

Chemical fertilizers have both negative and positive impacts. Besides advantages, it becomes harmful after long time applications. The use of chemical fertilizers could lead to serious soil acidification, change in soil pH, degrades the soil health and quality, damage plant's morphological as well as nutritional characteristics, and also cause soil pollution.[5] These types of fertilizers kill beneficial microorganisms of soil those are helpful to convert dead animal and plant into nutrient-rich organic matter and important for the biogeochemical cycle. These microorganisms are also useful to convert atmospheric nitrogen to nitrate. Chemical fertilizers increase the nitrate levels of soil and cause soil pollution. These chemical fertilizers contain a high amount of nitrogen, phosphate, and potassium that leach into groundwater and causing water pollution and disrupt aquatic ecosystems.[6] The presence high amount of phosphates, nitrates, mercury, cadmium, arsenic, lead, etc. causes major water and soil pollution.[7, 8, 9,10] All in all, these types of synthetic chemical fertilizers are harmful to all living matter.

To overcome these demerits of chemical fertilizer, biofertilizer is widely applicable in the diversified form in various regions of the world.[11] Various natural materials like animal by-products, animal wastes, crop residues, compost, and many other by-products of living microorganisms as well as bacteria, composted vegetable materials, etc. can be used as a biofertilizer or in its formulation.[12] These fertilizers are easily biodegradable by numerous microorganisms. Besides, this organic or biofertilizer can be prepare from various materials such as Manure, slurry, worm castings, peat, seaweed, sewage, and guano.[13]

The physical and chemical properties may nourish by using organic manures or fertilizers. There are various benefits include it increases soil fertility, crop production, increase the water holding capacity of the soil, and also help to maintain pH.[14,15] Also, it supplements nutrients and improves the biological properties of soil. [16] It has been proven to be highly beneficial for soil as well as its microorganisms. This is an alternative way to reduce the hazardous effects and cost of chemical fertilizers. Besides some other benefits such as protect plants from diseases, improve biological processes such as nitrogen fixation, phosphate solubilization, increase carbon fixation, etc.[17]

Recently, seaweed or marine algae is widely used as a biofertilizer. Seaweed is similarly known as marine macroalgae, macroscopic, multicellular, eukaryotic, photosynthetic marine plant. It has been found attached with rock, sand particles, shells, pebbles, or other marine plants. Mainly, it can be divided into three types based on its photosynthetic pigment as green alga (Chlorophyta), red alga (Rhodophyta), and brown alga (Phaeophyta). Seaweed is widely distributed among the Indian coastline which is more than 7500 km. It is widely distributed on the coast of Tamilnadu, the Western coast of Gujarat, the Gulf of Mannar, Andaman Nicobar, Tuticorin, Kerala, Visakhapatnam, etc.[18, 19, 20] Gujarat has about 1600 km longest coastline which is rich in marine algae diversity. On the western coast of Gujarat, there are many sites such as Dwarka, Beyt Dwarka, Veraval, Okha, Bhavani, Mundra, etc.[21, 22] Seaweed is an alternative way to improve crop yields and for promoting the growth of plants.[23, 24]

Marine macroalgae are rich in diversified chemical constituents such as amino acids, fatty acids, carbohydrates, proteins, lipids, vitamins, minerals, micro, and macronutrients, hormones, enzymes, growth factors such as plant growth-promoting hormones, betaine, algin, etc. Due to the presence of such active phycoconstituents, it can be used in various applications such as the Dairy industry, Pharmaceutical, Agriculture, Food and medicine, Polymer industry, etc. The present review study aims to check the applicability of marine algae as a biofertilizer. This study reviewed different marine algae, its hormone, and their effect on plant growth by different means.

There are various beneficial effects of biofertilizer on plants prepared from marine macroalgae or its components. Different types of marine macroalgae have plant growth-stimulating effects on the plant in terms of morphology (root and shoot parameters) as well as biochemical characteristics (pigment content, etc.) reviewed and tabulated in table 1(See Appendix). Many researchers reported promoting the effect of seaweed on seed germination, plant growth, and soil health.[25-28] Some other benefits include stimulation of seed germination, enhance shoot and root elongation, improve plant health, remediation of pollutants of

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polluted and contaminated soil, resistance towards pathogenic infections, improved water, and nutrient uptake by root elongation, etc.[29, 30, 31] It also contains essential macro and microelements as well as trace elements.[32] Along with, macroalgae contain natural plant-growth-promoting hormones or regulators such as auxin, cytokinin, and abscisic acid-like substances that enhance growth and crop yield.[33, 34, 35]

Role of Phycocompounds derived from marine macroalgae

One of the plant growth hormones, auxin played its role in many physiological and biological functions of the plants as well as in developments of plant resistance to pathogens attack as well as reduce abiotic stress.[36, 37] Likewise, gibberellins hormone has a central role in response to abiotic stress and fruit development.[38, 39] Many researchers found Indole -3- acetic acid (IAA) and another hormone from marine algae that stimulate plant growth and development characteristics.[40] Cytokinins affected plants during the whole cell cycle and influence numerous developmental programs.[41] It is found in many marine macroalgae such as *Porphyra perfroata*, *Sargassum muticum* as well as in green algae *Chara globularis*.[42, 43] Along with, Macro and micronutrients Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S), etc. are very needful for enhancing plant growth that found in seaweed.[6]

Nitrogen has a very essential role in the biochemical and physical functions of plants, nitrogen fixation as well as improve morphological growth.[44, 45] Potassium contributes to an important role in survival under drought stress.[46, 47] Besides, Phosphorus played a major role in seed germination, seedling establishment, and seed development.[48] Like Potassium, Calcium is essential for the resistance of the plants to disease and supports many metabolic processes.[49] Magnesium is required by plants in abiotic stress tolerance. It also plays its role in root and shoots formation, improves photosynthesis.[50, 51] Sulfur is countable as the fourth essential element after nitrogen, phosphorus, and potassium for the functioning of enzymes and protect against oxidative stress.[52] Copper proved itself as an antifungal agent and play its role in photosynthesis and respiratory electron transport chains.[53, 54] Iron is involved in the synthesis of chlorophyll in plants and improve photosynthesis.[55] Manganese played a significant role in oxidation and reduction processes in plants and responsible for the activation of many enzymes.[56, 57] Molybdenum micronutrient is required as catalytically active metal.[58] Deficiencies of zinc can affect a plant by stunting its growth, decreasing the number of fillers, chlorosis, and smaller leaves.[59] Boron is essential for the active growth of root tips and new leaf.[60] Likewise, Silicon alleviates biotic and abiotic stresses in plants.[61] Cobalt is helpful for the formation of leghemoglobin which is involved in the nitrogen fixation process in nodules of leguminous plants.[62]

Michalak et al. (2015) studied biostimulant properties of seaweed extracts by microwave extraction at different temperatures. In all the extracts, they found Na, K, and Ca at higher concentrations.[63] Extract of *Saccorhiza polyschides* is a potential source of essential macro and trace elements studied by Cristina Soares et al. (2020).[64] Lotze et al. (2016) found P, K, and Na macroelements at higher concentrations in three commercial Seaweeds.[65] Godlewska et al. (2017 & 2016) prepared different seaweed extracts by using an aqueous solution with different pH and temperature. In all extracts, they were found Na, K, and Mg present at higher concentrations.[66, 67] Various research studies have been carried out on marine macroalgae, micro, and macronutrients and their effects on plant growth tabulated in table no. 2 (See Appendix).

2. CONCLUSION

A little review study has been carried out to highlight the applicability of seaweed as a biofertilizer. Trends towards natural resources like marine algae best suitable and increase in demand for biofertilization and created various opportunities to reinvestigate the merits and demerits of macroalgal applications. Further, this study helpful to researchers for finding out a piece of information on the seasonal and geographic variability in the specific phycocompounds content found in marine macroalgae to protect plants from pathogens (bacterial, fungal or viral, etc.) as well as improve quality in terms of various parameters such as biochemical composition, morphological parameters in terms of increasing numbers of leaves, branch, stems, flowers, fruits, etc. It is well studied that marine algae are very rich in different types of active constituents which make them resistant to different climatic and environmental stresses and which could also enhance the fertility of agricultural soils and crops. This is surely one of the promising tasks for future investigation and development.

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APPENDIX

Table:1 Role of different marine algae, hormone, and plant growth-promoting effects

No.	Type of algae	Name of algae	Name of hormone/ regulators	Name of plant	Plant growth effect	References
1.	Brown algae	*Durvillea potatorum*	Cytokinins	Soybean	Liquid fertilizer	68,69
2.	Brown algae	*Ascophyllum nodosum*	IAA	Arabidopsis plant	Increasing the root and shoot growth	70
3.	Brown algae	Kelp	Auxin, Ck	Tomato	Promoted root growth	71,72
4.	Red-green algae	*Polysiphonia fucoides, Ulva fleruosa, Ulva clathrate, Cladophora glomerata*	Auxins, Cytokinins, Polyphenols	Garden cress (*Lepidium sativum L.*), Wheat (*Triticum aestivum*)	Enhanced chlorophyll 2 and carotenoid in plant shoot as well as root thickness and above-ground biomass	73
5.	Green-brown algae	*Caulerpa scalpelliformis, Gracilaria corticata*	BAP IBA	*Lycopersicon esculentum* L. (tomato)	endogenous plant growth regulators that enhance the growth of the plant at in vitro and in vivo condition	74
6.	Brown algae	*Ecklonia maxima*	Abscisic acid, Gibberellin, Brassinosteroids	Agricultural plants (rice, wheat)	Increased root and shoot growth, improve nutrient uptake	75
7.	Brown algae	*Ascophyllum nodosum*	Abscisic acid Gibberellic acid	Barley	enhanced germination and seedling vigor in barley	76
8.	Brown algae	*Gracilaria edulis, Sargassum wightii*	Cytokinins, IAA (indole 3 acetic acid) IBA	Tomato (*Lycopersicon esculentum*)	Provide a basis for the production of transgenics with high frequency and survivability of tomato plants	77
9.	Red algae	*Kappaphycus alvarezii*	Indole 3-acetic acid Gibberellin GA3 Kinetin Zeatin	-	-	78

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10.	Brown algae	*Ecklonia maxima*	indole-3-acetic acid (IAA) indole-3-carboxylic acid (ICA) indole-3-aldehyde (IAld) indole-3-acetamide (IAcet) Tryptophan (TRP)	Mung bean	Increasing rooting in mung bean and improve plant growth	79
11.	Brown algae	*Ascophyllum nodosum*	Indole·3-acetic acid (Auxins)	-	Improve growth by foliar uptake	80
12.	Green algae	*Ulva intestinalis*	Cytokinins	Arabidopsis thaliana	Low concentration stimulated root growth	81
13.	Brown algae	*Ascophyllum nodosum*	Abscisic acid	-	Regulate the growth of plants	82
14.	Green algae	*Chara globularis*	Cytokinins	-	Regulate the growth of plants	43
15.	Red algae	*Prionitis lanceolata*	3-hydroxyl indole	Lettuce	Stimulate root growth	83
16.	Brown-green algae	*Sargassum wightii, Ulva lactuca*	Cytokinins, Gibberellin, Auxins	Cluster bean (guar plant)	increased the growth of shoot length.	84
17.	Brown algae	*Stoechospermum marginatum*	Auxin Cytokinin Gibberellin	Brinjal	Lower concentration show promoting effect on growth and productivity of brinjal plants	85

Table:2 Different micro and macro elements of seaweed and its agricultural benefits

NO	NAME OF ALGAE	NAME OF MACRO AND MICRO ELEMENTS	Application	REFERENCES
1	*Laurencia obtuse, Corallina elongate, Jania rubens*	N, K, P	growth parameters	86
2	*Sargassum johnstonii*	Ca, Mg, Na, K, Fe, Cu, Zn, Mn	biofertilizer	87
3	*Kappaphycus alvarezii*	N, P, K, S	Foliar application	88
4	*Kappaphycus, Gracilaria*	N, P, K	Foliar application	89
5	*Stictosiphonia arbuscula, Apophlae alyallii, Scytothamnus australis, Xiphophora gladiata*	C, N	Agricultural application	90
6	*Stoechospermum marginatum*	Cu, Mg, Zn, Fe, K, Mg, Co, Na	Biofertilizer	91
7	*Ascophyllum nodosum*	N, P, K, B, Fe, Mn	Foliar application	92
8	*Saccorhiza polyschides*	K, Na, S, Ca, Mg, Zn, B, Cl, P, Mo, V, Se, I, N, Fe, Mn, Br, Cr, Cd	Agricultural application	93

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