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Effects of Foliar Application of Seaweed (*Sargassum crassifolium*) Liquid Extract on the Performance of *Lycopersicon esculentum* Mill. In Sandy Regosol of Batticaloa District Sri Lanka

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Abstract: The challenges faced by the agriculture sector are immense, today. The growing agricultural practices need more fertilizers for higher yield. At present, wide spread requirement for environment friendly agriculture for the production of quality and healthy food to nourish the increasing population is in high demand. Efforts are underway for the sustainable way of crop production with organic fertilizers and botanicals from natural resources to enhance the production of commercially important crops. In this regard, a field experiment was conducted at the Crop Farm of Eastern University, Sri Lanka, Vantharumoolai to find out the effects of seaweed (*Sargassum crassifolium*) extract foliar application on growth, yield and quality performances of *Lycopersicon esculentum* Mill. The experiment was arranged in a Randomized Complete Block Design (RCBD) with five treatments and four replications. Once a week the seaweed extract at different concentration (10%, 20%, 50% and 100%) were applied to tomato plants at five times from three weeks after transplanting and their performance was recorded once in two weeks. Foliar application of *Sargasssum crassifolium* extract had significant ($p<0.05$) effects on tested parameters of Tomato over the control. Seaweed extract with 20% of foliar application increased shoot dry weight (80.92%), root dry weight (81.57%), fruit number (57.87%), fruit yield per hectare (58.70%) along with Total Soluble Solids (25.71%) and Total acidity (76.95%) content of fruit significantly over the control, while seaweed extract with 100% of foliar application reduced above mentioned parameters significantly over the control in Tomato plants. Therefore, it could be concluded that the seaweed extract at 20% concentration level can be used to enhance the growth, yield and quality of *Lycopersicon esculentum* Mill.

Key words: Foliar application · *Lycopersicon esculentum* Mill. · Natural resources · *Sargassum crassifolium* · Seaweed liquid extract

INTRODUCTION

The WHO-UN 2013 reported that Sri Lanka as the highest per hectare user of pesticides and the eighth highest user of chemical fertilizers in the world. Once a paradise for lush greenery and vegetation, the soil under our feet has now critically deteriorated with the excessive dumping of chemical fertilizers and agro chemicals for the past 60 years. The situation is steadily aggravating as more and more chemical fertilizer is needed for plant growth while more agro chemicals are needed to protect them from pests and other diseases [1].

There is a necessity to review various approaches focusing on the use of available renewable resources of plant nutrients for complementing and supplementing the commercial fertilizer. As a result, numerous research efforts were made to systematically evaluate the feasibility and efficacy of organic sources, not only renovating soil productivity but also increasing crop productivity.

In this scenario, seaweeds are considered as a potential element which is available in plenty, easily accessible and not utilized properly in Sri Lanka. Seaweeds are marine macro algae, which form an important component of the marine living resources of the world. They are available in shallow coastal waters of sea, estuaries and backwaters [2]. Sri Lanka has a coastline of approximately 1700 km consisting many varieties of seaweeds [3]. About 320 species belonging to different families have been identified by several workers especially in Northern, Western and Southern coastal areas of Sri Lanka [4].

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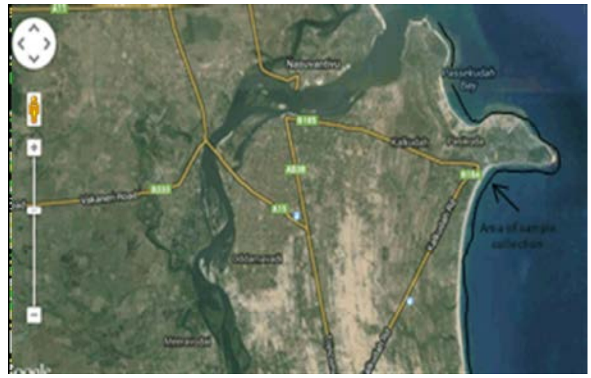
The seaweed extract has been found to contain growth stimulators such as auxins, gibberellins and cytokinin. The extract also comprises growth promoting hormones (IAA and IBA), trace elements (Fe^{2+}, Cu^{2+}, Zn^{2+}, $CO^{2+,}$ Mo^{6+}, Mn^{7+} and Ni^{4+}), vitamins and amino acids [5]. And also have been reported to stimulate the growth and yield of plants, develop tolerance to environmental stress [6], increase nutrient uptake [7] and enhance antioxidant properties [8]. The use of seaweed extract at the germinating stage showed encouraging results by stimulating the growth of roots and shoots [9]. About 2-10% of seaweed extracts in combination with NPK fertilizer has also been used in some developing countries to enhance the yield of the crop of the commercially important plants [10].

Tomato being one of the most essential vegetable crops in Sri Lanka is preferred by farmers due to high economic returns, export potential and nutritional value. In Sri Lanka, tomato is cultivated in more than 7916 ha, producing nearly 82,250 mt/ year. The average productivity of 10.39 mt/ha [11]. Tomatoes are a heavy feeder of plant nutrients including nitrogen, phosphorus and potassium and also require micronutrients for growth and development. Tomato responds well to organic fertilizers. The amount of fertilizer applied is influenced by fertility status of the soil, season and the cultivar [12]. Therefore, this study was planned to investigate the effects of seaweed (*Sargassum crassifolium*) foliar application on the performance of *Lycopersicon esculentum* Mill.

MATERIALS AND METHOD

Collection of Seaweeds: The seaweed *Sargassum crassifolium* were collected from Pasikudah, coastal area, East of Sri Lanka about 35km from Batticaloa. Seaweed sample was picked with hand and immediately washed with seawater to remove the foreign particles, sand particles and epiphytes. Then it was kept in polythene bag with seawater and immediately transported to the Crop Science Laboratory, Eastern university, Sri Lanka and washed thoroughly using tap water to remove the salt on the surface of the sample and finally distilled water. Then the seaweeds were spread on blotting paper to remove excess water.

Preparation of Seaweed Liquid Extract: Seaweeds were shade dried for four days. Then the material was hand crushed and made as coarse powder using a mixer grinder. Then the material was taken for the preparation of



Source: Satellite Earth Map, www. gosur.com

Fig. 1: Map showing the area of seaweed collection

Seaweed Liquid Extract (SLE) by following the methodology described by Rama Rao (1990). The above algal sample was added with distilled water at the ratio of 1: 20 (w/v) and autoclaved at 121 °C, 15 lbs/sq inch for 20 minutes. The hot extract was filtered through double-layered cheese cloth and it was allowed to cool at 4°C. Then the filtrate was centrifuged at 5000 × g for 15 minutes. The supernatant was collected and considered as 100% of seaweed liquid extract.

Physiochemical Analysis of Seaweed Liquid Extract: The colour of SLE was observed visually and the pH was measured using the pH meter. SLE was analyzed for different macro (Nitrogen, phosphorous, potassium, magnesium and calcium) and micro nutrients (Iron, manganese, zinc and copper). Nitrogen was tested using kjelahl digestion, Phosphorous was tested using UV visible spectrophotometry and other nutrients were analyzed by atomic absorption spectrometry.

Experimental Site: The experiment was conducted at the crop farm as well as at the Crop science Laboratory, Faculty of Agriculture, Eastern University of Sri Lanka. It is located in the latitude of 70° 43' N and the longitude of 81° 42' E at an elevation of 7.8 m above mean sea level. It belongs to the agro ecological region of low country dry zone in Sri Lanka. The mean annual rainfall ranges from 1400 mm to 1680 mm and temperature varies from 30°C to 32°C. The soil type is sandy regosol.

Experimental Design: The experiment consisted of five treatments (10% SLE – T_2, 20% SLE- T_3, 50 SLE- T_4, 100% SLE- T_5 (v/v) and distilled water spray (control) - T_1) and was laid out in a Randomized Complete Block Design (RCBD) with four replications. The foliar application was done five times during the experimental period at one week interval from three weeks after transplanting. Other crop management practices were followed as per the recommendation of the Department of Agriculture, Sri Lanka.

Measurement: Field data were collected in this experiment at two weeks interval from five weeks after transplanting to eleven weeks after transplanting, including growth parameters, plant characters, yield components and quality of fruit of tomato plant

Number of Leaf per Plant: Number of fresh leaves per plant was taken from the pre-tagged plants.

Leaf Area (cm^2): Leaves from the destructive plants were removed and leaf area was measured from each plant by using Portable Leaf Area Meter (LICOR- 3000C, Lincolin, USA).

Shoot Dry Weight (g): Shoot part of plants were taken from randomly selected plants from each replication and they were chopped into thin pieces and subjected to oven dry for 48 hours at 80°C explained by Somasundaram *et al*. [13]

Root Dry Weight (g): Root part of plants were taken from the randomly selected plants from each replication and subjected to oven dry for 48 hours at 80°C explained by Somasundaram *et al*. [13].

Number of Flowers per Plant and Number of Fruits per Plant: Numbers of flowers and fruits per plant were counted from the pre-tagged plants of each replication.

Average Fruit Polar Diameter and Equatorial Diameter (cm): Randomly picked sample fruits from each pre-tagged plants were used to determine the polar (steam to blossom end) diameter, equatorial (trans-verse diameter) diameter using a vernier caliper.

Average Total Yield per hectare (mt/ha): The mean total yield per hectare was obtained by adding total fruit yield of various pickings from each treatment until death of plants.

Total Acidity: Randomly picked sample fruits from each tagged plants were used to determine the acidity of the fruit by titration method with alkali. The result was expressed in terms of citric acid as reported by AOAC [14].

Total Soluble Solids (TSS): Randomly picked sample fruits from each tagged plants were used to determine the TSS of the fruits by hand held refractometer (ATAGO-S-28 E model). TSS value was expressed in degree Brix.

Statistical Analysis: Data were statistically analyzed using SAS 9.1 and mean comparison was performed within treatments using Duncan Multiple Range Test at 5% significant level.

RESULT AND DISCUSSION

Physiochemical Analysis of Seaweed *Sargassum crassifolium* Extract: The physiochemical properties of seaweed *Sargassum crassifolium* liquid extract have been analyzed. The extract was brown in colour and the pH recorded was 9.0 at room temperature. The extract contained macro nutrients like Nitrogen, Potassium, Phosphorous, Magnesium and micro nutrients like Iron, Manganese, Zinc and copper and their values are given in Table 1.

Effect of seaweed (*Sargassum crassifolium*) foliar application on growth of *Lycopercicon esculentum* Mill.

Plant Height: The analysis of data on average plant height showed that application of lower concentration (20%) of SLE significantly increased plant height (16%) of Tomato in comparison to control plants ($P<0.05$), while higher concentration (100% SLE) exhibited inhibitory effect on plant height, significantly (Fig.1). This might be due to the presence of macro and micro nutrients as well as growth promoting substances like auxin and cytokinin [5] in SLE of *Sargassum crassifolium*. These results were supported by Zodape *et al*. [15], who reported that

Table 1: Physio-chemical properties of seaweed liquid extract of *sargassum crassifolium* used for this study

Variables	Unit	Value	Laboratory
Colour	-	Brown	Crop Laboratory,
pH	-	9.0	Eastern university, Sri Lanka
EC	mS/cm	2.4	
Nitrogen	ppm	400.0	CIC Laboratory services, CIC
Phosphorous	ppm	9.0	Agribusiness centre, Pelwehera
Potassium	ppm	1520.0	
Magnesium	ppm	176.0	
Calcium	ppm	ND	
Iron	ppm	2.4	
Manganese	ppm	0.4	
Zinc	ppm	3.2	
Copper	ppm	0.2	

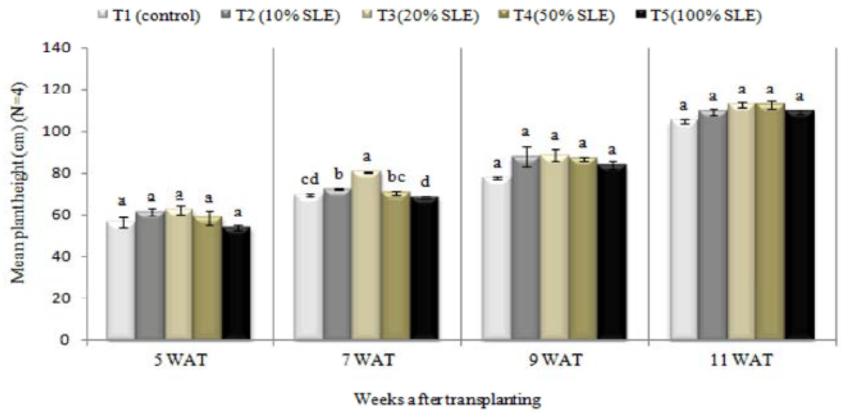


Fig. 1: Effect of seaweed foliar application on plant height at 5, 7, 9 and 11 weeks after transplanting of *Lycopercicon esculentum* mill.

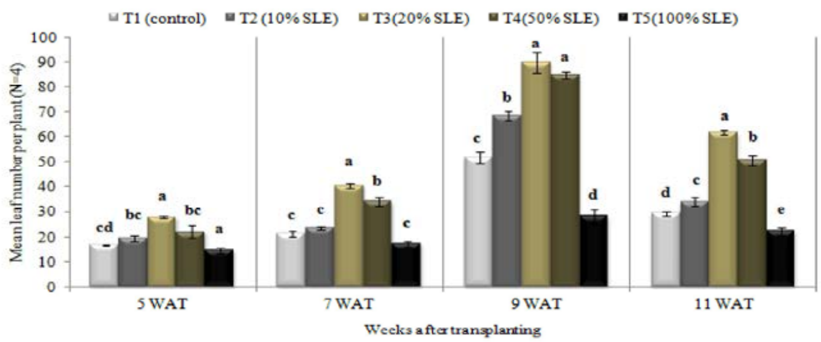


Fig. 2: Effect of seaweed foliar application on Leaf number per plant at 5, 7, 9 and 11 weeks after transplanting of *Lycopercicon esculentum* mill.

application of *Kappaphycus alvarezii* (red algae), with lower concentration had significantly increased plant height of tomato, while higher concentration exhibited inhibitory effect than control plants. Similar results have been reported in *Vigna sinensis* L. by Sivashankari [16] and in tomato by Featonby and Staden [8].

Leaves Number per Plant: All the way through the experiment, the maximum average leaves number per plant was recorded in T_3 (20% SLE), while the minimum number of leaves was recorded in T_5 (100% SLE) (Fig.2). It clearly indicated that foliar application of seaweed (*Sargassum crassifolium*) with lower concentration (20%) favours average leaves number per plant by 84.98% of tomato plant growth, while higher concentration (100% SLE) exhibited inhibitory effect on leaves number.

These results are in conformity with the reports of Sasikumar *et al*. [17], who conducted an experiment of foliar application of seaweed (*Dictyota dichotoma*) on *Abelmoschus esculantus* and the same results were also obtained by Thirumaran *et al*. [18].

Sargassum crassifolium extract could be an alternative organic source of biostimulant since macro nutrients, micro nutrients, cytokinin and auxin are the major components. Blunden *et al*. [19] reported that seaweeds and seaweed products enhance plant chlorophyll content. Whapham *et al*. [20], who stated, application of a lower concentration of *Ascophyllum nodosum* extract to soil or on foliage of tomatoes produced leaves with higher chlorophyll content than those of untreated controls. Further he reported, this increase in chlorophyll content was a result of reduction in chlorophyll degradation, which might be caused in part by betaines in the seaweed extract. Nagaraj *et al*. [21] proposed that there is a positive correlation between photosynthetic rate and chlorophyll content and small drop in chlorophyll content causes drastic reduction in photosynthetic rate.

Leaf Area per Plant: The present investigation showed that foliar application of *Sargassum crassifolium* with lower concentration (20% SLE) on tomato increased

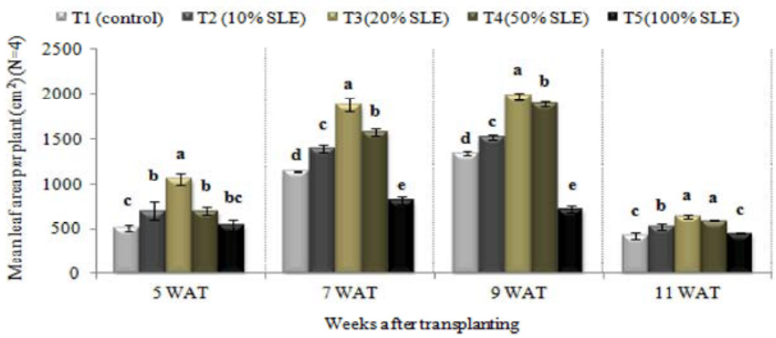


Fig. 3: Effect of Seaweed foliar application on Leaf area at 5, 7, 9 and 11 weeks after transplanting of *Lycopersicon esculentum* Mill.

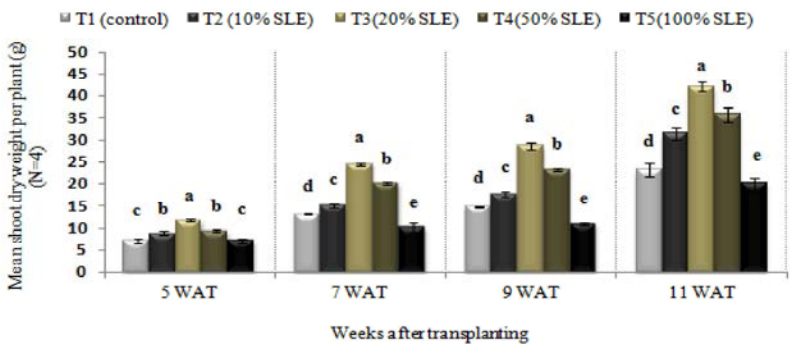


Fig. 4: Effect of seaweed foliar application on shoot dry weight at 5, 7, 9 and 11 weeks after transplanting of *Lycopersicon esculentum* mill.

the average leaf area per plant by 64.71%, while higher concentration (100% SLE) decreased average leaf area per plant than control plant (Fig.3). These results were supported by Gurusaravanan *et al*.[22], who reported, lower concentration of seaweed extract of *Turbinaria decurrens* on chickpea increased the leaf area (15.5cm^2 per plant) while higher concentration reduced the leaf area (8.5 cm^2 per plant) than control plant (12 cm^2 per plant). It was also supported by Erulan *et al*. [2].

It clearly indicates that foliar application of seaweed (*Sargassum crassifolium*) with lower concentration favours the tomato plant growth by increasing the photosynthesis through increased leaf area which is in agreement with Rasheed *et al*. [23]. Further, Crouch and Staden [5] reported that, there are many plant growth hormones, regulators and promoters available to enhance yield attributes.

Shoot Dry Weight: The treatment of 20% concentration of SLE foliar application (T_3) increased average shoot dry matter per plant significantly by 80.92% ($p<0.05$) compared to the control, except plants treated with 100% SLE (T_5) (Fig.4). It clearly showed that, foliar application of seaweed (*Sargassum crassifolium*) on tomato increased the dry matter accumulation of shoots while higher concentration exhibits inhibitory effects on dry matter accumulation. This was supported by Stephenson [24] where it was recorded that lower concentration of seaweed extract prepared from *Ascophyllum* (brown algae) and *Laminaria* (brown algae) accelerated the growth in maize. Further, Featon and Staden [25] observed an improvement in the growth of tomato root and shoot when a seaweed extract was used either as foliar spray or mixed with the soil, might be due to macro and micro elements as well as growth promoting substances like cytokinin.

Plant biomass associated with dry matter production of plants and it depends on leaf area. The higher value of leaf number and leaf area recorded in treatments which received seaweed foliar application than control treatment. It could be the reason for higher shoot dry weight in treatments of T_3, T_4 and T_2 than control. Soldati *et al*.[26] reported that an increase in leaf area leads to an increase in dry matter accumulation because proportion of dry matter allocated to leaves remain fairly constant, while an increase in leaf area leads to an increase in rate of dry matter accumulation because light interception is directly related to leaf area during this phase of development.

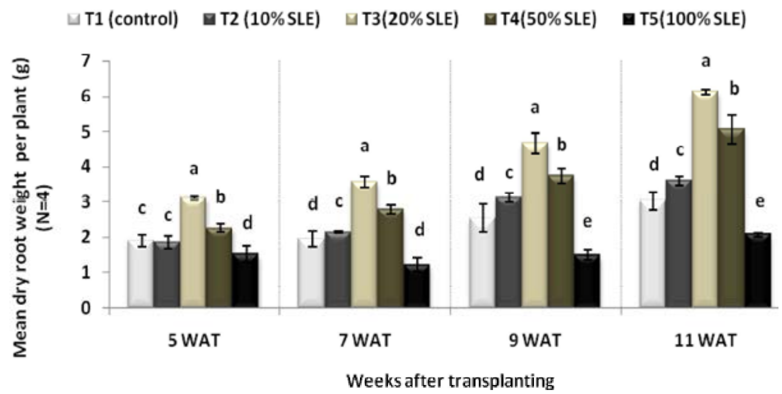


Fig. 5: Effect of Seaweed foliar application on root dry weight at 5, 7, 9 and 11 weeks after transplanting of *Lycopersicon esculentum* Mill.

Root Dry Weight: The maximum average root dry weight was recorded in T_3, followed by T_4, T_2 and T_1,while the minimum average of root dry weight was observed in T_5 (Fig.5). It might be due to the presence of good amount of P in the SLE which promotes the root development. An improved root system could be influenced by endogenous auxins as well as other compounds in the extracts (Bonkowski and Brandt, [27]; Crouch *et al*. [5]; Somasundaram *et al.* [13]). SLE is the opulent source of secondary nutrients like Mg; hence, it helps in root growth.

Mean values in a bar having the dissimilar letter/letters indicate significant differences at 5% level of significance by DMRT. Vertical error bars indicates the standard error of four replicates.

In this present investigation, plants received with 20% SLE (T_3) produced the highest root dry weight while plant received with 100% SLE (T_5) produced the lowest root dry weight during the experiment. The present finding indicated, application of *Sargassum crassifolium* extract has increased root dry matter accumulation in treated plants with lower concentration (20% SLE) by 81.57% compared to control while higher concentration (100% SLE) has exhibited inhibitory effect on root dry matter accumulation than control.

The present findings coincide with earlier studies made in Tomato by Couch and van Staden [5], who reported that dry matter accumulation in root of Tomato enhanced with the foliar application of seaweed extract with lower concentration by stimulating root growth. Further, Finnie and Van Staden [28] reported that which high concentrations inhibited root growth but stimulatory effects were found at a lower concentration in tomato. Similar results were recorded by Gurusaravanan *et al*. [22] in *Turbinaria decurrens* liquid extract which induced maximum root growth in chick pea at lower concentration.

Effect of seaweed (*Sargassum crassifolium*) foliar application on yield and yield attributing characters of *Lycopercicon esculentum* Mill.

Flower Numbers per Plant: Throughout the experiment, the maximum mean number of flowers per plant was recorded in T_3 (20% SLE), while the minimum mean number of flowers was recorded in T_5 (100% SLE). The analysis of data on mean number of flowers per plant showed that application of lower concentration (20%) of SLE had significantly ($P<0.05$) increased mean number of flowers per plant by 50.37% in treated plants in comparison to control plants while higher concentration (100%) of SLE reduced mean number of flowers per plant.

The data revealed that seaweed foliar application had remarkable effect on the mean number of flower per plant. The presence of higher amount of Potassium and growth regulators probably stimulated flower initiation and hence enhanced the number of flowers per plant in this experiment. These results are in conformity with the reports of Sasikumar *et al*. [17] who conducted an experiment of foliar application of seaweed (*Dictyota dichotoma*) on *Abelmoschus esculantus*. Similar observation was made by Mohan [29] in Green gram.

Fruit Number per Plant: All the way through the experiment, the maximum mean number of fruit per pant was recorded in T_3 (20% SLE), while minimum mean number of fruit per plant was recorded in T_5 (100% SLE). The statistical analysis of data on mean number of fruit per plant showed that application of lower concentration (20%) of SLE had significantly ($P<0.05$) increased mean number of fruit per plant by 57.87% in treated plants in comparison to control plants while higher concentration (100%) of SLE reduced mean number of fruit per plant because of its inhibitory effects.

These results are coincide with the findings of Zodape [15], who concluded that, application of *Kappaphycus alvarezii* sap on tomato significantly increased the fruit number per plant at lower concentration. Further, he reported fruit number per plant significantly reduced at higher concentration than control plants. Further it was in agreement with the findings of Sasikumar *et al*. [17], who said that, *Dictyota dichotoma* extract foliar application on *Abelmoschus esculentus* significantly increase the fruit number per plant at lower concentration comparison to control.

These results clearly showed that application of SLE of *Sargassum crassifolium* had significant influence on fruit formation of Tomato. It is due to the presence of reasonable quantity of micro nutrients like Zn, Cu, Mn and Fe and growth substance like cytokinin (Crouch and Staden [30]).

Fruit Polar Diameter: Data recorded on average fruit polar diameter per fruit is represented in Fig 4.7. The response of average polar diameter per fruit to different treatments were significant ($p<0.05$). The maximum average polar diameter per fruit was recorded in T_3 (4.56 cm per fruit), while the minimum average of polar diameter per fruit was recorded in T_1 (4.06 cm per fruit). Foliar application of SLE of *Sargassum crassifolium* with 20% concentration has significantly increased the average polar diameter per fruit by 12.31% compared to control plants. These findings are coincided with the reports of Zodape *et al.* [15] and Saravanan *et al.* [32] and this may be due to the presence of cytokinin in the SLE [30].

Equatorial Diameter: Results obtained revealed that there was no significant ($p < 0.05$) differences among the treatments on average equatorial diameter per fruit (Fig. 4.7). However, maximum average equatorial diameter per fruit was recorded in T_3 (3.31 cm per fruit), while the minimum average equatorial diameter per fruit was recorded in T_1 (3.23 cm per fruit). It clearly indicates that, application of SLE of *Sargassum crassifolium* had no significant influence on equatorial diameter of tomato. It was obtained a negative result from those previous studies made on tomato with the foliar application of SLE by Saravanan *et al*. [31] and Crouch and Staden [30]. A negative result was obtained due to the genotypic variances of tested variety.

Average Total Yield per hectare: Foliar application of seaweed *Sargassum crassifolim* significantly increased average yield per hectare land in all levels of foliar application except at highest level (T5). The statistical analysis of data on average yield per hectare land was showed that application of lower concentration (20%) of SLE had significantly ($P<0.05$) increased average yield per hectare land by 58.70% in treated plants in comparison to control plants while higher concentration (100%) of SLE reduced average yield per hectare land. Similar results in tomato with application of seaweeed extract was reported by Zodape *et al*. [15] and Saravanan *et al*. [31] and crouch and Staden [5]. Further it was supported by Arthur *et al*. [32] who found, the application of Kelpak foliar application significantly increase yield on *Capsicum annum*.

These results clearly showed that application of SLE of *Sargassum crassifolium* had significant influence on average yield per hectare of Tomato. It was due to increase in size of fruits as measured by polar and equatorial diameter and increase in number of fruits per plant. The increased yield and yield attributes may be due to the presence of plant growth regulators present in SLE [15] and the presence of reasonable quantity of macro and micro nutrients in SLE of Sargassum crassifolium. Saravanan *et al*. [31] reported that, increased yield may be due to increased fruit formation and latter fruit weight through better plant canopy establishment, better interception of light and through significant reduction in inter plant competition for solar energy and soil nutrients. This would increase efficiency of plant to do photosynthesis and translocation of assimilates to the points of fruit set.

Effect of seaweed (*Sargassum crassifolium*) foliar application on quality improvement of *Lycopercicon esculentum* Mill.

Total Soluble Solids: The present study clearly showed that, TSS of tomato fruit was improved over the controls in all the treatments of SLE of *Sargassum crassifolium* except at higher concentration (100% SLE). The finding of this study noticeably showed that, the seaweed foliar application of 20% concentration has significantly increased TSS of tomato fruit by 25.71% over the control plants. This is in accordance with earlier results reported by Zodape *et al.* [15] in tomato.

Nguyen-Quoc and Foyer [33] reported that, total soluble solids depends mainly on the transported ions and organic solutes, most of which are converted into glucose within the fruit. The present investigation apparently showed that, seaweed foliar application of *Sargassum crassifolium* with lower concentration significantly enhances the glucose accumulation in tomato fruit. Beneficial effects observed in this study might be due to the presence of micro elements such as Zinc, Manganese and copper in the *Sargassum crassifolium* exract.

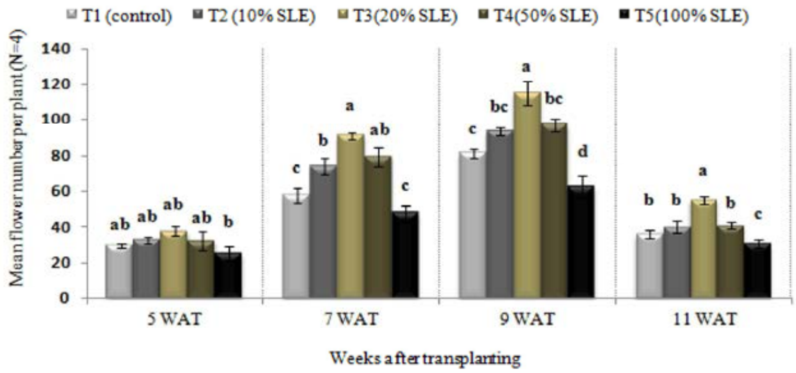


Fig. 6: Effect of seaweed foliar application on flower number at 5, 7, 9 and 11 weeks after transplanting of *Lycopersicon esculentum* mill.

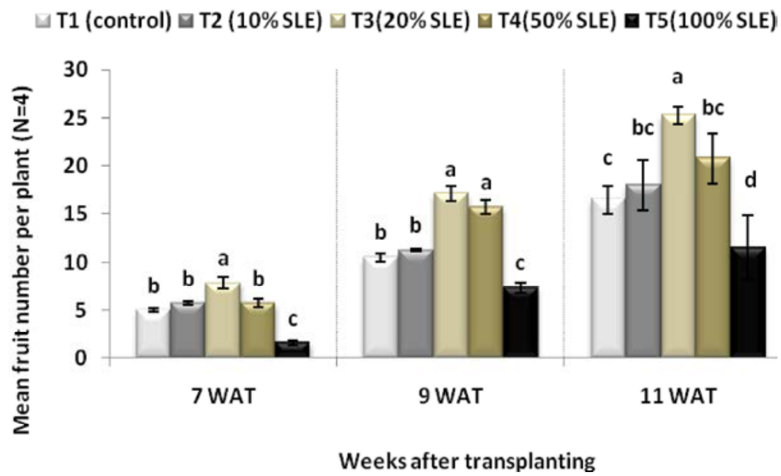


Fig. 7: Effect of seaweed foliar application on fruit number at 5, 7, 9 and 11 weeks after transplanting of *Lycopersicon esculentum* mill.

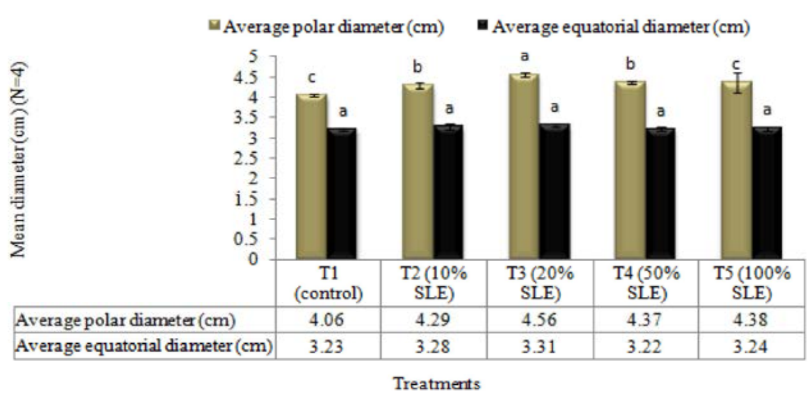


Fig. 8: Effect of Seaweed foliar application on fruit polar diameter and equatorial diameter of *Lycopersicon esculentum* Mill.

Total Acidity: The statistical analysis of data at 5% significant level showed, the foliar application of SLE at 20% concentration significantly increased total acidity of tomato fruit by 76.95% over the control plants. Finding of this study showed that, seaweed foliar application had remarable effect on total acidity of tomato fruit. These findings are in conformity with the studies of Saravanan *et al.* [31] in tomato. In tomato fruits, organic acids with sugar make a major contribution to the taste of the fruits. Most variation in flavor can be related to differences in

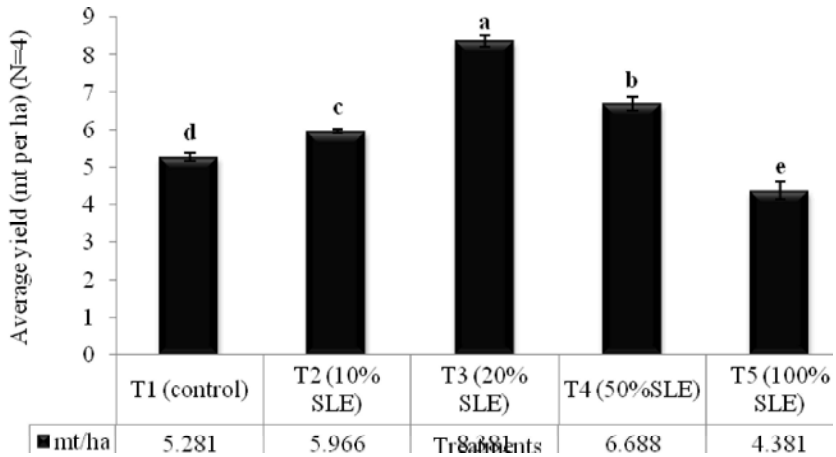


Fig. 9: Effect of Seaweed foliar application on total yield per hectare of *Lycopersicon esculentum* Mill.

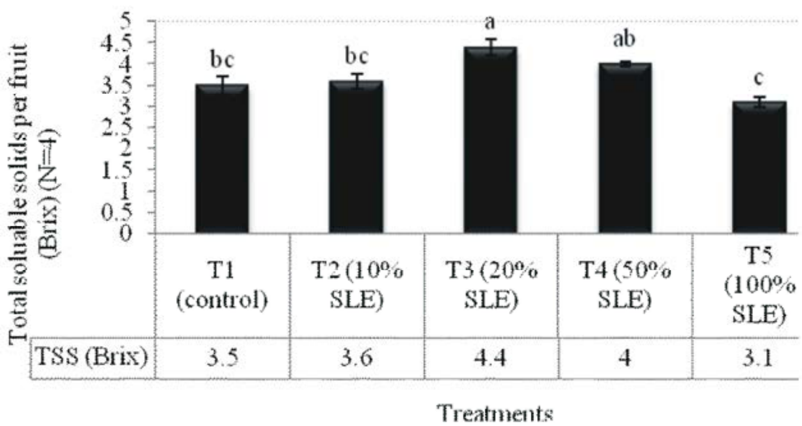


Fig. 10: Effect of Seaweed foliar application on total soluble solids of *Lycopersicon esculentum* Mill.

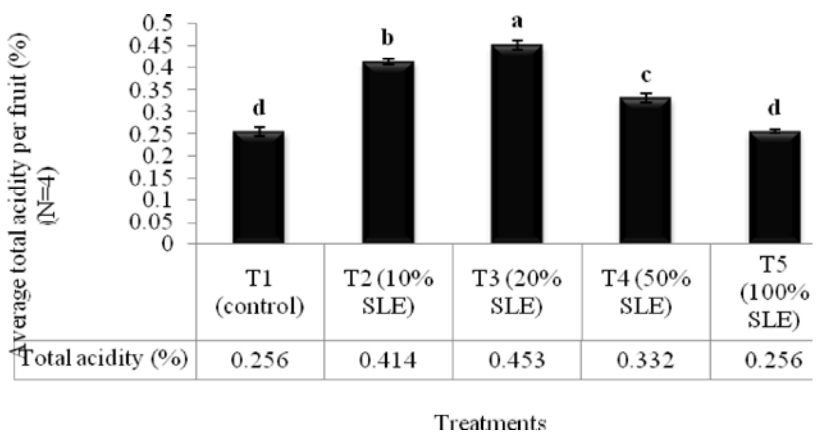


Fig. 11: Effect of Seaweed foliar application on total acidity of *Lycopersicon esculentum* Mill.

the sugar and acids contents of the fruits [34]. Finding of this study on quality improvement of tomato by seaweed foliar application undoubtedly explainthat the application of *Sargassum crassifolium* extract remarkably influenced on TSS and total acidity of tomato fruit, through which its influences on taste of tomato fruit which will enhance the marketability and consumer accessibility.

Mean values in a bar having the dissimilar letter/letters indicate significant differences at 5% level of significance by DMRT. Vertical error bars indicates the standard error of four replicates.

CONCLUSIONS

Findings of the study showed that seaweed extract with 20% concentration can be applied to Tomato plants in order to enrich the nutrient content of plant and intern to increase the growth and yield along with quality of Tomato plants. This study also confirmed that the use of seaweed extract is an eco friendly technique to enhance crop production.

REFERENCES

1. Daily, F.T., 2014. Sri Lanka develops Biofilm to come out of current chemical loop. Available online: http://www.ft.lk/2014/04/10/sri-lanka-develops-biofilm-to-come-out-of-current-chemical-loop Accessed on May, 20 2014.
2. Erulan, V., G. Thirumaran, P. Soundarapandian and G. Ananthan, 2009. Studies on the effect of *Sargassum polycystum* (C. agardh, 1824) extract on the growth and biochemical composition of *Cajanus cajan* (L.) Mill sp. American-Eurasian Journal of Agricultural and Environmental science, 6(4): 392-399.
3. Coppejans, E., F. Leliaert, O. Dargent, R. Gunasekara and O. De Clerck, 2009. Sri Lankan seaweeds: Methodologies and field guide to the dominant species, Abc Taxa:6
4. Durairatnam, M., 1961. Contribution to the study of marine algae of Ceylon. Bulletin of Fisheries Research. nStation, Ceylon, 10: 5-117.
5. Crouch, I.J. and J. van Staden, 1992. Effect of seaweed concentrates on the establishment and yield of green house tomato plants. Journal of Applied Phycology, 4: 291-296.
6. Pramanick, B., K. Brahmachari and A. Ghosh, 2013. Effect of seaweed saps on growth and yield improvement of green gram. African Journal of Agricultural Research, 8(13): 1180-1186.
7. Sridhar, S. and R. Rengasamy, 2002. Effect of Seaweed liquid fertilizer obtained from *Ulva lactuca* on the biomass, pigments and protein content of Spirulina platensis. Seaweed Research Utilisation, 24: 145-149.
8. Verkleij, F.N., 1992. Seaweed extract in agriculture and horticulture-A review. Biology of Agriculture and Horticulture, 8: 309-334.
9. Featonby-Smith, B.C., 1984.Cytokinins in Ecklonia maxima and the effect of seaweed concentrate on plant growth. Ph.D. thesis, University of Natal, Pietermaritzburg.
10. Chatterji, A., V.K. Dhargalkar, P.K. Sreekumar, P.S. Parameswaran, R. Rodrigues and S. Kotnala, 2004. Anti-influuenza activity with Indian seaweeds-A preliminary investigation. In the proceeding of the 2004 National Seminar on New Frontiers in Marine Bioscience Research, pp: 11-16.
11. Department of Censes & Statistics, 2012. Vegetable production. Available online: http://www.agrimin.gov.lk/web/. Accessed on August, 3 2014.
12. Agriculture, Forestry and fisheries, 2001. Production guidelines for tomato. Available online: http://www.nda.agric.za/docs/Brochures/ProdGuideTomato.pdf. Accessed on July, 29 2014.
13. Somasundaram, S., M. Bonkowski and M. Iijima, 2008. Functional role of mucilage -border cells: A complex facilitating protozoan effects on plant growth. Journal of Plant Production Science, 11(3): 344-351.
14. AOAC., 2002. Official Methods of Analysis. (17th Ed.). Association of Official Analytical Chemists. Washington, USA.
15. Zodape, S.T., A. Gupta, S.C. Bhandari, U.S. Rawat, D.R. Chaudhary, K. Eswaran and J. Chikara, 2011. Foliar application of seaweed sap as biostimulant for enhancement of yield and quality of tomato (*Lycopersicon esculentum* Mill.). Journal of Scientific and Industrial Research, 70: 215-219.
16. Sivasankari, S., V. Venkatesalu, M. Anantharaj and M. Chandrasekaran, 2006. Effects of seaweeds extracts on the growth and biochemical constituents of *Vigna sinensis*, Bioresource Technology, 97: 1745-1751.
17. Sasikumar, K., T. Govindan and C. Anuradha, 2011. Effect of seaweed liquid fertilizer of *Dictyota dichotoma* on growth and yield of *Abelmoschus esculentus* L. European Journal of Experimental Biology, 1: 223-227.
18. Thirumaran, G., M. Arumugam, R. Arumugam and P. Anantharaman, 2009. Effect of seaweed liquid fertilizer on growth and pigment concentration of *Abelmoschus esculentus* (I) Medikus. American-Eurasian Journal of Agronomy, 2(2): 57-66.
19. Blunden, G., T. Jenkins and Y. Liu, 1997. Enhanced leaf chlorophyll levels in plants treated with seaweed extract. Journal of Applied Phycology, 8: 535-543.
20. Whapham, C.A., G. Blunden, T. Jenkins and S.D. Hankins, 1993. Significance of betaines in the increased chlorophyll content of plants treated with seaweed extract. Journal of Applied Phycology, 5: 231-234.

21. Nagaraj, N., J.C. Reese, M.B. Kirkham, K. Kofoid, L.R. Campbell and T.M. Loughin, 2002. Relationship between chlorophyll loss and photosynthetic rate in greenbug (Homoptera:Aphididae) damaged sorghum. Journal of the Kansas Entomological Society, 75(2): 101-109.
22. Gurusaravanan, P., V. Pandiyarajan and N. Jayabalan, 2011. Effect of seaweed liquid fertilizer on growth and biochemical constituents of *Cicer arietinum* L. Journal of Basic and Applied Biology, 5 (1&2): 301-306.
23. Rasheed, M., Abid Hussain and Tariq Mohamood, 2004. Growth analysis of Hybrid Maize as influenced by planting and nutrient management. Department of Agronomy, University of Agriculture, Faisalabad-38040, Pakistan.
24. Stephenson, W.A., 1974. Seaweed in agriculture and Horticulture. Rateover, perumavalley. California, 3: 41.
25. Featonby-Smith, B.C. and J. van Staden, J., 1983. The effect of seaweed concentrates on the growth of tomato plants in nematode-infested soil. Scientia Horticulturae, 20: 137-146.
26. Soldati, A., A. Stehli and P. Stamp, 1984. Temperature adaptation of tropical highland Maize (*Zea mays* L.) during early growth and in controlled conditions. Crop science, 24: 28-32.
27. Bokowski and Brandt., 2002. Do soil protozoa enhance plant growth by hormonal effects. Soil Biology and Biochemistry, 33(11): 1709-1715.
28. Finnie, J.F. and J. van Staden, 1985. Effect of seaweed concentrate and applied hormones on *in vitro* cultured tomato roots. Journal of Plant Physiology, 120: 215-222.
29. Mohan, V.R., V. Venkataraman Kumar, R. Murugeswari, S. Muthuswami and S. Muthuswami, 1994. Effect of crude and commercial seaweed extracts on seed germination and seedling growth in *Cajanus cajan* L. Journal of Physiological society, 33(1&2): 47-51.
30. Crouch, I.J. and J. Van Staden, 1991. Evidence for rooting factors in a seaweed concentrate prepared from Ecklonia maxima. Journal of Plant Physiology, 137: 319-322.
31. Saravanan, S., S. Thampithurai, D. Veeraragavatnatnam and A. Sabbaia, 2003. Effect of seaweed extract and chlormequat on growth and fruit yield of tomato (*Lycoperscicon esculentum* Mill.). Indian Journal of Agriculture Research, 37(2): 79-87.
32. Arthur, G.D., W.A. Stirk and J. van Staden, 2003. Effect of a seaweed concentrate on the growth and yield of three varieties of *Capsicum annuum*. South African Journal of Botany, 69: 207-211.
33. Nguyen-Quoc, B. and C.H. Foyer, 2001. A role of ‘futile cycles’ involving invertase and sucrose synthase in sucrose metabolism of tomato fruit. Journal of Experimental Botany, 52: 881-889.
34. Malundo, T.M.M., R.L. Shewfelt, G.O. Ware and E.A. Baldwin, 2001. Sugars and acids influence flavor properties of mango (*Mangifera indica*). Journal of the American Society for Horticultural Science, 126(1): 115-121.