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Studies on the Effect of Seaweed Liquid Fertilizer (SLF) on different Growth Parameters, Biochemical Constituents and Pigment Production in a C_3 Plant , *Phaseolus mungo*

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Abstract

Application of seaweed liquid fertilizer to crops has been found to increase seed germination percentage, yield of crops, resistance to frost and fungal attacks and uptake of the organic nutrients from the soil. Seaweed liquid fertilizer are now commercially available in several trade names such as Algit, Algifert, Kalpak66, Maxicrop etc. Excessive use of fertilizers and pesticides has caused a serious problem of world-wide pollution and land fertility loss. The use of biofertilizer will be helpful to sustain soil fertility and pollution free soil environment. Seaweed extracts from Sargassum swartzii and Ulva fasciata have been found to increase the yield of C3 plant Phaseolus mungo. An increase in the pigment production such as Chl-a, Chl-b, Xanthophyll was experimentally proved.

Keywords: *Seaweed liquid fertilizer, C_3 plants, Chlorophyll, Xanthophyll.*

Introduction

India is mainly an agricultural country with approximately 70% of the population located in rural areas and directly engaged in agriculture. The growing population is facing pressure on food production and to meet the increasing demand farmers are using chemical fertilizers to enhance their crop production. Chemical fertilizers mixed with pesticides get accumulated in plants which lead to health problems in human due to biomagnification (Hansra, 1993).

Seaweeds are important marine renewable resources. They are used as food, feed, fodder, fertilizer, agar, alginate, carageenan and source of various fine chemical (Sahoo, 2000). In recent years, the use of natural fertilizer (Hong *et al.*, 2007) has allowed for substitution in place of conventional synthetic fertilizer (Crouch and Van Stader, 1993). Seaweed extracts are marketed as liquid fertilizers and biostimulants since they contain many growth regulators such as cytokinins (Durand *et al.*, 2003 ; Stirk *et al.*, 2003).

Formerly, the seaweed was applied as organic manure to the soil, but there are changes in the mode of application of seaweeds at present. The trend now is to use seaweed as liquid manures either for dipping the seeds in or to use it as a foliar spray, both the methods are effective (Sharma and Gupta, 1983). Application of seaweed liquid fertilizer to crops has been found to increase seed germination percentage, yield of crops, resistance to frost and fungal attacks and uptake of the organic nutrients from the soil (Bhosle *et al.*, 1973 ; Venkataraman Kumar *et al.*, 1993 ; Mohan *et al.*, 1994 ; Sekar *et al.*, 1995). In India, seaweed is used only as manure. The application of seaweed extracts not only promote growth and yield of plants but also enhance the disease resistance capacity in horticulture crops. Biofertilizers are the most advanced biotechnology necessary to support organic agriculture, sustainable agriculture, green agriculture and non-pollution agriculture.

The application of seaweeds as manure is practiced in many European countries. Addition of seaweeds to soil has improved the binding properties and the water retaining capacity of the soil. Therefore there is a constant effort made by scientists to use agricultural practices which are ecofriendly. Seaweed biomass can serve as an excellent source of organic manure because of its greater potential in improving soil fertility.

Materials and Methods

The healthy seaweeds such as *Ulva fasciata* (Chlorophyceae) and *Sargassum swartzii* (Phaeophyceae) were collected between July 2007 and August 2007 along the Kadiapattinam coast of Kanyakumari District, Tamilnadu. It is a rocky coast with sandy bottom in the inshore region. The rocks are exposed during low tide to a greater extent. Wave action was found to be moderate during the seaweeds collection. Constantly exposed surfaces of the larger rocks were devoid of flora and fauna. Intertidal rocks exhibited luxuriant growth of flora and fauna.

Algae collection and the preparation of Seaweed Liquid Fertilizer (SLF)

The seaweeds were hand picked and washed thoroughly with running tap water to remove all the unwanted impurities, adhering sand particles and epiphytes. Seaweeds were dried in sunlight for five days, and then oven dried for 24h at 60 – 65^{0}C. Hand crushed and made into coarse powder using a mixer grinder. The coarse powder was soaked in water for five minutes before extraction. Seaweed powders were cooked individually in pressure cooker for 2h. The ratio of material and water was 1 : 10. The extract was removed from the pressure cooker and filtered through a double layered cheese cloth. The filtrate was centrifuged at 5000 – 10,000 xg to remove most of the suspended impurities. The filtrate was dried in a hot air oven at 65^{0}C for 48 h and the powder was stored in air tight bottles. The dried seaweed sample was considered as 100% seaweed extract (Rama Rao, 1990). Different concentrations of seaweed liquid fertilizer and farm yard manure (cow dung) at different ratios (100, 75 : 25, 50 : 50, 25 : 75%) were prepared from the seaweed extract obtained from the green seaweed *U. fasciata* and brown seaweed *S. swartzii* individually.

Experimental plants

C3 plant *Phaseolus mungo* (black gram) is selected for the present investigation to understand its growth, biochemical characteristics and yield with reference to the effect of SLF's obtained from *U. fasciata* and *S. swartzii.* Healthy viable seeds of the above experimental plant were obtained from Tamilnadu Agricultural Office, Kurunthancode, Kanyakumari District, India. Seeds showing 90% viability (germination) were selected for the experimental studies.

Pot study

To understand the efficacy of SLF's obtained from *U. fasciata* and *S. swartzii* as a supplement to inorganic fertilizer, their effects on growth, biochemical features and yield of *P. mungo* were determined. The following experiments were conducted. Plants were grown in earthern pots (20 cm height and 22 cm diameter) containing a mixture of 3 kg loamy soil (pH 7.6 – 7.8 ; minerals like nitrogen – 76.0 ; phosphorus – 2.5 ; potassium – 18.75 ; iron – 4.87 ; copper – 0.41 ; Zinc – 0.28 and manganese 1.4 mg^{-1}) and 1 kg farm yard manure (FYM). In the present study, four set of experiments were conducted on *P. mungo*.

i. Effect of SLF without organic fertilizer (100%).
ii. SLF ± 25% recommended rate of organic fertilizer (75 : 25).
iii. SLF ± 50% recommended rate of organic fertilizer (50 : 50).
iv. SLF ± 75% recommended rate of organic fertilizer (25 : 75).

SLF obtained from *U. fasciata* and *S. swatzii* and recommended rate of organic fertilizers were applied by adopting soil drench. Control was maintained for all the experiments.

Statistical analysis

The results obtained in the present study were subjected to statistical analysis (Mean ± SD and ANOVA) following the standard methods described by Zar (1974).

Results

Effect of different concentrations of SLF of *U. fasciata* on different growth parameters of *P. mungo*

The effect of different concentrations of SLF of *U. fasciata* on different growth parameters of *P. mungo* is given in Table 1.

Number of flowers

The effect of SLF was clearly evident in all studied parameters over control plant. For instance, the number of flowers was maximum (13 ± 1.63) in 100% concentration of SLF and in control plant it was only 5 ± 0.00. In other concentrations such as 75 : 25, 50 : 50 and 25 : 75% number of flowers, were recorded as 12 ± 0.82, 8 ± 0.82 and 12 ± 0.82 respectively.

Shoot length (cm)

The shoot length showed that the maximum length of 47 ± 2.45 cm in 50 : 50% concentration of SLF, while the control plants showed only 30 ± 1.63cm. In other concentrations of SLF also, better shoot length was noted as 43 ± 1.63, 42 ± 1.63 and 40 ± 1.63 cm in 75 : 25, 100% and 25 : 75% respectively.

Root length (cm)
The maximum length of root observed was 15 ± 1.63 cm in 100% concentration of SLF. Whereas, it was decreased as 12 ± 1.63, 10 ± 0.82 in 75 : 25, 50 : 50 and 25 : 75% SLF concentration respectively. But the control plant showed very less value of 7 ± 0.0 cm.

Number of root nodules
The control plant showed only very low number of root nodule and it was noted as 1 ± 0.00. But, the plants received SLF at various concentrations, the number of root nodules increased to 6 ± 0.82 in both 100 and 50 : 50% concentrations. The other two concentrations showed comparatively less number of 5 ± 0.00 and 3 ± 0.82 root nodules in 75 : 25 and 25 : 75% concentrations of SLF respectively.

Number of fruits
Remarkable increase was noted in number of fruits as the concentration of SLF increased over the control plants. The control plant showed only 3 ± 0.00 fruits, but the number increased to 8.082 each in 75 : 25, 50 : 50 and 25 : 75% of SLF respectively and the maximum number of 10 ± 1.63 fruits was noted in 100% concentration of SLF.

Number of seeds
100% concentration of SLF showed the maximum number of seeds (7 ± 0.82). But the seed number values decreased as the concentration decreased i.e. 6, 5 and 4 numbers in 75 : 25, 50 : 50 and 25 : 75% SLF respectively. The minimum number (4) was noted in the control plant.

Leaf area (cm^2)
The maximum leaf area was noted in 25 : 75% concentration of SLF and organic manure (8 ± 0.00 cm^2), whereas the control plant showed the minimum leaf area of 5 ± 0.00 cm^2.

Table 1. Effect of different concentrations of SLF of *U. fasciata* on different growth parameters of *P. Mungo*

Parameters		Concentrations of SLF (%)				One way ANOVA	
		100	75 : 25	50 : 50	25 : 75	F test	P value
No. of flowers	5 ± 0.00	13 ± 1.63	12 ± 0.82	8 ± 0.82	12 ± 0.82	24.6428	**P < 0.0001**
Shoot length (cm)	30 ± 1.63	42 ± 1.63	43 ± 1.63	47 ± 2.45	40 ± 1.63	24.180	**P < 0.0001**
Root length (cm)	7 ± 0.00	15 ± 1.63	12 ± 1.63	10 ± 0.82	10 ± 0.82	13.050	**P < 0.0001**
No. of root nodules	1 ± 0.00	6 ± 0.82	5 ± 0.00	6 ± 0.82	3 ± 0.82	23.500	**P < 0.0001**
No. of fruits	3 ± 0.00	10 ± 1.63	8 ± 0.82	8 ± 0.82	8 ± 0.82	14.5714	**P < 0.001**
No. of seeds	4 ± 0.00	7 ± 0.82	6 ± 0.00	5 ± 0.82	4 ± 0.00	12.750	**P < 0.001**
Leaf area (cm^2)	**5.00 ± 0.00**	**.00 ± 0.82**	**.33 ± 0.47**	**.67 ± 0.47**	**8 ± 0.00**	**10.700**	**P < 0.001**

P < 0.05 is statistically significant

Effect of different concentration of SLF of *S. swartzii* on different growth parameters of *P. mungo*
The effect of different concentration of SLF of *S. swartzii* on different growth parameters of *P. mungo* is given in Table 2.

Number of flowers
The effect of SLF was clearly evident in all studied parameters over control plant. For instance, the no. of flowers was maximum 15 ± 1.63 in 50 : 50 concentration of SLF and in control plant it was only 5 ± 0.00. In other concentrations such as 100, 75 : 25%, 25 : 75 number of flowers was recorded as 14 ± 0.82, 12 ± 0.82 and 1.0 ± 1.63 respectively.

Shoot length (cm)
The shoot length showed the maximum length of 40 ± 1.63 cm in 100% concentration of SLF, while the control plants showed only 25 ± 1.63 cm. In other concentrations of SLF, better shoot length was noted as 38 ± 1.63, 38 ± 0.83, 33 ± 0.82 cm in 75 : 25, 50 : 50 and 25 : 75% SLF respectively.

Root length
The maximum root length observed was 19.50 ± 1.63 cm in 100% concentration of SLF whereas it was decreased as 15.00 ± 0.82, 18.50 ± 0.41, 15.33 ± 0.47 cm in 75 : 25, 50 : 50 and 25 : 75% SLF concentration respectively. But, the control plant showed less value of 12.00 ± 0.82 cm.

Number of root nodules

The control plant showed only very low number of root nodule and it was noted as 2 ± 0.00. But, the plants received SLF at various concentrations, the number of root nodules increased to 11 ± 0.82, 10 ± 0.82, 6 ± 0.82 in 100, 75 : 25 and 50 : 50 concentration of SLF respectively.

Number of fruits

Remarkable increase was noted in the number of fruits as the concentration of SLF increased over the control plants. The control plant showed only 4 ± 0.00 fruits, but the number increased to 12 ± 0.82, 11 ± 1.63, 15 ± 0.82, 8 ± 0.82 in 100, 75 : 25, 50 : 50 and 75 : 25% concentration of SLF respectively.

Number of seeds

With respect to number of seeds, almost all the tested concentrations of SLF showed the same value and the number of seeds recorded was 6 ± 0.82. In control plant, the number of seeds was reduced to 5 ± 0.00.

Leaf area (cm^2)

The maximum leaf area was noted in 25 : 75% concentration of SLF (6.67 ± 0.47 cm^2) whereas, the control plant showed the minimum leaf area of 4.00 ± 0.00 cm^2.

Table 2. Effect of different concentrations of SLF of *S. swartzii* on different growth parameters of *P. Mungo*

Parameters		Concentrations of SLF (%)				One way ANOVA	
		100	75 : 25	50 : 50	25 : 75	F test	P value
No. of flowers	5 ± 0.00	14 ± 0.82	12 ± 0.82	15 ± 1.63	10 ± 1.63	23.550	P < 0.0001
Shoot length (cm)	25 ± 1.63	40 ± 1.63	38 ± 0.82	38 ± 1.63	33 ± 0.82	39.321	P < 0.0001
Root length (cm)	12.00 ± 0.82	.50 ± 1.63	.50 ± 0.4	5.33 ± 0.47	5.00 ± 0.82	20.462	P < 0.0001
No. of root nodules	2 ± 0.00	11 ± 0.82	10 ± 0.82	10 ± 0.82	6 ± 0.82	53.250	P < 0.0001
No. of fruits	4 ± 0.00	12 ± 0.82	11 ± 1.63	15 ± 0.82	8 ± 0.82	37.500	P < 0.0001
No. of seeds	5 ± 0.00	6 ± 0.82	6 ± 0.82	6 ± 0.82	6 ± 0.82	0.750	P > 0.05*
Leaf area (cm^2)	**4.00 ± 0.00**	**.00 ± 0.82**	**.33 ± 0.47**	**.00 ± 0.00**	**.67 ± 0.47**	**9.200**	**P < 0.01**

P < 0.05 is statistically significant ; * Statistically non significant

Effect of different concentration of SLF of *U. fasciata* on biochemical constituents of *P. mungo*

The biochemical constituents of *P. mungo* when grown with different concentration of *U. fasciata* SLF showed better results over the control (Table 3). At 100% concentration of SLF, the soluble sugar content was maximum (7.2 ± 0.082 $mg.g^{-1}$ DW). In other concentrations (75:25, 50:50 and 25:75%) it gradually decreased to 7.180 ± 0.033, 7.120 ± 0.049 and 7.080 ± 0.016 $mg.g^{-1}$ DW respectively. While the control plant showed only 4.120 ± 0.033 $mg.g^{-1}$ DW of soluble sugar.

Soluble protein also showed the maximum value (2.420 ± 0.002 $mg.g^{-1}$ DW) at 100% SLF and it decreased gradually in other three concentrations. But the lipid content was maximum (1.340 ± 0.033 $mg.g^{-1}$ DW) at 50 : 50% concentrations and it was minimum (0.500 ± 0.041 $mg.g^{-1}$ DW) at 25 : 75% concentration. But the control plant showed 0.700 ± 0.049 $mg.g^{-1}$ DW of lipid. In all the other concentrations, the value ranged between these two.

Table 3. Effect of different concentrations of SLF of *U. fasciata* on the biochemical constituents of *P. Mungo*

Parameters	Control	Concentrations of SLF (%)				One way ANOVA	
		100	75 : 25	50 : 50	25 : 75	F test	P value
Soluble sugar ($mg.g^{-1}$ DW)	4.120 ± 0.033	7.200 ± 0.082	7.180 ± 0.033	7.120 ± 0.049	7.080 ± 0.016	1598.02	P < 0.0001
Soluble protein ($mg.g^{-1}$ DW)	1.799 ± 0.001	2.420 ± 0.002	1.785 ± 0.001	1.200 ± 0.002	1.374 ± 0.001	1937.19	P < 0.0001
Lipid ($mg.g^{-1}$ DW)	**0.700 ± 0.049**	**0.900 ± 0.049**	**0.730 ± 0.024**	**1.340 ± 0.033**	**0.500 ± 0.041**	**122.172**	**P < 0.0001**

P < 0.05 is statistically significant

Effect of different concentration of SLF of *S. swartzii* on biochemical constituents of *P. mungo*

Both soluble sugar and soluble protein showed maximum value at 50 : 50% concentration of SLF and organic fertilizer (6.180 ± 0.065 and 4.56 ± 0.049 $mg.g^{-1}$ DW respectively) over the control plants, which showed 4.100 ± 0.041 and 2.380 ± 0.065 $mg.g^{-1}$

DW respectively. Other concentrations showed lesser values than this. But, the lipid content was maximum at 100% concentration of SLF (2.420 ± 0.043 $mg.g^{-1}$ DW) over the control plant (0.606 ± 0.033 $mg.g^{-1}$ DW). In other concentrations such as 75 : 25, 50 : 50 and 25 : 75%, it decreased gradually to 2.380 ± 0.065, 1.680 ± 0.024 and 1.180 ± 0.073 $mg.g^{-1}$ DW respectively (Table 4).

Table 4. Effect of different concentrations of SLF of *S. swartzii* on the biochemical constituents of *P. Mungo*

Parameters	Control	Concentrations of SLF (%)				One way ANOVA	
		100	75 : 25	50 : 50	25 : 75	F test	P value
Soluble Sugar ($mg.g^{-1}$ DW)	4.100 ± 0.041	6.130 ± 0.024	6.070 ± 0.057	6.180 ± 0.065	6.030 ± 0.016	799.93	P < 0.0001
Soluble Protein ($mg.g^{-1}$ DW)	2.380 ± 0.065	4.420 ± 0.033	4.270 ± 0.057	4.560 ± 0.049	4.130 ± 0.024	688.077	P < 0.0001
Lipid ($mg.g^{-1}$ DW)	0.600 ± 0.033	2.400 ± 0.043	2.380 ± 0.065	1.680 ± 0.024	1.180 ± 0.073	2.89	P > 0.05*

* Statistically non significant ; P < 0.05 is statistically significant

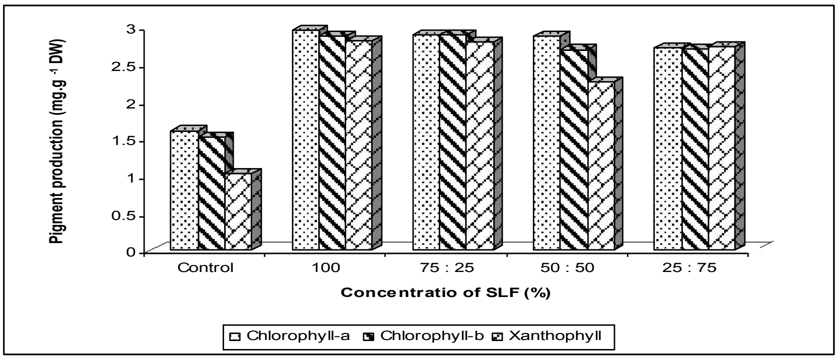
Effect of different concentration of SLF of *U. fasciata* on pigment production in *P. mungo*

At 100% concentration of SLF of *U. fasciata* maximum pigment production (chlorophyll-a) was noted (2.955 ± 0.002 $mg.g^{-1}$ FW) over the control (1.601 ± 0.00 $mg.g^{-1}$ FW). But, other concentrations (75:25, 250:50 and 25:75) did not show much variation, only slight variation were noted as 2.889 ± 0.001, 2.876 ± 0.002 and 2.707 ± 0.006 $mg.g^{-1}$ FW respectively.

Chlorophyll-b pigment production was maximum (2.889 ± 0.008 $mg.g^{-1}$ FW) at 75:25% concentration, Slight variation was noted (2.875 ± 0.001, 2.689 ± 0.001 and 2.698 ± 0.007 $mg.g^{-1}$ FW) in other tested concentrations such as 100, 50:50 and 25:75% concentrations respectively. But, the pigment production was relatively less in the control plant (1.52 ± 0.001 $mg.g^{-1}$ DW).

In respect to xanthophyll pigment, 100% concentration of SLF showed maximum value (2.809 ± 0.002 $mg.g^{-1}$ FW) and in control it was only 1.033 ± 0.003 $mg.g^{-1}$ FW. Other concentrations showed slight variations from 100% concentration of SLF (Fig. 1).

Fig. 1. Effect of different concentrations of SLF of *U. fasciata* on various pigment production by *P. Mungo*

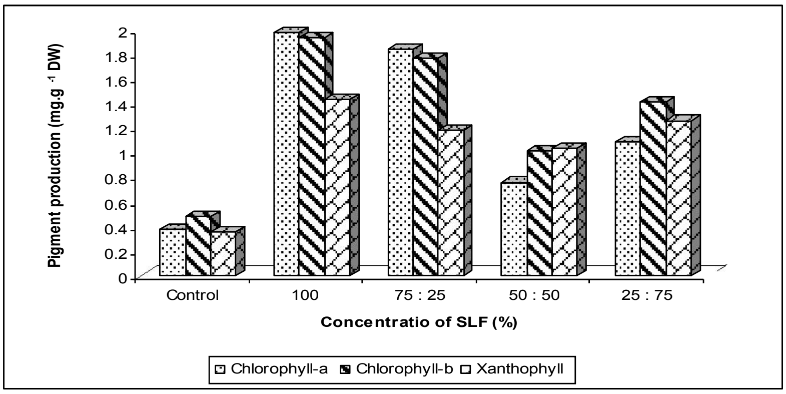


Effect of different concentration of SLf of *S. swartzii* on pigment production in *P. mungo*

With respect to *S. swartzii* SLF, maximum pigment production such as chlorophyll-a and chlorophyll-b were recorded at 100% concentrations (1.970 ± 0.008 and 1.927 ± 0.022 $mg.g^{-1}$ FW respectively). Slight variations were noted among the other tested concentrations. But, in control plant, both the pigments showed lesser value and it was 0.373 ± 0.002 and 0.480 ± 0.005 $mg.g^{-1}$ FW respectively.

Xanthophyll pigment production showed only slight variation among the tested concentration. At 100, 75:25, 50:50 and 25:75% SLF concentrations, the recorded values were 1.431 ± 0.025, 1.181 ± 0.33, 1.031 ± 0.025 and 1.257 ± 0.024 $mg.g^{-1}$ FW respectively but it was much more than the control plant (0.351 ± 0.005 $mg.g^{-1}$ FW) (Fig. 2).

Fig. 2. Effect of different concentrations of SLF of *S. swartzii* on various pigment production by *P. mungo*



Discussion

Seaweeds are the most important marine resources of the world. Seaweed extracts have been marketed for several years as fertilizer and of additives. In the present study, the seaweed liquid fertilizers of *U. fasciata* and *S. swartzii* accelerated the early growth of C3 plant was investigated.

At present, we use chemical fertilizers in great quantities to compensate the deficiency of nutrient in soil. It is observed that the abundant use of chemical fertilizers affects soil and plants in due course. Recent researchers proved that seaweed fertilizers are preferred not only due to their nitrogen, phosphorus and potash content but also because of the presence of trace elements and metabolites, similar to plant growth regulators. In India, as a step towards the expansion of native sources of natural manures, the seaweed fertilizers application will be useful now for achieving higher production. Recently, seaweed extracts as liquid fertilizers (SLF) has come in the market for the simple reason that they contain many growth promoting hormones like auxin, gibberlin, trace elements, vitamins, amino acids and micronutrients.

The application of aqueous seaweed extract in all the concentrations and treatments resulted in a significant increase in protein concentration. The higher protein concentration was measured with 10% seaweed extract application. Soil drench and foliar spray treated plants gave the best response. Such a rise in protein content may be attributed to the increased availability and absorption of necessary elements (Ca, Na, Mg, Cd and Zn) present in the aqueous extract that enhanced the efficiency of leaves. *Z. mays* and *P. mungo* responded well in maintaining high level of soluble proteins at 1% and 0.5%. *Sargassum* extract application (Lingakumar *et al.*, 2004). Significant increase in the levels of protein content of *Sorghum vulgare* was recorded with 1.5% seaweed liquid extract prepared from *Hydroclathrus clathratus* (Ashok *et al.*, 2004). The increase in protein content at lower concentrations of liquid extract may be due to absorption of most of the necessary elements by the seedling (Anantharaj and Venkatesalu, 2001).

In comparison to control plants treated with aqueous seaweed extracts in all three treatments showed a significant increase in total soluble sugars and reducing sugars at all concentrations above 0.1%. For foliar spray statistically significant increase was recorded at 8% and 10% of seaweed extract. Higher concentration of reducing sugars was measured at 10% seaweed extract applied as a foliar spray. This was statistically similar to 10% of soil drench ± foliar spray. The concentration of total soluble sugars and reducing sugars was maximum at higher concentrations of spray and drench treatments. This may be considered indicative of the fact that seaweed extracts stimulate various biological processes that increase the carbohydrate levels in tomato plants. Similar observations were recorded for *Vigna catajung* using 10% *Caulerpa racemosa* extracts (Ananthraraj and Venkatesalu, 2001). In *V. sinensis*, the sugar content increased upto 20% with *S. wightii* liquid extract but showed a decline at higher concentrations (Sivasankari *et al.*, 2006).

The effect of various treatments on starch concentrations did not display any specific trend. Higher starch concentration was measured with application of 0.8% and 2% seaweed extracts when applied as a foliar spray. High starch concentrations were measured in *Z. mays* seedlings treated with 1% *Sargassum* seaweed extract (Lingakumar *et al.*, 2004) and in *S. vulgare* treated with 1.5% seaweed extract prepared from *H. clathratus* (Ashok *et al.*, 2004).

Due to the increasing popularity of Lycopene for use in food and nutritional supplements, there is a demand for developing Lycopene rich products and ingredients (Chaudhary *et al.*, 2009). Lycopene concentrations in tomato fruits increased upto 94 $mg.g^{-1}$ DW in plants treated with higher concentrations of seaweed extract. This provide evidence that seaweed extract may be responsible for the translocation of cytokinin from the roots to the developing fruit or possibly even for increasing the level or synthesis of cytokinins within the fruit (Hahn *et al.*, 1974). With cytokinin like substances present in aqueous extract of *S. johnstonii,* mobilization of nutrients to the fruit may contribute to improving the lycopene concentration. The effect of various seaweed extract treatments on the vitamin C content of tomato fruit showed a linear increase with the higher vitamin C content observed at 10% seaweed extract. Vitamin C, one of the most important of all vitamins is an indicator of fruits ripening. It plays an important role in various biochemical processes, such as collagen formation, iron absorption and is involved in neurotransmission and immune response in humans (Peng *et al.*, 2008).

In the present study, the early growth and the productivity of *P. mungo* increased with increased concentration of SLF of both *U. fasciata* and *S. swartzii*. The maximum yield was observed at 100% SLF concentration and it could be attributed to the fact that SLF binds soil particles together and improves the soil properties and mineral acquisition. Since application of SLF is ecofriendly it can bring harmony to nature SLF could be excellently used as one of the organic manures to improve the productivity of crop plants.

Similar observation has reported by Thirumal Thangam *et al.* (2003), that the growth parameters such as shoot length, root length, fresh weight of shoot and root of vegetable plant *Cyanopsis tetragonoloba* increased with the application of optimum concentration of seaweed liquid fertilizer (SLF).

Seaweed extract is definitely capable of promoting growth in both prokaryotic organisms and higher plants (Venkataraman Kumar and Mohan, 1994, 1997a). These extracts have increased the yield of crops, seed germination, resistance to frost, fungal and insect attacks, uptake of inorganic constituents etc.

In the present investigation, the application of SLFs increased chlorophyll a, b and xanthophyll pigments content in most of the concentration tested. Similar results were observed by Menon and Srivastava (1984), Smith and Staden (1984), Blunden *et al.* (1986 and 1997) and Murugalakshmi Kumari *et al.* (2002). In the present study, the seaweed liquid fertilizer of *U. fasciata* and *S. swartzii* enhanced the synthesis of biochemical constituents such as photosynthetic pigments, soluble sugar, soluble protein and lipid in C3 plants.

Conclusion

Our present investigations revealed the enhancement on the growth, biochemical and yield characteristics of vegetable crop *Phaseolus mungo* and might be due to the presence of micro and macro nutrients and trace elements present in the seaweed liquid fertilizer. On the other hand, increase in crop growth may vary according to chemical constituents of seaweed extract. Vijayanand *et al.* (2004) reported that lower concentration of SLF from *Stoechospermum marginatum* promoted the growth of brinjal and Sivasankari *et al.* (2006) also reported similar effect in Cow pea and Ramamoorthy and Sujatha (2007) reported linear growth of both root and shoot in black gram seeds. Similar typical growth promotion was observed in this study at lower concentrations of the *S. swartzii* extracts. In conclusion, considering the above important findings, the seaweed extracts derived from *Sargassum swartzii, Ulva fasciata* act as an effective seaweed liquid fertilizer (SLF) in increasing the growth parameters and yield. Hence, this simple practice of application of eco-friendly seaweed liquid fertilizers to pulse crop, black gram of South India is recommended to the growers for attaining better germination, growth and yield.

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