International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

Vol. 39 No. 2 July 2023, pp. 304-310

An Overview: Seaweed Extract as Biostimulant

Millania Putri Shayen, Zozy Aneloi Noli*, Tesri Maideliza

Departement of Biology
Faculty of Mathematics and Natural Sciences
Padang, Indonesia
*zozynoli@sci.unand.ac.id

Abstract—Applying biostimulants to plants can improve their physiological functions, promoting growth and decreasing the impacts of stress factors on plants. Seaweed is one of the biostimulant sources that are widely explored on crops recently. Seaweed extract can improve plant growth at all stages including, germination, harvest, and even post-harvest. A variety of beneficial compounds in seaweed extract stimulates plant growth such as minerals, secondary metabolites, growth-promoting hormones, vitamins, and other bioactive compounds. A recent study showed that there are several factors affecting the effect of seaweed extract on crops such as types of seaweed, types of plants, concentration, and extraction method of seaweed extract. Several research reported that biostimulant can be more effective in combination with other bioactive compounds. Concerns about the effectiveness of this biostimulant are required in order to find the best formula for increasing plant development.

Keywords— Biostimulant; Concentration; Seaweed,

I. INTRODUCTION

A plant biostimulant is any substance applied to plants to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits, and its nutrient content. [1]. Insecticides and fertilizers act on plant metabolism differently, they directly supply nutrients to plants. Biostimulants differ from insecticides and fertilizers by their acting on plant metabolism, providing nutrients directly to plants [2]. Biostimulants are also able to activate several physiological processes that increase the efficiency of nutritional use and stimulate plant development [3]. Biostimulants decrease stress tolerance and increase plant growth, flowering, fruit production, and plant productivity [4]. Several studies have also shown that biostimulants may improve edible items' nutritional content and shelf life [5]. Some resources show that biostimulants include microorganisms (beneficial bacteria, mainly PGPRs, and beneficial fungi) and substances (chitosan, humic fulvic acid, protein hydrolysate, plant extract, and seaweed extract) (Calvo et al., 2014; du Jardin, 2015).

Seaweed represents most of the ocean biomass, which is about 25,000 - 30,000 species. Seaweed is found around the world's coastlines. Seaweed contains bioactive compounds that increase beneficial functions in food, pharmacy, industry, and agriculture [6]. Seaweed offers a lot of potential for sustainable agriculture. Seaweed Extract (SWE) has been widely studied as a biostimulant including phaeophyta, rhodophyta, and chlorophyta (brown, red, and green macroalgae). Seaweed has high beneficial content that leads to increased plant growth and yield.

Bioactive content in seaweed that lead to promoting plant growth. Certain nutrients and plant bioactive compounds, these substances can directly or indirectly change plant metabolism and physiology, improve soil conditions, and improve food quality. This content is not just used for nutritional use but can also be an activator or precursor to produce compounds that stimulate plant growth [3]. Seaweed extract is rich in macro and micronutrients (Na, K, Ca, Mg, Fe, Zn, Mn, and Cu) that are important for plant growth and development. Growth-promoting hormones (kinetin, zeatin, IAA, gibberellins, auxins, and cytokinins) in seaweed

Corresponding Author: Zozy Aneloi Noli

extract that may increase plant growth and yield by promoting cell proliferation, elongation, and differentiation. Seaweed extract also contain secondary metabolites (flavonoid, phenolic, terpenoid, saponin, steroid, and alkaloid) that can improve plant growth and stress tolerance. Seaweed also contains protein, carbohydrates, amino acids, and vitamins that can initiate physiological processes in plant [5].

The effectiveness of biostimulant on plants is influenced by several factors environmental conditions, dosage and application time, genetic diversity, biostimulant composition, purpose of use, and application method, and extraction method [3]. Environmental factors affecting biostimulant effect such as temperature, humidity, light, and soil type [7]. Because of the variety of types, amounts, and qualities of substances found in seaweed, we should use the suitable formula to offer optimal impacts on plant growth. Combining biostimulants with additional bioactive substances can result in synergistic effects, targeted impacts, improved plant nutrition, and crop management customization and flexibility. This strategy can maximize the benefits and efficiency of biostimulant treatments in increasing plant growth and production of crops [4]. Understanding these variables may assist in optimizing the usage of biostimulants to obtain the expected results.

II. RESULT AND DISCUSSION

The recent study of the application of seaweed extract as biostimulant to improve growth and yield of plants. There are several factors affected the effect of seaweed extract on plants including:

A. Types of seaweed and crops

Studies about the effect of the types of seaweed extract on growth and yield of plants showed in Table 1.

TABLE I. EFFECT OF THE TYPES OF SEAWEED EXTRACT ON GROWTH AND YIELD OF PLANTS

Seaweed Spesies	Plant	Treatment response	Reference
Ascophyllum nodosum	Carrot	Increase in soil microbial activity associated and yield	[9]
	Tomato	Improved germination percentage as well as other growth parameters, including root and shoot length and seedling dry weight	[10]
	Onion	Increased the yield, nutrient contents, and total soluble solids (TSS)	[11]
	Tomato	Improve productivity gains.	[12]
	Onion	Increase total soluble solids, mineral content (N, P, and K), bulb weight and yield	[11]
Kappaphycus alvarezii	Soybeans	Highest grain yield	[13]
	Amaranthus polygamous	Improved water uptake and nutrients, which ultimately led to the promotion of overall vigor and the growth of plants.	[14]
Padina minor	Soybean	Increasing plant height	[15]
	Rice	Increase root wet weight, grain weight per clump, and 100-grains weight	[16]
	Soybean	*Padina minor* was the best increase plant height, number of leaves, number of branches and fresh weight	[17]
Sargassum wightii	Rice	Improved germination percentage, germination speed, shoot length, root length, and seedling fresh and dry weight.	[18]

The compatibility of the biostimulants and plants used is crucial. Each of seaweed spesies may have a different composisition. The bioactive compound of each spesies biostimulants can affect their effectiveness [19]. Biostimulants are able to give effect when integrated into plant tissues ussualy from the leaves. The chemical structure and bioactive components of biostimulants sources have a significant impact on their penetration and absorption into the leaves, particularly in the cuticle. Besides, the permeability of the leaves varies on each spesies [3]. The genetic variability of plants can affect the response to biostimulants. Therefore, when tested on different plants, the effects of biostimulant could not always be the same [7].

B. Concentration of seaweed extract

Studies about the concentration of seaweed extract on growth and yield of plants showed in (Table 2).

TABLE II. EFFECT OF CONCENTRATION OF SEAWEED EXTRACT ON GROWTH AND YIELD OF SEVERAL ON PLANTS

Seaweed Spesies	Plant	Concentration	Treatment response	Reference
Kappaphycus alvarezii and *Gracilaria edulis*	*Vigna radiate* L	2.5%, 5%, 10%, and 15%, 7.5%	Enhanced quality of grains in terms of protein, P and K content.	[20]
Kappaphycus alvarezii and *Gracilaria edulis*	Rice	2.5, 5, 10 and 15%	10% concentration spray recommended to obtain high yield and grain quality	[21]
Kappaphycus alvarezii	*Amaranthus polygamous*	10% and 50%	Less saline water	[14]
Sargassum crassifolium	Rose	10%, 20% and 30%	Promoting growth and flowering of roses	[22]
Ecklonia maxima	Soybean	0.7% and 1.0%.	Improved the growth and yield	[23]
Padina minor	Soybean	0, 10, 20, 30, and 40%	40% with 1x application increase plant height and shorten soybean harvest life. While, 40% with 2x and 3x applications increase the gross and dry weight of plants, the number of pods, gross and dry mass of whole seeds.	[17]
Padina minor	Soybean	0.1%, 0.2%, 0.3% and 0.4%	*Padina minor* 0.4% was most effective stimulating the vegetative growth of soybean, and therefore, they can be considered as a potential source of bio stimulant to enhancing the growth of	[17]

The positive effect of biostimulant extract highly influenced by the dose and concentration [3]. Plant growth can be enhanced by using biostimulant at an appropriate concentration [24]. Because the extracts contain various amounts of bioactive chemicals, concentration plays a key role in determining biostimulant effect [25]. Bioactive compound can act positive effect on plant in optimum concentration. Biostimulant usually effective at lowest concentration dose to get desire effect [26]. Meanwhile, high amounts of seaweed extract can inhibit plant growth. The extracting of the seaweed extract product results in the loss of biostimulant activity, indicating the key role of the organic fraction of these seaweed extracts in inducing positive growth responses in plants [27]. However, using large amounts may not be economical. As a result, it is critical to employ the proper concentration to obtain the required results while wasting resources [28]

C. Extraction Method

Studies about the concentration of seaweed extract on growth and yield of plants showed in Table 3.

TABLE III. EFFECT OF EXTRACTION METHOD OF SEAWEED EXTRACT ON GROWTH AND YIELD OF PLANTS

Seaweed Sesies	Plant	Extraction method	Treatment response	Reference
Padina minor	Rice	water, ethanol, methanol	Methanol was the best type of solvent increase productivity of upland rice.	[16]
Sargassum sp	Corn	acidic, alkaline, and water-based	The acidic extract gavethe highest growth promotion with the lowest phytohormones content.	[29]
Sargassum crassifolium	Soybean	Liquid and powder	Liquid extract improve root system, fresh and dry weight, chlorophyll content, and 100 seeds weight. While, powder extracts shown the best result on the total seed weight.	[30]
Sargassum myricocystum	Pigeonpea	Nanoformulation	Improve plant height, total chlorophyll content, leaf area index, crop growth rate, relative growth rate and yield attributes,	[31]

The extraction method chosen should be able to deal with the complexity of the seaweed composition while maintaining the integrity of biologically active compounds with biostimulant potential. The most common extraction method is alkaline extraction at high pressure. Seaweeds are extracted using both physical procedures (heat, pressure, and microwaves) and chemical methods (solvents, acids, and alkalis). The extraction procedures have a significant impact on the content of seaweed extracts [27]. The complex compounds, including polysaccharides, are transformed into oligomers during the extraction process, which are extremely bioactive in plants. The critical extraction process, as well as the influence of such products on nutrient intake and their function in abiotic and biotic stress tolerance, are being studied with a focus on the relevant mechanisms at the metabolic and genetic levels [28]. As a result, the seaweed extraction process is crucial because it influences the quality and composition of the seaweed extract, which in turn influences its biostimulant properties.

D. Combination with another compound

Studies about the concentration of seaweed extract on growth and yield of plants showed in Table 4.

TABLE IV. COMBINATION OF SEAWEED EXTRACT WITH ANOTHER BIOACTIVE COMPOUND ON GROWTH AND YIELD OF PLANTS

Types of seaweed	Combination	Crops	Treatment response	Reference
Ecklonia maxima and *Saragassum*	Humic and fulvic acids	Corn	Promote shoot and root growth.	[32]
Sargassum cristaefolium	Amino Acid	Rice	Increase growth and yield	[33]
Sargassum sp	Polysaccharide	*Vigna radiate* L	8% polysaccharide content and 15% liquid seaweed extraction content resulting in 14% and 8% of germination increment against the control.	[34]
Padina minor	*Centella*	Soybean	Increasing plant height, number of leaves, leaf	[15]

	asiatica		area and wet weight of soybeans planted.	
Padina minor	BSF (Black Soldier Fly)	Soybean	Increasing the number of leaves, leaf area, chlorophyll b, and total chlorophyll.	[35]
Padina minor	Amino acid	Rice	Not gave significantly effect	[36]

Plant growth and development can be aided by combining seaweed biostimulant with another bioactive component. This is due to the synergistic effect, targeted effects, plant nutrition content, and for customization and flexibility factor[37]. Every seaweed extract contain different compound variety and the level. The additional of another compound can improve and complement the compounds present in biostimulants. [28]. The plant growth induced by biostimulants can be associated with an increase of amino acids and enhanced protein biosynthesis [3]. Observation with polysaccharide showed that the higher growth at a lower concentration of polysaccharide compared to seaweed extract is attributed to a higher concentration of growth regulators in polysaccharide than seaweed extract, which may have enhanced photosynthesis, driving vegetative development [34]

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