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BIOSTIMULANTS AND BIOEFFECTOR MEDIATED MITIGATION OF ABIOTIC STRESS IN CROP PLANT

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Introduction

The term "bio stimulants" was actually coined by horticulturists for denoting the various substances which are used for promoting plant growth without being a nutrient or pesticides. In a web journal named Ground Maintenance (http://grounds-mag.com), Zhang and Schmidt from Virginia Polytechnic Institute and State University, defined biostimulants as "*materials that, in minute quantities, promote plant growth*".Kauffman et al. (2007) defined biostimilants as 'materials, other than fertilizers, that promote plant growth when applied in low quantities'. Kauffman et al. (2007) summarized bio stimulants by introducing a categorization: 'Bio stimulants in a variety of formulations are generally classified into three major groups on the basis of their source and content. These groups include products contain hormone, humic substances and amino acid containing products. Seaweed extracts contain identifiable amounts of active plant growth substances such as auxins, cytokinins, or their derivatives'. Plant bio stimulants, also referred as agricultural bio stimulants, are group of diverse substances which can be supplemented to the close environment of plants and have positive effect on nutrient uptake and plant growth (du Jardin 2012). Although, the application of plant biostimulants in the rhizosphere facilitates nutrient uptake and plant growth, however, many of these plant biostimulants are reported to alleviate abiotic stresses such as salt, drought and heat stresses (Van Oosten et al., 2017).Over the following years, the term 'biostimulant' is being increasingly applied by the scientific community and literatures increasing the array of substances and of modes of actions as well (Calvo et al., 2014, du Jardin, 2012). Truth be told, 'biostimulant' come into view as a flexible descriptor of any substance advantageous to plants excluding fertilizers, pesticides and soil amendments.Industries and Companies in this particular sector have formed many associations, such as 'European Biostimulants Industry Council' (EBIC) in Europe and the

ISSN PRINT 2319 1775 Online 2320 7876

 UGC CARE Listed (Group -I) Journal Volume 10, Iss 04, 2021

'Biostimulant Coalition' in the USA, with primary aim to dialogue with scientists, stakeholders and regulators. Study and understanding of biostimulants and their possible effect has been growing at a significant rate (Colla and Roupharl 2015). The effectiveness of biostimulants, exclusively in view with plant growth promotion and nutrient uptake, has been examined (du Jardin 2015; Calvo et al. 2014 ;). In addition to plentiful manuscripts, researchers have extensively reviewed various classes of specific biostimulantsincludingseaweed extracts, humic and fulvic acids, protein hydrolysates, phosphite, silicon, chitosan, PGPRs, *Trichoderma*, arbuscular mycorrhizal fungi.

Table 1: Various types of biostimulants reported to alleviate abiotic stresses in crop plants

Stress	Types of Biostimulants	Crop	References
Drought tolerance	*Azospirillumbrasilense*	*Triticumaestivum*	Pereyra et al. 2012; Hamaoui et al. 2001
Drought tolerance	*A. brasilense*	*Lycopersiconlycopersicum*	Romero et al. 2014
Drought tolerance	*A. nodosum*	*Camellia sinensis*	Spann et al. 2011
Drought tolerance	Fulvic and humic acids	*Festucaarundinacea*	Zhanget al. 2002;Zhang et al. 2000
Drought tolerance	Fulvic and humic acids	*Arachispalustris*	Zhang et al. 2004
Drought tolerance	Megafol	*L. lycopersicum*	Petrozza et al. 2014
Drought tolerance	Sea weed extract	*Spinaciaoleracea*	Xu Cet al. 2015

ISSN PRINT 2319 1775 Online 2320 7876

 UGC CARE Listed (Group -I) Journal Volume 10, Iss 04, 2021

Drought tolerance	Sea weed extract	*Spiraeanipponica*	Elansary et al. 2016
Drought tolerance	Sea weed extract	*Pittosporum eugenioides*	Elansary et al. 2016
Drought tolerance and ion homeostasis	Sea weed extract	*Vitisvinifera*	Mancuso et al. 2006
Drought and oxidative stress	Humic acids	*Oryzasativa*	García et al. 2012
Salt tolerance	*A. brasilense*	*Cicer arietinum*	Hamaoui et al. 2001
Salt tolerance	*A. brasilense*	*Viciafaba*	Hamaoui et al. 2001
Salt tolerance	*A. brasilense*	*Lactucasativa*	Barassiet al. 2006; Fasciglione et al. 2015
Salt and osmotic stress	*A. brasilense*	*T. aestivum*	Fasciglione et al. 1997
Salt tolerance	*Pantoeadispersa/ A. brasilense*	*Capsicum annuum*	Del Amor et al. 2012
Salt tolerance	*A. chrococcum*	*Zea mays*	Rojas-Tapias et al. 2012
Salt tolerance	*A. chrococcum*	*T. aestivum*	Chaudhary et al. 2013[25]

ISSN PRINT 2319 1775 Online 2320 7876

Salt tolerance	*A. lipoferum*	*T. aestivum*	Bacilio et al. 2014
Salt tolerance	*Hartmannibacterdiazotrophicus*	*Hordeum vulgare*	Suarez et al. 2015
Salt tolerance and ion homeostasis	Humic acid and phosporous	*Capsicum annuum*	Çimrin et al. 2010
Salt tolerance	Humic acids	*Phaseolus vulgaris*	Aydin et al. 2012
Salt tolerance	Protein hydrolysates	*Z. mays*	Ertani et al. 2012
Salt tolerance, cold tolerance	Protein hydrolysates	*L. sativa*	Botta et al. 2013; Lucini et al. 2015
Salt tolerance	Protein hydrolysates	*Diospyros kaki/D. lotus*	Visconti et al. 2015
Salt tolerance	*Rhizobium leguminosarum*	*V. faba*	Del Pilar Cordovilla et al. 1999
Salt tolerance	*R. leguminosarum*	*Pisumsativum*	Del Pilar Cordovilla et al. 1999
Salt tolerance	Sea weed extract	*Poapratensis*	Nabati et al. 1994
Cold tolerance	*A. nodosum*	*Kappaphycusalvarezii*	Loureiro et al. 2014
Cold tolerance	*Burkholderiaphytofirman*	*Vitisvinifera*	Fernandez et al. 2012;

ISSN PRINT 2319 1775 Online 2320 7876

 UGC CARE Listed (Group -I) Journal Volume 10, Iss 04, 2021

			Theocharis et al. 2012
Cold tolerance	*Flavobacteriumglaciei*	*Solanum lycopersicum*	Subramanian et al. 2016[34]
Cold tolerance	*Pseudomonas frederiksbergensis*	*Solanum lycopersicum*	Subramanian et al. 2016
Cold tolerance	*P. vancouverensis*	*Solanum lycopersicum*	Subramanian et al. 2016
Cold tolerance	*P.dispersa*	*T. aestivum*	Selvakumar et al. 2008
Cold tolerance	Sea weed extract	*Z. mays*	Bradáčová et al. 2016
Cold tolerance	Sea weed extract	*Arabidopsis thaliana*	Nair et al. 2012; Rayirath et al. 2009
Heat tolerance	*P. putida*	*T. aestivum*	Ali et al. 2011
Heat tolerance	*P. putida*	*Sorghum bicolor*	Ali et al. 2009
Heat tolerance	Protein hydrolysates	*Loliumperenne*	Botta et al. 2013
Heat tolerance	Sea weed extract	*Agrostis stolonifera*	Zhang et al. 2008
Ion homeostasis	*A. nodosum*	*Prunusdulcis*	Saa et al. 2015
Ion homeostasis	SWE	*L. sativa*	Möller et al. 1998

ISSN PRINT 2319 1775 Online 2320 7876

Ion homeostasis	Protein hydrolysates	*H. vulgare*	Cuin et al. 2007
Temperature tolerance	*A. chrococcum*	*T. aestivum*	Egamberdiyeva et al. 2009; Egamberdiyeva et al. 2004
Chilling stress	Glycinebetaine	*L. lycopersicum*	Park et al. 2004
Chilling tolerance	Melatonin	*Z. mays*	Kołodziejczyk et al. 2016
Heavy metal tolerance	Protein hydrolysates	*T. aestivum*	Zhu et al. 2006

Algal Extract

Marine algae commonly known as seaweeds constitute a vital part of marine coastal ecosystem. These seaweeds comprise of the multicellular marine algae that frequently reside in the coastal area of the oceans where proper substrata present. Approximately about 9,000 species of macroalgaehave been estimated and are broadly classified into three primarycategories based on their pigments. These classes are brown, red, and green algae or Phaeophyta, Rhodophyta, and Chlorophyta; respectively. Among them second most abundantly present group having approximately 2000 species is brown seaweeds. These seaweeds attain their utmost biomass levels near rocky shores of the temperate zones. They are the most commonly used seaweeds in agriculture (Blunden and Gordon 1986) and, among them, *Ascophyllumnodosum* (L.) Le Jolis is the most investigated species and used in agriculture (Ugarteet al. 2012).

In addition to A. nodosum, other species of brown algae such as *Laminaria* spp., *Fucus* spp., *Sargassum* spp. and *Turbinaria* spp. are currently being used as biofertilizer in agriculture (Hong et al. 2007). These seaweeds have a potential of prominent source of organic matter and nutrient and thus have been used as soil conditioner for the centuries (Mettinget al. 1988; Temple

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and Bomke 1988). Approximately 15 million MT of seaweeds are produced annually, and a significant portion of these products are used as biostimulants and biofertilizers. A range of commercially available SWEs are being used in agricultural and horticultural plants (Table 2). Extensive researches and studies have revealed the various beneficial effects of SWEs on plant health and growth, improved crop yield and elevated tolerance to the biotic and abiotic stresses(Beckett and van Staden 1989; (Fig. 1).

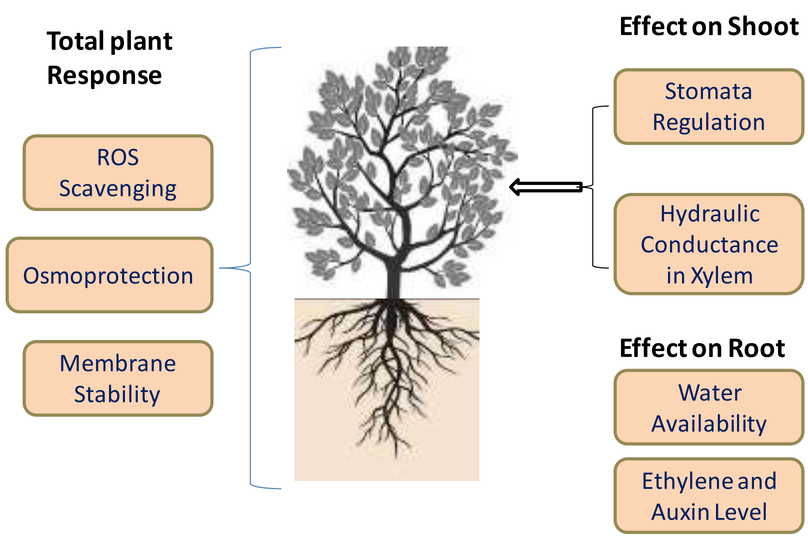

Figure 1: Main key mechanism by seaweed extracts

The role of SWEs in alleviating the cold stress in crop plants has been studies. In recent investigations the research work has focused on SWEs and their potential role in enhancing tolerance to the chilling stress. Bradáčová et al. 2013, has tested multiple extracts for their capacity to enhance cold tolerance in maize. He reported that the extract rich in Zn and Mn were only able to mitigate the cold stress via enhanced ROS response. These outcomes specify that nutrient deficiency in plant induced by cold stress can be overcome by applying SWEs to advance oxidative stress tolerance. In priorresearchwith corn seedlings subjected to root chilling stress and treated with essential micronutrients confirmed the efficacy of nutrient seed priming (Imran et al. 2013)

ISSN PRINT 2319 1775 Online 2320 7876

 UGC CARE Listed (Group -I) Journal Volume 10, Iss 04, 2021

SWEs have been extensively used in horticultural crops and trees. *A. nodosum* extract is reported to increase the fresh and dry weight in spinach plant under drought stress. Lettuce plant treated with SWEs showed enhanced cotyledon growth resemblance to potassium fertilization (Mollar et al. 1998)Grape plants subjected to the foliar application with marine bioactive isopropanol extract of microalgae showed increased stomataal conductance and leaf water potential under drought stress

Table 2: Commercially available seaweed products used in agriculture

Seaweed Name	**Product Name**	**Manufacturing Company**	**Application**
Ascophullumnodosum	Acadian®	Acadian Agritech	Plant Growth stimulant
A. nodosum	Agri-Gro Ultra	Agri-Gro Marketing Inc.	Plant Growth stimulant
Lithothamnioncalcareum	Acid Buf	Chance & Hunt Ltd.	Plant Growth stimulant
A. nodosum	Espoma	The Espoma Company	Plant Growth stimulant
A. nodosum	Alg-A-Mic	Biobizz Worldwide N.V.	Plant Growth stimulant
A. nodosum	Kelpro	TecniprosesosBiologicos, S.A. de C.V.	Plant Growth stimulant
A. nodosum	Kelprosoil	Productos del Pacifico S.A. de C.V.	Plant Growth stimulant
A. nodosum	Stimplex	Acadian Agritech	Plant Growth stimulant
A. nodosum	Synergy	Green Air Products Inc.	Plant Growth stimulant
A. nodosum	Tasco	Acadian Agritech	Plant Growth stimulant
A. nodosum	Maxicrop	Maxicrop USA Inc.	Plant Growth stimulant
A. nodosum	Nitrozime	Hydrodynamics International Inc.	Plant Growth stimulant
Microcystispyrifera	Agro-Kelp	Algas y BioderivadosMarinos, S.A. de C.V.	Plant Growth stimulant
Red Marine Algae	Emerald RMA	Dolphin Sea Vegetable	Plant Growth stimulant

ISSN PRINT 2319 1775 Online 2320 7876

		Company	
Durvelleapotatorum	Seasol	Season International Pty Ltd.	Plant Growth stimulant
Ecklonia maxima	Kelpak	BASF	Plant Growth stimulant
Durvelleaantarctica	Profert	BASF	Plant Biostimulant

Conclusion

Abusive use of synthetic chemicals in agriculture has led to the hazardous effect on the human, animal and ecosystem health. Safeguarding the food security for increasing population while maintaining the ecosystem harmony is the prime challenge for the scientists. Crop production is hampered by various biotic and abiotic stresses. Various strategies have been used to alleviate the abiotic stresses in crop plants. Various biostimulants, mainly seaweed extracts have been reported to mitigate the abiotic stresses in crops. These SWEs have provided the sustainable solution to the crop management under abiotic stresses. Further investigation and studies is required to understand the mechanisms of these SWEs and other biostimulants.

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