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Effect of Seaweed Liquid Fertilizer on Plant Growth of *Capsicum annum*

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ABSTRACT

Seaweed contains all the trace elements and growth hormones required by plants. Recently there is a growing concern over the use of seaweed liquid fertilizer (SLF). Today, there is a high demand for environment friendly agriculture for production of quality and healthy food to nourish the increasing population. The present study investigates the effect of seaweed extract, from *Ulvalactuca*, *Sargusum wightti*, *Kapphaphycus alvarezii* and *Gracilaria verrucosa* on the seed germination and plant growth of *Capsicum annum*. The Seaweed Liquid Fertilizer (SLF) was tested both with and without chemical fertilizers. The experiment was arranged in randomized Complete Block design (RCBD) with nine treatments four replications. Once a week a different Seaweed Liquid Fertilizer

(SLF) individually and different SLF concentrations in combination with Recommended rate of Chemical Fertilizer (RCF) were applied to plants after germination and transplanting. Their performance was recorded once in two weeks. The average maximum fresh shoot height (15cm) and the dry weight (0.856g) were observed in application of foliar spray SLF75% plus RCF extracted from *Sargussum wightti* and *Kapphaphycus alvarezii* respectively. Seaweed extract 75% SLF with RCF increased significantly to root dry weight, number of leaves, number of flowers, number of pods, pod length over the control respectively in seaweed extracts from *Sargussum wightti, Gracilaria verrucosa*,*Sargussum wightti* and *Ulvalactuca*. The seaweed liquid fertilizer of each species with 100% (SLF only) foliar application was less effective on increase in above parameters than combined fertilizers (SLF plus CRF), but also has significant effect on increase in shoot height and other growth parameters when compared to control and recommended rate of chemical Fertilizer (RCF) only. Therefore, it could be concluded that combined effect in (SLF 75% plus CRF) foliar application could have met the requirement of micro nutrients in chili crop than SLF individually. The SLF -75% plus CRF foliar application of *Sargussum wightti* significantly increased several growth parameters such as shoot weight, root weight, number of leaves and number of pods when compared to the extracts preparation from other species. SLF applications in combination with CRF are proposed to be used for enhance the growth, yield and quality of *Capsicum annum*.

Keywords: seaweed extracts, germination, plant growth, liquid, fertilizer

Abbreviations: ANOVA - one way analysis of variance, Univarrent and Multivarent- two way analysis of variance

1. INTRODUCTION

WHO-UN in 2013 reported that Sri Lanka has the highest per hectare use of pesticides and the eight highest user of chemical fertilizer per hectare in the world (Sutharsan, et al., 2014). Today soil has critically deteriorated with the excessive dumping of chemical fertilizers and agro chemicals for the fast 60 years (Sutharsan, et.al., 2014).This situation is steadily aggravating as more and more chemical fertilizer is used for plant growth while more agro chemicals are needed to protect them from pests and other diseases (Daily, 2014). It is a growing trend to focus on plant nutrients as alternative supplement of chemical fertilizer. The numerous research efforts have been made to evaluate the feasibility and efficacy of organic sources increasing plant growth and soil productivity. Seaweed is one of the potential source available around Sri Lankan coast but today it is not properly utilized in Sri Lanka. This resource is available in North Eastern and South West coastal belt in Sri Lanka. About 320 species belonging to different families are distributed in shallow coastal waters of sea, estuaries and backwaters (Erunal, et.al. 2009). Seaweed extracts contain trace elements and plant growth hormones IAA and IBA growth stimulators such as auxin, gibberellins and cytokinin required by plants. It is also reported that seaweed extracts are rich in vitamins, amino acids, trace elements (Fe, Cu, Co, Ni, Zn and Mn) (Booth, 1969). Seaweed extracts have nitrogen, phosphorus and higher amount of water soluble potash, other minerals and trace elements in a readily absorbable by plants. They control deficiency diseases. Today is being used of low concentration of seaweed extracts in combination with commercial fertilizer. It has been used more effectively in the world in promoting plant growth (Chatterji, 2004). *Capsicum annum* is one of the most essential spicy crop in Sri Lanka which is commonly grown by farmers in dry climatic zones due to high economic returns and export potential. The present study intends to investigate the effect of foliar application of seaweed liquid fertilizer (SLF) extracted from seaweed species *Sargussum. wightti*, *Ulva lactuca*, and *Gracilaria verrucos and Kappaphycus alvarezii* combined with commercial fertilizer and individually, on growth of *Capsicum annum*.

2. MATERIALS AND METHODS

Collection of samples:

The seaweed *Sargussum wightti* and *Ulva lactuca* were collected from South coast in Beruwala and Kogalla. *Kapphaphycus alvarezii* and *Gracilaria verrucosa* were collected from North East coastal belt in Sri Lanka. Seaweed samples were handpicked and immediately washed with seawater to remove foreign particles, sand particles and epiphytes. The samples were kept in polythene bags with seawater and immediately transported to the processing plant in Post Harvest Technology Division at National Aquatic Resource Research and Development Agency (NARA). Then washed thoroughly using tap water to remove the salt on the surface of the sample and finally with distilled water. Then seaweeds were spread on blotting papers to remove excess water.

Preparation of samples:

Liquid fertilizers were extracted using the method mention below. The species used for extraction of liquid fertilizer were *Sargussum wightitti, Ulva lactuca, Gracilaria verucosa,* and *Kappaphycus alvarezii.* The agar *(Gracilaria verucosa)* and carrageenan *(Kappaphycus alvarezii)* were extracted according to the method SOP (2003) and Ohino (1994) respectively. The residues obtained from the agar extraction from *Gracilaria verrucosa* and carrageenan extraction from *Kappaphycus alvarezii* filtrates were used to prepare fertilizer. The extracted liquid fertilizers were stored in the glass bottles until the physical-chemical properties such as pH, electrical conductivity and mineral composition were measured.

Extraction of seaweed liquid fertilizer:
Fifty gram of dried powder from each seaweed species were blended at the ratio of dried powder: water (1:20). Then it was blended for 10 minutes using motor and pestle and boiled under 15lbs using a pressure cooker. This process yielded one liter of concentrated extract of seaweed from each species. Concentrated extract was filtered through a double layered muslin cloth to remove debris. For each 1 liter of concentrated extract, 0.1% of formaldehyde solution (5ml) was added to preserve the extract. The extracts were diluted with distilled water to achieve different dilutions. The commercial liquid chemical fertilizer was purchased from the Agro chemical outlet. The combination of Chemical Fertilizer (CF) with different dilutions of SLF were prepared by adding distilled water.

Selection of crop plant:
The crop plant, selected for the present study was *Capsicum* species. The seeds were collected from agriculture sales outlet in Colombo. Seeds with uniform size; color and weight were chosen for the experimental purpose. The selected seeds were stored in a plastic container until use.

Culture of seed:
Plastic trays with seeding holes were used for raising the crops. The seedling holes were filled with 10 g of garden soil in which evenly treated seeds were sowed at a depth of 1.5cm. They were kept in a net house to prevent damage until germination. The trays were labeled as in above concentration. The trays were rearranged at regular intervals to ensure uniform environmental impact on the plant growth. The foliar sprays and watering were done at five days intervals.

Plant culture:
The seaweed liquid fertilizer (SLF) was prepared in above concentrations using four different seaweed species *Sargussum wighitti, Ulva lactuca, Gracilaria verrucosa, Kappaphycus alvarezii*. *Capsicum annum* plants were laid out in Randomized Complete Block Design (RCDB) with three replicates. The foliar application was done at weekly intervals from two weeks after transplanting.

Plant growth parameters:
The plants from each treatment were randomly drawn for different analyses. Plants taken from the trays were uprooted carefully after 30, 69th days and 105th days and pods were separated by hand picking and following growth parameters, yield components and quality of fruit were measured.

Plant Height:
The height of each plant was measured from the base to the tip of the plant in centimeters and the mean value of the height was calculated for each treatment.

Leaf count:
Total number of leaves growing on one plant was counted and the mean number for three plants was recorded. The leaves that appeared for the first time were not considered as real leaves as they were dicotyledons. They were thicker and rounder than actual leaves.

Shoot dry weight:
The shoot parts of plant were taken from randomly selected plants from each replicate and they were chopped into thin pieces and subjected to oven dry for 48 hours 60^{0}C.

Root height:
The height of the each root was measured from bottom to tip of the each root in millimeters and mean value of the height was calculated for each treatment.

Flowers count:
Numbers of flowers in each plant was counted

Pods count:
The total numbers of pods were counted and it was taken for data analyze

Length of pods:
The total length of pods were measured and the mean length was taken for data analyze

Average total yield per hectare (MT/ha):
The mean total yield per hectare was obtained by adding total pod yield of various pickings from each treatment until death of plant. The yield was calculated using the following equation.

Yield = Number of pods x weight of one pod (2g) (g) x 100 /907185 / 0.0025(M^2) Plot area (1M^2)x0.0001 (Ton/Ha)

Statistical analysis:
Data were statistically analyzed using SPSS 22 and mean separation was performed for each measured outcome within treatments and species using Dennett' s univariate (two factor factorial CRP) at 5% significant level., significant within treatments based on multiple range test (Tukey-test)

Physiochemical analysis of seaweed Liquid Extract:
The color of SLF was observed visually and the pH was measured using the pH meter. SLF was analyzed for different macro (Nitrogen, phosphorous, potassium, magnesium, sodium, and calcium) and micro nutrients (manganese, nickel, chromium, and boron) according to the (AOAC, 1983).Nitrogen was tested using kjeldahl digestion method in (AOAC, 1984), Phosphorous was tested using UV visible spectrophotometer (APHA, 1995) and other nutrients were analyzed by atomic absorption spectrometry.

3. RESULTS

Physiochemical properties of four different seaweed species of *Sargussum wightti*, *Ulva lactuca*, *Kapphaphycus* and *Gracilaria verrucosa* (SLF) liquid extract have been analyzed (table-2). The extracts were brown, green and red in color and pH was recorded at room temperature. The extract contained macro nutrient like Nitrogen, Potassium, Phosphorus, Magnesium. *Gracilaria verrucosa* extract has significantly lower Ca ($P < 0.5$) level when compared to other seaweed extracts. The higher Ca content (252mg/l) was recorded in seaweed extract from *Ulva lactuca* and was followed by *Sargussum wightti* and *Kapphaphycus alvarezii*.Ca level in commercially available fertilizer (97.62 mg/l) is lower than the *Sargussum wightti* extracts. Table 3 shows the performance in shoot growth in four different seaweed extracts. The analysis of data on average plant height showed that the application of lower concentrations (25% of SLF) of *Sargussum wightti* has significantly ($p<0.05$) increased the plant height by 72% In Capsicum annum when compare to the application of RCF only. In application of *Kapphaphycus alvareazii a* highest shoot height was recorded in SLF (75% plus CRF) and was significantly increased (more than 100%) when compared to control plant. With respect to *Gracilaria verrucosa* extract, application of SLF 100% shoot height has significantly increased by 28% when compared to the control sample.

The spray prepared using twenty five percent (25%) of SLF from *Ulva lactuca* application increased the shoot weight by 20 times higher when compared to control sample. Extract of *Sargussum wightti* 75% SLF plus RCF foliar spray recorded mean shoot weight increase of four fold when compared to control. In *Gracilaria verrucosa* foliar application SLF (50% plus RCF) mean shoot weight increased significantly by 47% when compared to control sample. In foliar application of *Kapphaphycus alvarezii* SLF 100% average shoot weight per plant increased significantly by (75%) than in control sample. The statically analyzed of results of shoot weight indicated that interaction effect of treatment in the shoot weight depends on the SLF concentration of different species. It clearly show that, foliar application of SLF in lower concentrations extracted from *Ulva lactua* on chili plant increased dry matter accumulation of shoot weight.

Among four different seaweed fertilizer extracts, 75% SLF plus RCF application of *Sargussum wightti* recorded the maximum mean root weight of 0.734g when compared to extract of other species. Application of *Kapphaphycus* extracts of SLF 50% plus RCF found to result in second maximum mean root weight 0.6321g. The third maximum root weight (0.456g) was found for SLF (50% only) foliar spray application in *Ulva lactuca*. *Gracilaria verrucos a* foliar application SLF-50% recorded significantly lowest value (0.175g) root weight compared to other treatments.

The SLF concentration application combined with RCF and individually both affected on increase of root height significantly. In these results, the interaction effect is statistically significant. The interaction effect indicates that the relationship between root weight and SLF concentrations depends on the seaweed species used. Application of SLF (75% only) foliar spray of *Kapphaphycus alvarezii* extract was found second highest average root height 4.7 cm. Application of SLF 100% foliar spray of *Ulva lactuca* extract was resulted in maximum mean root height (5 cm) compared to other species. The results indicated that application of different SLF concentration combined with RCF and SLF concentration individually affect to improve root height significantly.

It is clear that foliar application of seaweed (SLF) combined with chemical fertilizers significantly increased the average leave number of leaves per plants while higher concentration of SLF (100%) only resulted in lower numbers.

Throughout the experiment, the maximum mean number (69) of flowers per plant was recorded for *Gracilaria verrucosa* SLF (75%) plus RCF whereas average minimum number of flowers (35) was recorded in control sample. In the same time SLF extract prepared from *Ulva lactuca* where average maximum mean number of flowers 65.87 were recorded in SLF of 75% plus RCF. Seaweed foliar application had remarkable effect on average number of flowers per plants.

The maximum mean value of number of pods (66) was recorded in application of *Sargussum wightti extract of fertilizer (*SLF (75%plus RCF). In the same time maximum mean number of pods in *Kappaphycus alvarezii* SLF (75%) application significantly

increased by 20% when compared to 25% -SLF extract. Application of *Ulva lactuca* extract foliar spray (SLF-75% plus RCF) gave maximum average number of pods (54%).These results clearly shows that there is an influence on mean number of pods by application of different proportions of SLF individually as well as in combination with RCF.

Data recorded on average mean fruit length of different treatments of foliar sprays and species were significant ($p<0.05$). The maximum mean of pods length 0. 92 cm was recorded in application of *Ulva lactuca* as fertilizer, (SLF- 75% with RCF). Application of *Sargussum wightti* as fertilizer SLF (75% plus RCF) showed 0.79 cm of maximum value and significant increase compared with SLF-25% only (minimum average length of pods values).

In application of *Kappaphycus alvarezii* extract as fertilizer maximum mean length of pods (0.78 cm) was recorded in SLF (75% with RCF). Similar pattern was observed in application of *Gracilaria verrucosa* SLF (75%, plus RCF).

All levels of foliar applications except very lowest level and very highest levels of SLF significantly improved average yield as given in table-9. The similar changers were observed in maximum mean number of pods and average yield of the *Capsicum annum*.

4. DISCUSSION

The important characteristics of seaweeds are basically synthesizing of important compounds. Seaweeds rarely show any photodynamic damage during metabolism, as they have efficient protective and oxidative mechanisms. This important characteristics also helps in protecting commercially important plants from extreme sun heat when seaweed extract have been used as fertilizer (Matsukawa, et al., 1997). Attempts have also been made for isolate many other important compounds useful for various purposes (Moore et al., 1978). The potential of enhance the growth characteristic of terrestrial plants is fast and becoming an acceptable practice of the seaweed liquid fertilizer. In the present study, the beneficial effects of SLF obtained brown, red and green seaweed such as *Sargussum wightti*, *Gracilaria verrucosa*, *Kapphaphycus alvarezii* and *Ulva lactuca* on growth of *Capsicum annum* evaluate the certain findings (Sadhar et al., 2012) states that liquid foliar application of *Sargussum wightti* obtained from study contained maximum concentrations of auxins and cytokinins. Seaweed concentration applied to wheat significantly increased clam diameter (Nelson and Van Staden, 1984). In the present study has been found seaweed liquid fertilizer was more successful as effective fertilizer for enhance shoot length, dry weight and root, number of leaves, number of flowers, number of pods, yield of *Capsicum annum*. The results indicated that SLF more effective to enhance plant growth combined with chemical fertilizer than applied individually. The maximum growth of plant parameters observed in SLF-75% plus recommended rate of chemical fertilizer. Whereas *Sargussum wightti* found more effective than other seaweed extracts. This may be due to presence of macro and micro element as well growth promoting substances in seaweed. This confirms the studies of SLF application on *Capsicum annum* (Sadhar et al., 2012). It also recorded that, foliar application of SLF in lower concentrations increase dry matter accumulation of shoots and roots. The results of root height on SLF application on *Capsicum annum* was found SLF combined with RCF and higher levels of SLF only effective on improve the root height. This situation may be due to the good amount of phosphorus in the SLF which promote root development. But SLF contribute to low amount of phosphorus than chemical fertilizer. An improvement of the root system could be influenced by endogenous auxin as well as other compounds in the extracts (Bonkowski and Brandt, 2006). SLF is the opulent source of secondary nutrients like Mg hence it helps to root growth. The interaction effect indicates that relationship between root weight and SLF concentration depends on seaweed species used. In the present study higher SLF concentrations of *Sargussum wightti* resulted higher root weight than other seaweeds. These findings coincide with studies done in *Capssicum annum* by Sidhar and Rengasamy, (2012). These results were different from findings of Sudharsan, et al., (2014) where dry matter accumulation in treated tomato plants with lower SLF concentrations. In the present study, it was recorded that the lower concentration of application of seaweed combined with chemical fertilizer significantly increased average leaf number per plant. These results were similar to the findings of Bluden 1997: Sidhar and Rengasamy, (2012). He also reported that seaweed extract enhance the plant chlorophyll content. Whapham et al., (1993) who stated that increase in chlorophyll resulted in which have caused by betanies in seaweed extract. The number of flowers also increase in combination of SLF plus RCF. The average number of flowers significantly increased than to RCF only treatments. The presence of higher number of potassium and growth regulators and growth regulators probably have stimulated flowers per plant and enhance plant yield. Crouch and Staden (1991) indicates the presence of reasonable quantity of macro and micro elements Ca, Mg, K and P in the SLF unable to meet requirement of growth parameters successfully. This may be due to the inhibitory effect of some higher concentration of SLF even SLF contain higher concentrations of macro elements (table-1). These minerals strong bonding with natural compounds and These constitutes of natural compounds can be separated by chemical reactions (Hill et al., 2005). There could be possibility of initiating of a chemical reactions when extract was being diluted (Hill, et al., 2005). However, the appropriate concentrations of seaweed also plays an important role in enhancing the growth of plant. In the present study; all SLF concentration in 1: 20 had better influence on growth and productivity of Capsicum annum. This study also emphasized that all four different seaweed extracts can be used as organic bio stimulator to the agricultural crops and also much useful in the practice of organic farming.

5. CONCLUSION

In the present study Seaweed extracts applied alone and combined with recommended rate of chemical fertilizer to *Capsicum annum* have a significant effect on increase of height and weight of shoot and root, number of leaves, number of buds, number of

pods, length of pods and yield. The 75% SLF plus recommended rate of chemical fertilizer (RCF) found to be very effective than the other concentrations to enhance the growth parameters and yield of Capsicum annum. It was also found maximum and early germination rate and early harvest can be obtained using even lower concentration of SLF. From the results it can be suggested that moderate concentrations of SLF individual extracts from *Ulva lactuca , Sargussum wightti, Gracilaria verrucosa and Kapphaphycus alvarezi* can be used as well as different proportion of recommended chemical fertilizer. With respect to some growth parameters, shoot weight, root height and root weight of plants received only SLF has given higher yield compared to the plants that received only recommended rate of chemical fertilizer. This study confirms that the use of seaweed extract is an eco -friendly technique to enhance not only growth and yield but also the quality of C*apsicum annum* production as organic fertilizer. These findings are beneficial for the farmer community to utilize this abundant resource as organic fertilizer to replace of commercial chemical fertilizer.

SUMMARY OF RESEARCH

Seaweeds are rich source of micro and macro elements strongly bond with natural compounds. Constitutes of natural compounds can be separated by chemical reactions. There could be possibility of initiating of a chemical reactions, when extract was being diluted. The lower concentration of seaweed liquid fertilizer effective improve some growth parameters than higher concentrations, may be due to the separation of strong bonds with natural compounds. The aqueous extract of SLF treatments of four different species, successfully effect on the enhancement of plant growth parameters of *Capsicum annum*. Among the four different seaweed species *Sargussum wightti* very effective increase the root weight than other species. The some of the growth parameters such as shoot and root height, number of flowers were significantly increased at lower SLF concentrations where as other parameters seed germination and maximum yield obtained by combined effect of SLF plus RCF than application of SLF individually. The results of statically analysis of different SLF treatment of four different seaweed species on plan growth parameters indicates that relationship between growth parameter and SLF concentration depend on seaweed species used for extraction.

FUTURE ISSUES

Today bio fertilizers have emerged as highly potent alternative to chemical fertilizer due to their eco- friendly easy apply, non-toxic and cost effective nature, Also they make nutrients that are naturally abundance in soil or atmosphere usable for plants and act as supplements to agro chemicals. But these seaweed species are seasonal and insufficient for current fertilizer demand. In addition these bio fertilizers likely to be commercially promising in the long run one, one of constraints of market of this fertilizer to lack of awareness of farmers and it quality assurance when available and production in commercial level. Future research and development works need to expand to evaluate the effectiveness of SLF on growth parameters of other crops.

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Table 1 Experimental design of plant SLF treatments

Type of SLF	Concentrations					No of replicates	No of total plants
SLF concentrations only	25%	50%	75%	1	Water only	3	120
SLF plus RCF	25% plus 75%RCF	50%plus 50% RCF	75% plus 25% RCF	RCF only		3	120

SLF- Seaweed Liquid Fertilizer, RCF- Recommended Rate of Chemical Fertilizer

Table 2 Variations in mineral composition of different seaweed liquid fertilizer

Minerals	Seaweed Liquid fertilizers(SLF) from different seaweed species					
	Gracilaria verrucosa	*Ulva Lactuca*	*Sargussum wighitti*	*Kapphaphycus alvarezii*	Market available seaweed liquid extract	Market available chemical fertilizer (RCF only) (Albert solution)
Na (mg/l)	64.4287±12.8	83.24±16.5	92.84±8.9	102.32±20.3	96.67±20.7	103.6±23.9
K(mg/l)	121.54±27.8	113.50±21.9	6.88±1.4	129.29±	127.6±18.9	103.178±25.7
Mg(mg/l)	139.29±17.9	420±47.8	88.26±13.4	458±56.7	225±42.3	306.95±26.7
Ca(mg/l)	25±3.89	252±29.56	173.79	185.2±	212.9±45.7	97.62±14.5
Mn(mg/l)	0.0156±0.0026	0.0456±0.0037	0.0197±0.04	0.052±0.007	0.0182±0.089	0.01150.0076
P(mg/l)	3.47±0.94	6.82±0.64	3.68±0.025	6.29±1.56	4.67±0.67	11.17±2.67
N(mg/l	06±0.73	6.7±0.001	4.5±0.03	5.7±0.024	9.2±0.087	9.2±0.0256
pH	4.6	6.23	4.25	4.32	5.6	5.4
Colour	pink	Green	brown	Light red	brown	White powder

SLF- Seaweed Liquid Fertilizer, RCF- Recommended Rate of Chemical Fertilizer

Table 2 Effect of recommended rate of chemical fertilizers *(RCF) and different proportions of seaweed extract foliar spray (SLF) from different seaweed species on shoot height of 30th day old *Capsicum annum* (Mean± SE)

Shoot height (cm) at different seaweed liquid fertilizer (SLF) concentrations ands plus Recommended rate of chemical fertilizer (RCF)									
Treatments	SLF-25%	SLF-50%	SLF75%	100%	SLF-25%RCF	SLF-50%RCF	SLF-75%RCF	RCF only	Water only
Species *Sargussum wightti*	14±0.221[a]	8±0.162[b]	11.5±0.96[c]	10.25±0.137[d]	13.5±0.1137[e]	12.5±0.116[f]	11.5±0.115[g]	11.7±0.065[h]	6.8±0.065[i]
Gracilaria verrucosa	10±0.098[a]	10±0.08[b]	11±0.10[c]	11±0.06d	13.5±0.10e	10±0.05f	13±0.17g	13±0.15h	10.5±0.11i
Ulva Lactuca	10±0.118[a]	12±0.19[b]	09±0.013[c]	9.5±0.049[d]	12±0.019[e]	13.5±0.157[f]	10±0.094[g]	11±0.145[h]	08±0.100[i]
Kapphaphycus alvarezii	10±0.259[a]	12±2.07[b]	12.5±0.08[c]	13±0.13[d]	11±0.123[e]	12±0.123[f]	15±0.124[g]	13±0.096[h]	8±0.102[i]

*denotes significant at 5% level, different alphabets between concentration denotes statistically, significant within treatments based on multiple range test (Tukey-test), significant within treatment and species based on univariate (Anova) Dennett's (two factor factorial CRP) at 5% significant level. SLF 25%- Seaweed Liquid Fertilizer 25%, SLF 50% - Seaweed Liquid Fertilizer 50%, SLF 75% - Seaweed Liquid Fertilizer 75%, SLF 100% - Seaweed Liquid Fertilizer 100%, RCF- Recommended Rate of Chemical Fertilizer only, SLF 50% plus RCF- Seaweed Liquid Fertilizer 50% with Recommended Rate of Chemical Fertilizer, SLF 75% plus RCF- Seaweed Liquid Fertilizer 75% with Recommended Rate of Chemical Fertilizer,

Table 3 Effect of different proportions of recommended rate of chemical fertilizers (RCF) and (SLF) foliar spray extracted from four seaweed extracts on shoot weight of 30 day old *Capsicum annum*. (Mean ± S.E.)

Shoot weight (g) atdifferent seaweed liquid fertilizer (SLF) concentrationsand SLF plus Recommended rate of chemical fertilizer (RCF)									
Treatment	SLF-25%	SLF-50%	SLF-75%	SLF-100%	SLF-25%plus RCF	SLF-50% plus-RCF	SLF-75% plus RCF	RCF only	Water only
Species *Sargussum wightti*	0.678±0.018[a]	0.543±0.015[b]	0.348±0.042[c]	0.289±0.009[d]	0.489±0.007[e]	0.556±0.0008[f]	0.856±0.0059[g]	0.067±0.0019[h]	0.065±0008[i]
Gracilaria verrucosa	0.3219±0.056[a]	0.7326±0.0277[b]	0.6647±0.0186[c]	0.3135±0.007[d]	0.3529±0.0008[e]	0.7326±0.121[f]	0.4653±0.008[g]	0.3135±0.00[h]	0.4972±0.0124[i]
Ulva lactuca	0.34±0.087[a]	0.234±0.0286[b]	0.56±0.0128[c]	0.456±0.4296[d]	0.567±0.0359[e]	0.430±0.461[f]	0.346±0.057[g]	0.426±0.034[h]	0.0378±0.034[i]
Kapphaphycus	0.3253±0.015[a]	0.4328±0.0074[b]	0.4836±0.008[c]	0.742±0.0062[d]	0.3253±0.004[e]	0.7432±0.005[f]	0.7235±0.0045[g]	0.5632±0.0097[h]	0.2435±0.0086[i]

*denotes significant at 5% level, different alphabets between concentration denotes statistically, significant within treatments based on multiple range test (Tukey-test).significant within treatment and species based on univariate (Anova) Dennett's (two factor factorial CRP) at 5% significant level.SLF 25%- Seaweed Liquid Fertilizer 25%, SLF 50% - Seaweed Liquid Fertilizer 50%, SLF 75% - Seaweed Liquid Fertilizer 75%, SLF 100% - Seaweed Liquid Fertilizer 100%, RCF- Recommended Rate of Chemical Fertilizer only, SLF 50% plus RCF- Seaweed Liquid Fertilizer 50% with Recommended Rate of Chemical Fertilizer, SLF 75% plus RCF- Seaweed Liquid Fertilizer 75% with Recommended

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Table 4 Effect of different proportions of recommended rate of chemical fertilizers and (RCF) and SLF extracted from different seaweed species foliar spray on root height of 30 day old *Capsicum annum*. (Mean ± S.E.)

Root height at different (cm) Seaweed liquid fertilizer (SLF) concentrations and (SLF) concentrations with Recommended rate of chemical fertilizer(RCF)

Treatment	SLF-25%	SLF-50%	SLF-75%	SLF-100%	SLF25% plus RCF	SLF50% plus RCF	SLF75% plus RCF	RCF only	Water only
species *Sargussum wightti*	2.5±0.013[a]	4.5±0.014[b]	5.5±0.045[c]	4.5±0.062[d]	2.5±0.167[e]	3±0.13[f]	5.8±0.034[g]	3.5±0.335[h]	03±0.06[i]
Gracilaria verrucosa	2.5±0.267[a]	3±0.163[b]	3.5±0.132[c]	3.5±0.285[d]	1.5±0.16[e]	03±0.102[f]	3.5±0.027[g]	3.2±0.16[h]	3.3±0.018[i]
Ulva lactuca	04±0.11[a]	4.5±0.05[b]	**4±0.0**13[c]	5±0.117[d]	03±0.107[e]	04±07532[f]	04±0.126[g]	3.5±0.112[h]	03±0.114[i]
Kapphaphycus	2±0.13[a]	4±0.874[b]	4.7±0.015202[c]	4±0.0055[d]	3±0.0951[e]	3.5±0.081[f]	4.2±0.040[g]	4.5±0.082[h]	4.8±0.071[i]

*denotes significant at 5% level, different alphabets between concentration denotes statistically, significant within treatments based on multiple range test (Tukey-test), significant within treatment and species based on univariate (Anova) Dennett's (two factor factorial CRP) at 5% significant level. SLF 25%- Seaweed Liquid Fertilizer 25%, SLF 50% - Seaweed Liquid Fertilizer 50%, SLF 75% - Seaweed Liquid Fertilizer 75%, SLF 100% - Seaweed Liquid Fertilizer 100%, RCF- Recommended Rate of Chemical Fertilizer only, SLF 50% plus RCF- Seaweed Liquid Fertilizer 50% with Recommended Rate of Chemical Fertilizer, SLF 75% plus RCF- Seaweed Liquid Fertilizer 75% with Recommended Rate of Chemical Fertilizer

Table 5 Effect of different proportions of recommended rate of chemical fertilizer (RCF) and foliar spray (SLF) extracted from four extracted from different species on number of leaves of *Capsicum annum* under field trial on 69th days (Mean± S.E.)

Number of leaves at different seaweed liquid fertilizer (SLF) concentrations and (SLF) concentrations plus Recommended rate of chemical fertilizer(RCF) /

Treatment	SLF-25%	SLF-50%	SLF-75%	SLF-100%	SLF-25% plus RCF	SLF-50% plus RCF	SLF-75% plus RCF	RCF only	Water only
Species *Sargussum wightti*	54.79±0.086[a]	58.63±0.051[b]	57.4±0.48[c]	79.7±0.66[d]	90.9±0.75[e]	96.8±1.45[f]	95.5±0.05[g]	92.7±0.04[h]	47.9±0.09[i]
Gracilaria verrucosa	47±0.032[a]	48.78±0.023[b]	52.6±0.02[c]	54.7±0.02[d]	67.6±0.02[e]	82.50±0.01[f]	94.50±0.01[g]	97.6±0.01[h]	47.79±0.03[i]
Ulva lactuca	54.79±0.1[a]	58.63±0.1[b]	57.4±0.1[c]	79.7±0.0[d]	90.9±0.01[e]	96.8±0.01[f]	95.5±0[g]	92.7±0.1[h]	47.9±0.1[i]
Kapphaphycus alvarezii	52.79±0.03[a]	55.63±0.02[b]	53.4±0.021[c]	55.7±0.034[d]	58.9±0.021[e]	67.8±0.01[f]	93.5±0.01[g]	92.7±0.01[h]	47.9±0.01[i]

*denotes significant at 5% level, different alphabets between concentration denotes statistically, significant within treatments based on multiple range test (Tukey-test), significant within treatment and species based on univariate (Anova) Dennett's (two factor factorial CRP) at 5% significant level. SLF 25%- Seaweed Liquid Fertilizer 25%, SLF 50% - Seaweed Liquid Fertilizer 50%, SLF 75% - Seaweed Liquid Fertilizer 75%, SLF 100% - Seaweed Liquid Fertilizer 100%, RCF- Recommended Rate of Chemical Fertilizer only, SLF 50% plus RCF- Seaweed Liquid Fertilizer 50% with Recommended Rate of Chemical Fertilizer, SLF 75% plus RCF- Seaweed Liquid Fertilizer 75% with Recommended Rate of Chemical Fertilizer

Table 6 Effect of different proportions of recommended rate of chemical fertilizer (RCF) and Foliar spray (SLF) extracted from four different seaweed species on number of flowers of *Capsicum annum* under field trial on 69th days (Mean± S.E.)

Number of flowersat different concentration of seaweed liquid fertilizer (SLF) concentrations and (SLF) concentrations Recommended rate of chemical fertilizer(RCF)

Treatments	SLF-25%	SLF-50%	SLF-75%	SLF-100%	SLF-25% Plus RCF	SLF-50% Plus RCF	SLF-75% Plus RCF	RCF only	Water only
Species *Sargussum wightti*	47.5±0.00[a]	48.9±0.00[b]	57.07±0.01[c]	52.23±0.01[d]	41.44±0.012[e]	58.56±0.01[f]	61.55±0.001[g]	55.67±0.2[h]	30.75±0.02[i]
Gracilaria verrucosa	53±0.02[a]	52±0.0[c]	54±0.0[c]	43±0.01[d]	65±0.02[e]	63±0.03[f]	69±0.012[g]	52±0.01[h]	35±0.03[i]
Ulva lactuca	47±0.00[a]	42±0.01[b]	44±0.032[c]	42±0.021[d]	56±0.022[e]	65±0.024[f]	65.87±0.02[g]	58±0.022[h]	35±0.021[i]
Kapphaphycus	53±0.05[a]	51±0.04[b]	56±0.02[c]	45±0.01[d]	53±0.03[e]	66±0.03[f]	62±0.01[g]	48±0.04[h]	38±0.01[i]

*denotes significant at 5% level, different alphabets between concentration denotes statistically, significant within treatments based on multiple range test (Tukey-test), significant within treatment and species based on univariate (Anova) Dennett's (two factor factorial CRP) at 5% significant level. SLF 25%- Seaweed Liquid Fertilizer 25%, SLF 50% - Seaweed Liquid Fertilizer 50%, SLF 75% - Seaweed Liquid Fertilizer 75%, SLF 100% - Seaweed Liquid Fertilizer 100%, RCF- Recommended Rate of Chemical Fertilizer only, SLF 50% plus RCF- Seaweed Liquid Fertilizer 50% with Recommended Rate of Chemical Fertilizer, SLF 75% plus RCF- Seaweed Liquid Fertilizer 75% with Recommended Rate of Chemical Fertilizer

Table 7 Effect of different proportions of recommended rate of chemical fertilizer (RCF) and foliar spray (SLF) extracted from of four different species on number of pods of *Capsicum annum* under field trial on 105th days (Mean± S.E.).

Number of pods at different seaweed liquid fertilizer (SLF) concentrations and(SLF) concentrations with Recommended rate of chemical fertilizer(RCF)

Treatment	SLF-25%	SLF-50%	SLF-75%	SLF-100%	SLF-25% Plus RCF	SLF-50% Plus RCF	SLF-75% plus RCF	RCF only	Water only
Species *Sargussum wightti*	37±0.031[a]	48±0.031[b]	45±0.031[c]	50±0.035[d]	58±0.021[e]	62±0.034[f]	66±0.032[g]	64±0.045[h]	46±0.056[i]
Gracilaria verrucosa	37±0.031[a]	37±0.031[b]	35±0.031[c]	40±0.035[d]	45±0.021[e]	42±0.034[f]	50±0.032[g]	48±0.045[h]	36±0.056[i]
Ulvalactuca	24±0.02[a]	36±0.01[b]	39±0.2[c]	44±0.2[d]	47±0.1[e]	49±0.011[f]	54±0.023[g]	52±0.01[h]	28±0.01[i]
Kapphaphycus	27±0.1[a]	38±0.00[b]	35±0.1[c]	40±0.1[d]	48±0.01[e]	52±0.061[f]	56±0.036[g]	54±0.042[h]	34±0.031[i]

*denotes significant at 5% level, different alphabets between concentration denotes statistically, significant within treatments based on multiple range test (Tukey-test), significant within treatment and species based on univariate (Anova) Dennett's (two factor factorial CRP) at 5% significant level. SLF 25%- Seaweed Liquid Fertilizer 25%, SLF 50% - Seaweed Liquid Fertilizer 50%, SLF 75% - Seaweed Liquid Fertilizer 75%, SLF 100% - Seaweed Liquid Fertilizer 100%, RCF- Recommended Rate of Chemical Fertilizer only, SLF 50% plus RCF- Seaweed Liquid Fertilizer 50% with Recommended Rate of Chemical Fertilizer, SLF 75% plus RCF- Seaweed Liquid Fertilizer 75% with Recommended Rate of Chemical Fertilizer

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Table 8
Effect of different proportions of recommended rate of chemical fertilizer(CRF) and foliar spray (SLF) extracted from four different species on length of pods of *Capsicum annum* under field trial on 105thdays (Mean± S.E.).

Length of pods (cm) at different seaweed liquid fertilizer (SLF) concentrations and (SLF) concentrations with Recommended rate of chemical fertilizer(RCF)

Treatment	SLF-25%	SLF-50%	SLF-75%	SLF-100%	SLF25% Plus RCF	SLF-50% plus RCF	SLF-75% plus RCF	RCF only	Water only
Species *Sargussum wightti*	0.46±0.01^{a}	0.43±0.032^{b}	0.50±0.00^{c}	0.68±0.001^{d}	0.67±0.00^{e}	0.62±0.021^{f}	0.79±0.03^{g}	0.62±0.02^{h}	0.63±0.021^{i}
Gracilaria verrucosa	0.53±0.03^{a}	0.52±0.032^{b}	0.55±0.034^{c}	0.54±0.031^{d}	0.68±0.035^{e}	0.72±0.001^{f}	0.78±0.0.031^{g}	0.76±0.023^{h}	0.44±0.056^{i}
Ulvalactuca	0.63±0.022^{a}	0.62±0.021^{b}	0.65±0.00^{c}	0.64±0.031^{d}	0.88±0.022^{e}	0.92±0.03^{f}	0.92±0.021^{g}	0.89±0.06^{h}	0.66±0.00^{i}
Kapphaphycus	0.56±0.012^{a}	0.53±0.001^{b}	0.50±0.012^{c}	0.68±0.03^{d}	0.57±0.00^{e}	0.72±0.013^{f}	0.78±0.033^{g}	0.72±0.031^{h}	0.53±0.021^{i}

*level. SLF 25%- Seaweed Liquid Fertilizer 25%, SLF 50% - Seaweed Liquid Fertilizer 50%, SLF 75% - Seaweed Liquid denotes significant at 5% level, different alphabets between concentration denotes statistically, significant within treatments based on multiple range test (Tukey-test), significant within treatment and species based on univariate (Anova) Dennett's (two factor factorial CRP) at 5% significant level., SLF 25%- Seaweed Liquid Fertilizer 25%, SLF 50% - Seaweed Liquid Fertilizer 50%, SLF 75% - Seaweed Liquid Fertilizer 75%, Fertilizer 75%, SLF 100% - Seaweed Liquid Fertilizer 100%, RCF- Recommended Rate of Chemical Fertilizer only, SLF 50% plus RCF- Seaweed Liquid Fertilizer 50% with Recommended Rate of Chemical Fertilizer, SLF 75% plus RCF- Seaweed Liquid Fertilizer 75% with Recommended Rate of Chemical Fertilizer,

Table 9 Effect of different proportions of recommended rate of chemical fertilizer (CRF) and foliar spray (SLF) of extracted from four different species on average yield per plot of *Capsicum annum* under field trial on 69thdays (Mean± S.E.).

Average yield (ton/hectare) at different seaweed liquid fertilizer (SLF) concentrations and (SLF) concentrations Recommended rate of chemical fertilizer(RCF

Treatment	SLF-25%	SLF-50%	SLF-75%	SLF-100%	SLF-25% plus RCF	SLF-50% Plus RCF	SLF-75% PlusRCF	RCF only	Water only
Species *Sargussum wightti*	573±0.031^{a}	749±0.031^{b}	705±0.031^{c}	705±0.035^{d}	903±0.021^{e}	970±0.034^{f}	1036±0.032^{g}	1003±0.045^{h}	716±0.056^{i}
Gracilaria verrucosa	573±0.031^{a}	573±0.031^{b}	551±0.031^{c}	628±0.035^{d}	705±0.021^{e}	661±0.034^{f}	787±0.032^{g}	639±0.045^{h}	562±0.056^{i}
Ulvalactuca	374±0.02^{a}	562±0.01^{b}	606±0.2^{c}	683±0.2^{d}	738±0.1^{e}	776±0.011^{f}	848±0.023^{g}	815±0.01^{h}	440±0.01^{i}
Kapphaphycus	418±0.1^{a}	595±0.00^{b}	551±0.1^{c}	628±0.1^{d}	749±0.01^{e}	815±0.061^{f}	881±0.036^{g}	848±0.042^{h}	529±0.031^{i}

*level. SLF 25%- Seaweed Liquid Fertilizer 25%, SLF 50% - Seaweed Liquid Fertilizer 50%, SLF 75% - Seaweed Liquid denotes significant at 5% level, different alphabets between concentration denotes statistically, significant within treatments based on multiple range test (Tukey-test), significant within treatment and species based on univariate (Anova) Dennett's (two factor factorial CRP) at 5% significant level., SLF 25%- Seaweed Liquid Fertilizer 25%, SLF 50% - Seaweed Liquid Fertilizer 50%, SLF 75% - Seaweed Liquid Fertilizer 75%, Fertilizer 75%, SLF 100% - Seaweed Liquid Fertilizer 100%, RCF- Recommended Rate of Chemical Fertilizer only, SLF 50% plus RCF- Seaweed Liquid Fertilizer 50% with Recommended Rate of Chemical Fertilizer, SLF 75% plus RCF- Seaweed Liquid Fertilizer 75% with Recommended Rate of Chemical Fertilizer