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Potential of liquid extracts of *Sargassum wightii* on growth, biochemical and yield parameters of cluster bean plant

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ABSTRACT

Objective: To explore biofertilizing efficiency of seaweed liquid extracts of brown alga *Sargassum wightii* (*S. wightii*) on growth, biochemical and yield parameters of *Cyamopsis tetragonoloba* (*C. tetragonoloba*). **Methods:** Seaweeds were made to coarse powder and stock solution was prepared. Different concentrations such as 0.5%, 1.0%, 1.5%, 2.0%, 2.5% and 5.0% were prepared and given as foliar spray. **Results:** Seaweed Liquid Extract (SLE) at low concentration (1.5%) exhibited promoting effect on growth and yield parameters. Differential responses in the content of photosynthetic pigments, protein, reducing sugar, ascorbic acid and in the activity of nitrate reductase were also observed in the leaves of SLE treated seedlings when compared to untreated seedlings. Higher concentrations (above 1.5%) of SLE were found to show inhibitory effect. **Conclusion:** The presence of micro and macro nutrients, vitamins, growth hormones and other constituents in the seaweed extract might be very much useful to the crops but their level should be appropriate to enhance growth and productivity. It may be concluded that liquid seaweed extracts could serve as cost effective eco-friendly product for sustainable agriculture.

1. Introduction

Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health including biodiversity, biological cycles, and soil biological activity. Synthetic fertilizers were used widely in those days for agricultural purposes which had led to cause severe health and environmental hazards such as soil erosion, water contamination, pesticide poisoning, water logging, salinisation, depletion of biodiversity, etc. Thus, farmers are switching over to organic fertilizers for sustainable agriculture. Unlike chemical fertilizer, manure derived from living resources is biodegradable, non-toxic, non-polluting and non-hazardous to soil ecosystem [1].

Seaweeds are the macroscopic marine algae found attached to the bottom in relatively shallow coastal water. Liquid fertilizers derived from natural sources like seaweeds are found to be viable alternatives to fertilizing input for agricultural crops due to its high level of organic matter, micro and macro elements, vitamins, fatty acids and also rich in growth regulators [2]. Seaweed extract is a new generation of natural organic fertilizers containing highly effective nutritious source and promotes faster germination of seeds, increase in yield and resistant ability of many crops [3]. The organic matter of seaweeds increases humus content of the soil, thereby ameliorating the soil texture and preservation of its moisture.

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Seaweed liquid fertilizer is a blend of both plant growth regulators and organic nutrient input is eco–friendly promoting sustainable productivity and maintaining soil health. In recent years, the use of natural seaweed products as substitutes to the conventional synthetic fertilizers has assumed importance [4–6]. Thus, the extracts are applied to improve nutritional status, vegetative growth, yield and fruit quality in crop plants [7–9]. Liquid crude extracts derived from marine algae such as *Cladophora* [10], *Gracilaria* [11] were reported to have manurial efficiency. The present study was undertaken to evaluate the fertilizing efficiency of seaweed liquid extracts of brown marine alga *Sargassum wightii* on cluster bean(*S. wightii*).

2. Materials and methods

2.1. Preparation of seaweed liquid extracts (SLE)

The marine alga *S. wightii* belongs to Phaeophyceae was collected from Mandapam (Lat 9 ° 45′N; Long79 ° 15′E) located in South East Coast of Tamilnadu. The alga was brought to the laboratory and washed thoroughly in tap water for 3 times to remove all epiphytes, sand particles and associated fauna. The wet weight of sample of collected brown alga was taken, shade dried and then the sample dry weight was determined. Different concentrations of boiled extracts were prepared by mixing appropriate level of liquid extracts with distilled water [12]. The SLE concentrations used in this experiment were ranged from 0.5% to 5.0%.

2.2. Physico–chemical and hormone analyses of SLE

The physical characteristics such as colour and pH were observed using standard method. The composition of elements such as copper, manganese, iron, zinc, cobalt, potassium, magnesium and sodium were estimated using Atomic Absorption Spectrophotometer [13]. Further, the liquid extract of marine alga was also subjected for estimation of auxin [14], gibberellin [15] and cytokinin [16].

2.3. Growth promoting efficiency of SLE on cluster bean seedlings

Seeds of cluster bean were purchased from Agriculture College and Research Institute, Madurai. Healthy seeds free from visible infection, with uniform size were segregated. They were surface sterilized with 0.1% mercuric chloride and then sown in earthen ware pots (9 cm dia) filled with sterilized standard soil mix supplemented with sufficient quantity of NPK. The seed to seed distance in pot was maintained as 3–5 cm and the pots were irrigated regularly. Foliar application of different concentrations (0.5% to 5.0%) of liquid extracts was given to potted plants after 20 days. Routinely, separate set of potted plants were used for each concentrations. About 50 mL of different concentrations of extracts was given at interval of 3 days for a period of 15 days. Growth parameters viz., shoot length, root length, total height, total fresh and dry weight, leaf area and moisture content were determined. Biochemical profiles such as photosynthetic pigments [17], protein [18], reducing sugar [19], ascorbic acid [20] and nitrate reductase activity were assessed in the leaves of treated plants. Growth and biochemical parameters were observed in 5 weeks old treated and control plants. Yield characteristics were measured in 90 days old plants. All pot experiments were done in four replicates each under natural uniform conditions.

2.4. Statistical analysis

Data were subjected to one–way ANOVA and means were separated by Duncan′s test (P<0.05, n=5). Statistical analysis was carried out using IRRISTAT ver. 4.0 (IRRI, Manila, Phillipines) [21].

3. Results

The manurial analyses of liquid extract of our experimental brown marine alga revealed the presence of potassium (1.37 mg/L), copper (2.2 mg/L), manganese (1.53 mg/L), zinc(1.8 mg/L), iron (0.88 mg/L), cobalt (1.103 mg/L), sodium (5.3 mg/L) and magnesium (16.31 mg/L) in appreciable level. Among the elements estimated, magnesium (16.31 mg/L) was found to be abundant in the extract. Similarly, in case of phytohormones analysis, cytokinin (5.5 mg/L) was found to be more when compared to auxin (2.5 mg/L) and gibberellins (2.8 mg/L).

In our experiments, use of seaweed liquid extracts of *S. wightii* significantly promoted the rate of growth and physiology of cluster bean. There was a noticeable increase in growth and biochemical parameters when 1.5% of seaweed liquid extracts of *S. wightii* applied to cluster bean plant. Higher concentrations (2.0% and above) were found to show inhibiting effect on all the above parameters studied. Total plant height (33%), total fresh weight (155%), dry weight (140%), leaf area (61%) and moisture content (55%) were enhanced when 1.5% concentrations of liquid extracts was applied. Further, the retarding effect (reduction by 2% to 27%) in growth parameters was corresponding to increase in the concentrations (2.0%, 2.5% and 5.0%) (Table 1). Statistically significant differences were noticed in total plant height fresh and dry weight, leaf area and moisture content. Similarly, cluster bean plants when treated with different concentrations of *S. wightii* extracts showed differential responses in biochemical parameters also. (Table 2). The amount of photosynthetic pigments (by 78%), protein (by 73%), sugar (by 101%) and the activity of nitrate reductase (by 159%) were found to be enhanced in cluster bean plants when 1.5% concentrations of extract were given. Other treatments such as 2.0%, 2.5% and 5.0% showed reduced levels of these parameters in the treated plants.

The observations on yield attributes revealed that *S. wightii* at 1.5% concentration enhanced the formation of number of clusters/plant (56%), number of flowers/plant (93%) and number of pods/plant (55%). Moreover, pod weight (by 53%), pod length (40%) number of pods/plant (by 55%) were also increased when compared to untreated plants (Table 3). Inhibitive effect (reduction by 20%–48%) was observed when the plants were treated with higher concentrations (2.0%, 2.5% and 5.0%).

In general, low concentrations of liquid extracts of seaweed extracts had maximum positive influence on growth, biochemical and yield characteristics of cluster bean as reported in previous studies due to the presence of micro and macro elements, growth hormones and vitamins [58-60]. Further, presence of phycocolloids and other ingredients in brown algae may also be responsible for better enhancement in growth and yield production.

Table 1

Influence of liquid extracts of *S. wightii* on growth characteristics of cluster bean.

Treatments	Shoot length (cm)	Root length (cm)	Total height (cm)	Total fresh wt (mg)	Total dry wt (mg)	Leaf Area (mm^2)	Moisture content (%)
Control	8.725^{b}	12.250^{a}	20.000^{ab}	1.015^{a}	0.400^{a}	42.115^{b}	41.533^{a}
0.5%	9.325^{b}	13.050^{ab}	21.400^{bc}	1.130^{bc}	0.492^{b}	44.183^{b}	54.685^{bc}
	(106)	(106)	(107)	(111)	(123)	(104)	(131)
1.0%	10.000^{c}	13.400^{bc}	23.325^{bc}	1.620^{de}	0.620^{c}	50.790^{c}	63.645^{bc}
	(114)	(109)	(116)	(159)	(155)	(120)	(152)
1.5%	11.400^{cd}	15.250^{d}	26.650^{bc}	2.595^{f}	0.962^{d}	68.165^{d}	64.825^{c}
	(130)	(124)	(133)	(255)	(240)	(161)	(155)
2.0%	10.300^{c}	14.450^{cd}	24.750^{c}	1.800^{e}	0.605^{c}	58.400^{d}	64.808^{c}
	(118)	(117)	(123)	(177)	(151)	(138)	(155)
2.5%	8.950^{b}	14.200^{cd}	23.150^{bc}	1.365^{cd}	0.515^{b}	43.425^{b}	53.720^{b}
	(102)	(115)	(115)	(134)	(128)	(102)	(128)
5.0%	6.425^{a}	12.300^{a}	18.725^{a}	0.915^{ab}	0.400^{a}	35.450^{a}	55.785^{bc}
	(73)	(100)	(93)	(90)	(100)	(84)	(133)

Means sharing different letters within the columns are significantly different ($P<0.05$ level), different letters followed in each column statistically significant based on DMRT, values in parenthesis are per cent over control.

Table 2

Influence of liquid extract of *S. wightii* on biochemical characteristics of cluster bean.

Seaweed extract treatments	Chlorophyll-a (mg/g fr.wt)	Chlorophyll-b (mg/g fr.wt)	Total chlorophyll (mg/g fr.wt)	Protein (mg/g fr.wt)	Reducing sugar (mg/g fr.wt)	Ascorbic acid (mg/g fr.wt)	NRA (μ moles No-2/g fr.wt/hr)
Con	0.5225^{a}	0.4200^{a}	0.9425^{a}	19.200^{b}	41.650^{a}	0.568^{a}	0.820^{a}
0.5%	0.6500^{a}	0.4450^{b}	1.095^{a}	24.550^{b}	55.850^{b}	0.656^{ab}	1.090^{b}
	(124)	(105)	(116)	(127)	(134)	(115)	(131)
1.0%	0.6650^{ab}	0.515^{c}	1.180^{c}	28.250^{c}	62.650^{c}	0.700^{c}	1.635^{d}
	(127)	(122)	(125)	(146)	(150)	(123)	(190)
1.5%	0.975^{d}	0.710^{d}	1.685^{d}	33.30^{d}	84.10^{d}	0.775^{bc}	2.125^{e}
	(186)	(168)	(178)	(173)	(201)	(136)	(259)
2.0%	0.805^{c}	0.530^{b}	1.335^{b}	26.625^{bc}	66.80^{c}	0.637^{ab}	1.725^{d}
	(154)	(126)	(141)	(138)	(160)	(112)	(210)
2.5%	0.650^{c}	0.442^{b}	1.092^{a}	21.350^{a}	51.50^{b}	0.593^{a}	1.345^{c}
	(124)	(105)	(115)	(111)	(123)	(104)	(164)
5.0%	0.590^{b}	0.315^{a}	0.905^{a}	19.90^{a}	39.10^{a}	0.562^{a}	0.970^{ab}
	(112)	(74)	(96)	(103)	(93)	(98)	(118)

Means sharing different letters within the columns are significantly different ($P<0.05$ level), different letters followed in each column statistically significant based on DMRT, values in parenthesis are per cent over control.

Table 3
Influence of liquid extracts of *S. wightii* on yield parameters of cluster bean.

Seaweed treatments	Number of clusters/ plant	Number of flowers/ plant	Number of Pods/ plant	Pod length (cm)	Pod weight (g)	Number of seeds/ pod
Control	4.000^{bc}	4.000^{bc}	2.250^{a}	6.250^{bc}	3.075^{ab}	6.250^{c}
0.5%	4.750^{cd}	5.000^{cd}	2.500^{ab}	6.750^{cd}	3.350^{ab}	6.750^{cd}
	(118)	(125)	(111)	(108)	(108)	(108)
1.0%	5.500^{de}	6.500^{de}	3.250^{bc}	8.250^{e}	3.750^{bc}	8.250^{e}
	(137)	(162)	(144)	(132)	(121)	(132)
1.5%	6.250^{e}	7.750^{e}	3.500^{c}	8.750^{de}	4.725^{c}	8.750^{e}
	(156)	(193)	(155)	(140)	(153)	(140)
2.0%	5.000^{cd}	4.750^{cd}	2.500^{ab}	6.750^{cd}	4.125^{bc}	7.750^{de}
	(125)	(118)	(111)	(108)	(134)	(124)
2.5%	3.500^{b}	3.500^{ab}	2.500^{ab}	5.500^{b}	3.500^{ab}	5.000^{b}
	(88)	(87)	(111)	(88)	(113)	(80)
5.0%	2.500^{a}	3.000^{a}	1.750^{a}	3.750^{a}	2.600^{a}	3.250^{a}
	(62)	(75)	(77)	(60)	(84)	(52)

Means sharing different letters within the columns are significantly different ($P<0.05$ level), different letters followed in each column statistically significant based on DMRT, values in parenthesis are per cent over control.

4. Discussion

The presence of phytohormones is in accordance with the earlier findings that reported auxins in the extracts of *Ascophyllum nodosum* (*A. nodosum*) [22] and cytokinins in the extracts of *Ulva* sp.[23], *Durvillaria potatorum* (*D. potatorum*) and *A. nodosum* [24]. Our findings also corroborated with the previous reports made on *Dolichos biflorus* (*D. biflorus*) [11], *Solanum melongena* (*S. melongena*) [25], *Triticum aestivum* (*T. aestivum*) [26], *Abelmoschus esculentus* (*A. esculentus*) [27; 28], *Cajanus cajan* (*C. cajan*) [5], *Brassica nigra* (*B. nigra*) [29], *Lycopersicon esculentum* (*L. esculentum*) [30], *Cyamopsis tetragonoloba* (*C. tetragonoloba*) [31] and *Vigna mungo* (*V. mungo*) [3]. Moreover, lower concentration of 1% *Padina boergesenii (P. boergesenii)* and *Ulva lactuca* (*U. lactuca*) extract significantly increased the shoot length, leaf breadth, leaf length, root length and number of roots in *Rhizophora mucronata* (*R. mucronata*) [32] and *Arachis hypogea* (*A. hypogea*) plants [33] respectively. On the contrary, it has been reported that concentration at 20% of *S. wightii* [34] and *Rosenvingea intricate* (*R. intricate*) [35] promoted shoot length, root length, fresh and dry weight of *Abelmoschus esculentus* (*A. esculentus*) and *Cyamopsis tetragonolaba* (*C. tetragonolaba*) respectively. Growth enhancement by seaweed extracts may be due to components such as macro- and microelement, amino acids, vitamins, cytokinins, auxins and abscisic acid (ABA)-like growth substances which affects cellular metabolism in treated plants leading to enhanced growth and crop yield [36-38]. The increased growth of these crops may be due to the occurrence of some growth promoting substances present in the seaweed extract [39, 40]. These hormones play an important role in enhancement of cell size and cell division and together they complement each other as cytokinins are effective in shoot formation and auxin in root development, while micronutrient improve soil health[41]. Several studies have shown that kelp extracts increased nutrient uptake to plants by chelating nutrients due to presence of some organic acids [9, 42]. Therefore, the higher growth rate in lower concentration of extracts may be directly attributed by the presence of optimum level of essential nutrients and phytohormones as observed during chemical analysis of SLE of *S. wightii*.

Lower concentrations of *S. wightii* (1.5%) enhanced the biochemical components also. This is in accordance with the earlier reports that lower concentrations of seaweed extracts enhanced the biochemical constituents in *C. cajan* [5], *B. nigra* [29], *Citrullus lanatus* (*C. lanatus*) [43], *Trigonella foenum-graecum* (*T. foenum-graecum*) [32], *Solanum melongena* (*S. melongena*) [44], *Abelmoschus esculentus* (*A. esculentus*) [28]. The increase in photosynthetic pigments may be due to the presence of betaines [40], increase in number and size of the chloroplast and better grana development [45]. The increase in the protein content at lower concentrations of SLE confirmed the efficiency of foliar spray as it enhanced the absorption of most of the necessary elements by the seedlings [11]. It would also be associated with increased nitrate reductase activity in the treated plants. The increase in chlorophyll content could also be a result of reduction in chlorophyll degradation, which might be caused in part by betaines in the seaweed liquid extract [46]. It may also be attributed with abundance of elements like magnesium which plays vital role in organization of chlorophyll pigments. However, it has been reported that seaweed liquid fertilizer at 10% extracted from brown alga *S. wightii* increased the content of photosynthetic pigments, protein and total sugars in *Vigna radiata* (*V. radiate*) [47] and SLE of *Rosenvingea intricate* (*R. intricate*) at 20% enhanced the photosynthetic pigments and carotenoids in *C. tetragonoloba* [35]. Moreover, in a study, 1% *Ulva lactuca* (*U. lactuca*) extract along with 50% recommended rate of chemical fertilizers enhanced the content of protein, carbohydrate and lipid in *Tagetus erecta* (*T. erecta*) [48].

In many crops, yield is associated with the number of flowers at maturity. As the onset and development of flowering and the number of flowers produced are linked to the developmental stage of plants, seaweed extracts probably encourage flowering by initiating robust plant growth. Yield increases in seaweed extract treated plants are thought to be associated with hormonal substances present in the extracts, especially cytokinins [53]. Cytokinins have been implicated in nutrient mobilization in vegetative plant organs [54] as well as reproductive organs [55]. Such a response indicates the seaweed extracts are involved in inducing the mobilization of cytokinins from the roots to the reproductive organ or more likely by inducing the amount or synthesis of endogenous fruit cytokinin [56]. This increase in cytokinin availability will eventually result in a greater supply of cytokinins to the later stages (reproductive) of plants and thus initiated flowering and triggered yield.

It may be concluded that the growth and biochemical characteristics of vegetable crop *C. tetragonoloba* could be promoted by the presence of micro and macro elements, growth hormones, vitamins etc. in the SLE of *S. wightii*. Cytokinin and magnesium, which are considered as essential growth promoting constituents in chlorophyll biosynthesis might have played a key role in enhancement of growth and physiology of cluster bean. However, optimum concentration of seaweed liquid extracts is necessary as in this study 1.5% SLE had better influence on growth and productivity of cluster bean plants. The study also emphasizes that seaweed extracts can be effectively used as organic biostimulants to the agricultural crops and also much useful in the practices of organic farming.

Conflict of interest statment

We declare that we have no conflict of interest.

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