Research Article

# EVALUATION OF SEA WEED SAPS ON PERFORMANCE OF TOMATO (*LYCOPERSICUM ESCULENTUM*) UNDER ORGANIC PRODUCTION SYSTEM

**Jayanta Layek[1*], Anup Das[1], Arup Ghosh[2], Mesaya Rangsa Marak[1], Krishnappa R.[1], Ramkrushna, G.I.[3], A.S. Panwar[4] and Shidayaichenbi Devi[1]**

[1]*Division of crop production, ICAR Research Complex for NEH Region, Umiam, Meghalaya 793 103, INDIA*

[2]*Waste Research Discipline, Central Salt & Marine chemical research institute, Bhavnagar, Gujarat, INDIA*

[3]*ICAR-Central Institute of Cotton Research and Development, Nagpur, Maharashtra, INDIA*

[4]*ICAR-Indian Institute of Farming Systems Research (IIFSR), Modipuram, Meerut, Uttar Pradesh, INDIA*

**Corresponding author's E-mail: jayanta.icar@gmail.com*

**KEYWORDS:**
Chlorophyll index, Lycopene content, Organic, Seaweed sap, Tomato, Vermiwash

**ARTICLE INFO**
**Received on:** 02.07.2018
**Revised on:** 20.12.2018
**Accepted on:** 21.12.2018

**ABSTRACT**

**Out of the millions of seaweed products produced every year, considerable portions are used as nutrient supplements or bio-stimulants or bio-fertilizers to improvise plant growth and productivity. Anfield experiment was conducted during *kharif* 2015 at mid Himalayan conditions of (ICAR Research Complex for NEH Region, Umiam), Meghalaya to study the realistic impact of foliar application of seaweed extracts on the growth and yield of tomato. Treatments comprise 3 types of saps viz., *Kappaphycus alvarezii* (Ksap), *Gracilaria edulis* (Gsap)and vermiwash @ 2 concentrations (5 and 10%) and set of spray schedule @ three growth stages (at seedling, early vegetative and flowering /fruiting stage). The results revealed that fruits/plant were recorded to be highest under application of K sap @ 10 % (12.6), followed by G sap @ 10% (12.5). Whereas the fruit yield was recorded significantly higher at K sap @ 10 % (13.06 t/ha). The ascorbic acid and Lycopene content were found to be significantly higher at $GA_3$ free sap @ 10% (25.41 and 13.74 mg/100g, respectively). Foliar spray application at the 3 stages of tomato with K or G sap @ 5 and 10% concentrations was resulted in significantly higher shoot height, dry-matter accumulation, leaf chlorophyll content and fruit yield, as compared to the control (water spray). The yield attributes like fruits/plant, weight/fruit, ascorbic acid and lycopene content were significantly higher with foliar application of 10% G or K sap over the controlled treatment (water spray) which suitably act as low cost crop supplements under stressful environments of NEH-Region.**

## INTRODUCTION

Seaweeds are exclusively known as abundant space occupiers but act as primary producers in the marine ecosystems with ample ecological and economic significance (Ba-akdah *et al.*, 2016). The drift driven-seaweed washed up seen on beaches has been used for centuries as natural fertilizer in across many coastal regions throughout the world (McHugh, 2003). Seaweeds are being enormous sources for various economically important value added products, including compost, they serve as vital fertilizers containing lots of ready to use micro-nutrients at optimum concentration which can be readily absorbed bythe plants without any further chemical decomposition. Seaweeds harbor the necessary micro and other nutrient elements which are easily absorbed for enhanced nourishment of plants (Layek *et al.,* 2018). Previous studies clearly indicate that the seaweeds are active bio-resources to be used as substrates for organic compost, and liquid fertilizer production (RaniJuneius *et al*., 2018). Moreover, these research efforts mainly focused on liquid fertilizer or compost production from seaweeds and their effects on crops and soil fertility for agriculture utility point of view. Moreover, compost and liquid fertilizer production from seaweeds are well documented. The seaweed biomass has been loss frequently utilized for vermin-conversionorvermin-culture (Fantonalgo and Salubre, 2019).Vermi-wash is obtained as liquid extracts from the vermin-compost units, commonly used as foliar spray in crop plants. It contains the array of excretory products and mucus secretion of earthworms which being known richness in vitamins, hormones, enzymes, macro nutrients and micro nutrients. In recent scenarios of specialized agriculture for and other logistics where organic manure application is also very less in crops (Mukherjee *et al*., 2017) due to lower availability, bulkiness in nature, difficult to carry and to be application preference towards high value crops like vegetables, seaweed sap which can become permanent alternative (Zodape *et al*., 2011) as it is an organic in content and low cost product. Seaweed saps contain all the trace elements and plant growth regulators such as auxins, cytokinins and gibberellins that provide a major boost to crop yields by sustaining and accelerating the plant's metabolic activities. Many studies revealed that seaweed saps produce effective responses to crops which presumably as good as chemical fertilizers (Zodape *et al*., 2008).

Tomatoes **(***Lycopersicum esculentum***)** have been associated with several health benefits, including reduced risk of heart diseases and cancer, and source for other major dietary elements of the antioxidant, Lycopene. They being rich source of vitamin C, potassium, folate and other bioactive compounds, it is one of the important vegetables in the North Eastern region (NER) of India. In these regions, as the use of chemicals are meager, organic farming of crops and vegetables are mostly practiced by the local farmers (Layek *et al.,* 2018). Therefore, to meet the increasing demand of organic fertilizers, one of the viable options is the use of sea-weed extracts as fertilizers (Layek *et al.,* 2016). Organic manure application rate is also very less and inadequate in crops of NER due to poor availability, bulky nature, difficulties in transportation and application. The region has great potential for the promotion of organic farming as many studies revealed that seaweed saps are successful in enhancing productivity of crops when applied alone as well as along with chemical fertilizer or organic manure (Layek *et al.,* 2016). Seaweed extracts aid the requirement of fertilizers and promotes growth and quality of tomato (Zodape et al., 2008). About 15 million metric tonnes of seaweed products are produced every year across the globe (FAO, 2006) among which a considerable portion can be used for nutrient supplements or bio-stimulants or bio-fertilizers to improve plant growth and productivity. Crop stimulants can enhance the growth of any crop plant in order to increase yield or quality attributes (Jena *et al*., 2017). Seaweed has recently gained much emphasis as foliar spray by inducing faster growth and yield in cereals, vegetables, fruit orchards and horticultural plants (Zodape *et al*., 2008). Hence, seaweed cast continued to be so valuable to farmers and used both in agriculture and horticulture (Verkleij, 1992).In India, large quantity of macroscopic marine algae had been utilized directly as manure or in the form of compost by coastal peoples. In India, Central Salt and Marine Chemical Research Institute (CSMCRI), had explored and introduced the commercially important seaweeds viz., *Kappaphycusalvarezii* and *Gracilaria edulis* and developed a prismatic cultivation technology leading to large scale farming of seaweed in shallow coastal waters. Previous studies revealed that seaweed saps are effective in enhancing productivity of crops such as wheat (*Triticum aestivum*), soybean (*Glycine max*), tomato (*Solanum lycopersicum*) by 10-60% and produce good results when applied along with chemical fertilizer or organic manure. Keeping in view, an experiment has been conducted using seaweed extracts, K sap and G sap, and vermiwash on the growth and yield of tomato.

## MATERIALS AND METHODS

### Preparation of seaweed extract

Using the methodology of Singh *et al.* (2016), K and G saps were extracted from fresh *Kappaphycusalvarezii* and *Gracilaria edulis*, respectively. These seaweeds were cultivated in coastal seawater of Tamil Nadu, India (Layek *et al., 2014*). The K sap (commercially available as Aquasap) is being prepared by M/s Aquagri Processing Pvt. Ltd., in collaboration with CSIRCSMCRI, Gujrat, India. By milling mechanically, under ambient conditions after washing the seaweed with freshwater, the sap from *K. alvarezii* was expelled. The slurry obtained through milling was centrifuged and preserved (Eswaran *et al*., 2005). Likewise, The G sap was prepared by mechanistically expelling the sap from *G. edulis* at regional station of CSIR-CSMCRI in Tamil Nadu followed by filtration. This sap was preserved using a mixture of 0.02% propyl paraben, 0.2% methyl paraben and 0.1% potassium benzoate (Singh *et al.,* 2016). One litre of seaweedextract was considered as 100% concentration of the seaweed extract, and fromthis, different concentrations (2.5, 5, 7.5,10 and 15%) were prepared using distilled water (Sivasankari *et al.,* 2006).

### Preparation of Vermiwash

Vermiwash units can be set up either in barrels or in buckets or even in earthen pots. The bucket/barrel is filled with pieces of stone up to a height of 10 cm from the bottom. A plastic net is placed and spread. A thick layer of coir fibre along with humus containing 1000-1500 worms of species, *Eisenia foetida* or *Eudrillus euginae* is laid down. A hole is drilled at the base to fix a tap to it, through which vermiwash is collected. Cattle dung pats and hay is placed on top of the soil layer and gently moistened. The tap is kept open for the next 15 days. Water is added every day to keep the unit moist (<humid). On the 16th day, the tap is closed and on top of the unit a metal container or mud pot perforated at the base as a sprinkler is suspended. About five litres of water (the volume of water taken in this container is one fiftieth of the size of the main container) is poured into this container and allowed to gradually sprinkle on the barrel overnight. This water percolates through the compost, the burrows of the earthworms and gets collected at the base. The tap of the unit is opened the next day morning and the vermiwash is collected. Vermiwash is diluted with water before spraying as per treatment requirement.

**Field Experiment**

Field experiment was carried out during *kharif* of 2015 & 2016 at the research farm (agronomy field) of the ICAR Research Complex for NEH Region, Umiam, Meghalaya. The soil of the experimental field was sandy clay loam in nature, acidic in reaction (pH 5.2) with low in available N (253.9 kg/ha) and phosphorus (8.9 kg P/ha) and medium in available potassium (221.3 kg/ha) (Table1). The treatments comprised of three foliar application of K sap @ 5%, K sap @ 10%, G sap @ 5%, G sap @ 10%, $GA_3$ free sap @ 5%, $GA_3$ free sap @ 10%, Vermiwash @ 5%, Vermiwash @ 10% and control (water spray).The nine treatment combination were tried in Randomized Block Design (RBD) replicated thrice. The tomato was grown with 100% recommended dose of nutrients under organic nutrient management practice and sprayed with sea weed saps and vermin-wash as per treatment specifications. Three sprays of the treatments were done in tomato viz., seedling, early vegetative and flowering stage. Growth and yield parameters were recorded at the different growth stages and during physiological maturity. The experimental data pertaining to each parameter of study were subjected to statistical analysis by using the technique of analysis of variance (ANOVA) and their significance was tested by "F" test (Gomez and Gomez, 1984). Standard error of means (SEm+) and least significant difference (LSD) at 5% probability (p=0.05) were worked out for each parameter studied to evaluate differences between treatment means.

*Weather parameters*

The experimental site (Umiam) is characterized by a subtropical climate. The region receives annual average rainfall of 2450 mm with 80-85% of it received from May to October. The temperature is found to be moderate almost all the year round, except for a few months of winter. The maximum temperature ranges from 26ºC to 29ºC during the months of March to October, while during the winters, the minimum temperature rarely goes below 5ºC. Most of the times of year the maximum relative humidity ranges above 80% while minimum relative humidity rarely goes below 50%. The mean annual evaporation of this place is about 850 mm. The total amount of rainfall received during the experimental period (April 2015-March 2016) was 2550 mm,out of which most occurred during April to October month (Fig. 1.). Very less amount of rainfall was received from the month of December and February. Soil of the experimental site is a TypicPaleudalf (Das *et al.,* 2014), low in available N (258.3 kg $ha^{-1}$) and P (9.4 kg $ha^{-1}$) but medium in available K (175.3 kg $ha^{-1}$). The experimental soil is acidic in reaction (pH 5.3) and relatively high in soil organic carbon (SOC) concentration (15.8 g $ha^{-1}$).

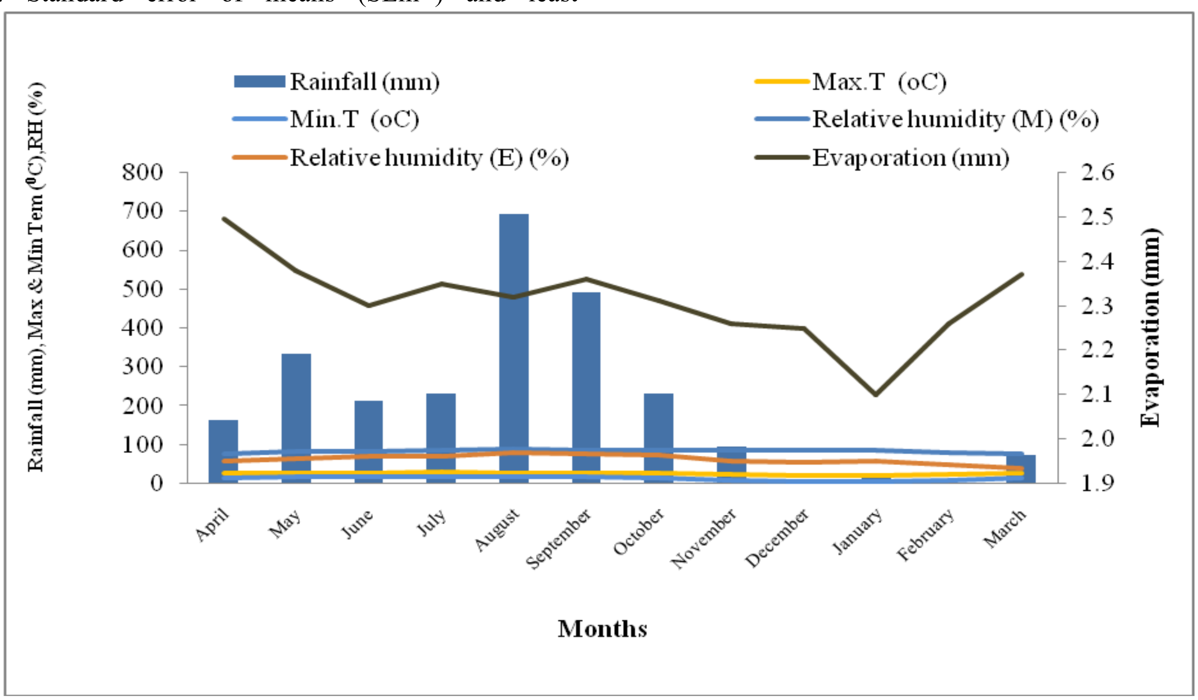


**Fig. 1. Monthly average weather data of Umiam, Meghalaya 2015**

**RESULT AND DISCUSSION**

**Growth and physiological parameters**

Growth is the irreversible change occurring in the cells or organs of plants. Therefore, growth analysis is important to explain the variations in plant growth in terms of the differences between and within the species growing under the same or different environmental conditions. Although the maximum plant height of tomato was recorded with the application of $GA_3$ free sap @10% followed by G free sap @10%, but as compared to other sea weed sap and vermin-wash treatments they were not statistically significant (Table 1). This increase in plant height may be owing to higher nutrient availability with higher concentration of saps applied (Shah *et al.,* 2013; Layek *et al.,* 2016).The presence of macro and micro-nutrients, cytokinins, auxins and betadines in seaweed extracts, might be the contributing factor for such increment in the plant height and dry matter production, which has boosted the photosynthetic process and stimulated the vegetative growth (Devi and Mani, 2015), as similar to other reports conducted for gram (Pramanick *et al*., 2013), maize (Layek *et al.,* 2016), wheat (Shah *et al.,* 2013) and rice (Layek *et al.,* 2018). As compared to control (water spray), significantly higher number of primary branches per plant was recorded with 10% K sap, 10% G sap and 10% GA3 sap. However, lower concentrations of sea weed sap and vermin-wash did not yield any significant increase in number of primary branches over control. Significantly higher number of leaves per plant in tomato were recorded on application of all the three sea weed saps (both 5 and 10% concentrations) along with 10% vermin-wash. This may be due to the increased mineral components in tomatoes after multiple treatments with bio-algae (Dobromilska *et al*., 2008). Similar results were observed on the earlier studies conducted on marigold (Russo *et al.,* 1994) where application of seaweed extract showed increase in vegetative growth.Similarly, significantly higher chlorophyll content was recorded upon application of all the sea weed saps and vermin-wash, as against control (water spray). The highest chlorophyll content was recorded under 10% vermin-wash (44.7 SPAD reading) followed by 10% K sap (44.4). It was observed that whenever seaweed extract was used as foliar spray it enhanced the chlorophyll level in plants (Blunden *et al.,*1996; Layek *et al.,* 2018). This increase in chlorophyll content in leaves can be attributed to reduction in chlorophyll degradation due to presence of betaines in the seaweed extract (Sivasankari *et al.,* 2006).

**Table 1. Growth attributes of tomato (70 days after sowing) as influenced by different concentrations of sea weed sap and vermiwash**

| Treatments | Plant height (cm) | Primary branch/ plant | No. leaves/ plant | Chlorophyll index |
|---|---|---|---|---|
| Control (water spray) | 38.7 | 3.7 | 261.7 | 40.3 |
| K sap @ 5% | 41.5 | 4.7 | 316.7 | 43.3 |
| K sap @ 10 % | 41.1 | 6.3 | 353.3 | 44.4 |
| G sap @ 5% | 41.3 | 5.0 | 313.3 | 43.0 |
| G sap @ 10% | 41.9 | 6.0 | 336.7 | 44.0 |
| $GA_3$ free sap @ 5% | 40.5 | 4.8 | 346.7 | 42.7 |
| $GA_3$ free sap @10% | 42.1 | 5.8 | 360.0 | 44.1 |
| Vermiwash @ 5% | 39.6 | 4.3 | 303.3 | 44.0 |
| Vermiwash @10% | 40.7 | 4.7 | 330.7 | 44.7 |
| SEm$\pm$ | 1.1 | 0.6 | 14.5 | 0.7 |
| CD (*p*=0.05) | NS | 1.9 | 43.6 | 2.0 |

**Yield attributes**

Crop yield is the measure of the economic produce of a crop per unit area of land cultivation. The importance of understanding and estimating yield of crop cannot be understated as estimating crop yield allows us to understand food security and also the ability to produce enough food to meet human needs in the foreseeable future.It was observed that the yield attributes of tomato viz., fruits plant$^{-1}$ and weight fruit$^{-1}$ varied significantly as influenced by different concentrations of sea weed sap (Table 2). As compared to control, on application of K sap @ 10% (12.6 fruits/plant), significantly higher number of fruits/plant was recorded, followed by 10% G sap, 10% GA3 free sap.The highest fruit weight was recorded with 10% K sap (47.3 g) followed by 10% vermin-wash (46.7 g) and 10% GA3 free sap (46.0 g). However, the average diameter of fruit (mm) did not vary significantly across the treatments (Table 3). Significantly higher fruit yield of tomato were recorded in the treatment of tomato with K sap @10% (13.06 t/ha), followed by 10% vermi-wash (13.0 t/ha) as compared to control (9.97 t/ha). Increase in yield attributes and actual yield owing to application of K sap and G sap extracts were also reported in soybean (Rathore *et al.,* 2009).Similarly, on application of foliar spray of seaweed extracts, there was improvement in the yield and quality of *Zizyphus mauritiana* Lamp (Rama Rao, 1991).

**Table 2. Yield attributes, yield and quality parameters of tomato as influenced by different concentrations of sea weed sap and vermiwash**

| Treatments | Fruits/ plant | Weight/fruit (g) | Average diameter of fruit (mm) | Fruit yield (t/ha) | Ascorbic acid (mg/100g) | Lycopene (mg/1000g) |
|---|---|---|---|---|---|---|
| Control (water spray) | 8.7 | 40.0 | 43.3 | 9.97 | 19.77 | 10.68 |
| K sap @ 5% | 10.7 | 45.7 | 45.6 | 11.94 | 22.43 | 12.12 |
| K sap @ 10 % | 12.6 | 47.3 | 46.3 | 13.06 | 23.33 | 12.94 |
| G sap @ 5% | 10.3 | 44.3 | 45.5 | 11.47 | 22.33 | 12.07 |
| G sap @ 10% | 12.5 | 45.3 | 46.1 | 12.64 | 24.23 | 13.10 |
| $GA_3$ free sap @ 5% | 10.3 | 44.0 | 44.6 | 11.83 | 23.27 | 12.57 |
| $GA_3$ free sap @10% | 11.2 | 46.0 | 45.3 | 12.08 | 25.41 | 13.74 |
| Vermiwash @ 5% | 10.8 | 43.3 | 43.9 | 12.36 | 21.50 | 11.29 |
| Vermiwash @10% | 11.7 | 46.7 | 45.9 | 13.00 | 21.83 | 11.80 |
| SEm± | 0.6 | 1.5 | 1.2 | 0.48 | 0.67 | 0.40 |
| CD ($p$=0.05) | 1.7 | 4.5 | NS | 1.45 | 2.01 | 1.20 |

**Yield and quality parameters**

The quality parameters of tomato such as ascorbic acid and lycopene content were also recorded to vary significantly and observed to be enhanced by application seaweed sap. Lycopene is the pigment that renders red or pink colour to fruits and also produce anti-oxidant properties. Lycopene is also said to have health benefits ranging from healthy hearts as well as protection against sunburns and certain types of cancer.Significantly highest ascorbic acid (25.41 mg/100g) and lycopene (13.74 mg/1000g) were recorded in treatment having foliar spray of $GA_3$ free sap @10% followed by 10% G sap (24.23 mg/100g and 13.10 mg/100g of ascorbic acid and lycopene, respectively). Presence of micro- elements (Featonby-Smith and van Staden, 1984) and plant growth regulators, especially cytokinins in *Kappaphycus* and *Gracilaria* extracts (Zhang and Ervin, 2008) could be the reason for this yield enhancement. Also, foliar spray (5% v/v) of the red alga Kappaphycusalvarezii sapon tomato plants resulted in improved plant growth and yield of the fruit (60–89%), as compared to control plants sprayed with water (Zodape *et al*., 2011). Similar results of increase in yield attributes and yield by application of K and G saps have also been reported for rice (Patel *et al*., 2015; Singh *et al.,* 2015), wheat (Zodape *et al.,* 2009; Shah *et al.,* 2013), green gram (*V. radiata*) (Pramanick *et al.,* 2013), tomato (Zodape *et al*., 2011), okra (Sylvia *et al.,* 2005), soybean (Rathore *et al*., 2009) and maize (*Zea mays*) (Layek *et al.,* 2014 & 2015). Presence of micro-elements and plant growth regulators, especially cytokinins in K and G saps, increased the yield of diverse crops fertilised with recommended RDF (Zhang and Ervin, 2008; Zodape *et al*., 2009).

**CONCLUSION**

Growth, yield and quality parameters of tomato were found comparatively higher in the treatments of K sap, G sap and Vermiwash @10%, as compared to other treatments. It also produces evidence on the bio-stimulatory effect of seaweed extracts and Vermiwash in agriculture for the improvement of both crop yield and also particular role to increase the quality of the produce.

**ACKNOWLEDGEMENT**

The authors are thankful to the Central Salt and Marine Chemical Research Institute (CSMCRI), Bhavnagar, Gujarat and ICAR Research Complex for NEH region, Umiam, Meghalaya for providing financial support and necessary facilities to conduct the study.

**REFERENCES**

**Ba-Akdah, M.A., S. Satheesh and A.A. Al-Sofyani. 2016.** Habitat preference and seasonal variability of epifaunal assemblages associated with macroalgal beds on the CentralRed Sea coast, Saudi Arabia. *J. Marine Biol. Assoc.*, **96**(7):1457–1467.

**Blunden, G., T. Jenkins and Y.W. Liu. 1996**. Enhanced chlorophyll levels in plants treated with seaweed extract. *J. Appl. Phycol.,* **8**: 535–543.

**Devi, N.L. and S. Mani. 2015.** Effect of seaweed saps Kappaphycusalvarezii and Gracilaria on growth, yield and quality of rice. *Indian J Sci Techn*., **8**: 19.

**Dobromilska, R., M. Mikiciuk and K. Gubarewicz. 2008.** Evaluation of cherry tomato yielding and fruit mineral composition after using of Bio-algeen S-90 preparation. *Journal of Elementology*, **13**: 491-499.

**Eswara, K., P.K. Ghosh, A.K. Siddhanta, J.S. Patolia, C. Periasamy, A.S. Mehta, K.H. Mody, B.K. Ramava, K. Prasad, M.R. Rajyaguru, C.R. Reddy, J.B. Pandya and A. Tewari. 2005.** Integrated method for production of carrageenan and liquid seaweed fertilizer from fresh seaweeds USA Patent: 2005/6893479.

**Fantonalgo, R.N. and J.F. Salubre. 2019.** In: Waste Management and Resource Efficiency. Springer Nature

Singapore Pte Ltd, pp. 59–69. https://doi.org/10.1007/978-981-10-7290-1_6.

**Featonby-Smith, B. and J. Van Staden. 1983**. The effect of seaweed concentrate and fertilizer on the growth of Beta vulgaris. *Z. planzenphysiol*., **112**: 155-162.

**Gomez, K.A. and A.A. Gomez. 1984.** Statistical procedure for Agricultural Research. 2nd Ed. International Rice Research Institute, John Wiley and Sons, New York, Singapore.

**Jena, S., A. Panda and A. Mishra. 2017.** Biostimulants: an alternative to conventional crop stimulators. *Innovative Farming*, **2**(2): 111-113.

**Krishnamurthi, V. and H.V. Joshi. 1970**. A Check List of Indian Marine Algae. Central Salt and Marine Chemical Research Institute, Bhavanagar, Gujarat, India 36 p.

**Layek, J., G.I. Ramkrushna, A. Das, A. Ghosh, R. Krishnappa, A.S. Panwar, N.S. Azad Thakur, S.V. Ngachan, S.T. Zodape, J. Buragohain and B. Mawlong. 2014.** Seaweed sap as organic biostimulant for rice and maize production. Research bulletin no. **82**. ICAR research complex forNEH region, Umiam, Meghalaya, India.

**Layek, J., A. Das, G.I. Ramkrushna, K. Trivedi, D. Yesuraj, M. Chandramohan, D. Kubavat, P.K. Agarwal and A. Ghosh. 2015.** Seaweed sap potential towards sustainable improvement of maize productivity: a dominant staple food crop of the northeast India. *Int J Environ Stud*., **72**:305–315.

**Jayanta Layek, Anup Das, G.I. Ramkrushna, Arup Ghosh, A.S. Panwar, R. Krishnappa and S.V. Ngachan. 2016.** Effect of seaweed sap on germination, growth and productivity of maize (*Zea mays*) in North Eastern Himalayas. *Indian Journal of Agronomy,* **61** (3): 354-359.

**Layek, J, A. Das, G.I. Ramkrushna, D. Sarkar, A. Ghosh, S.T. Zodape, Lal Rattan, G.S. Yadav, A.S. Panwar and S.V. Ngachan. 2018.** Seaweed extract as organic bio-stimulant improves productivity and quality of rice in eastern Himalayas. *Journal of Applied Phycology,* **30**:547–558.

**McHugh, D.J. 2003.** A Guide to the Seaweed Industry, FAO Fisheries Technical Paper 441. FAO, Rome, Italy, pp. 91p.

**Mukherjee, A., S. Pati, A. Bag, N. Chatterjee and B. Pal. 2017.** Organic agriculture expands and contributes to sustainable food security. *Innovative Farming,* **2**(1):45-48.

**Oza, R.M. and S.H. Zaidi. 2001.** A Revised Checklist of Indian Marine Algae. Central Salt & Marine Chemicals Research Institute, Gijubhai Badheka Marg, Bhavnagar, Gujarat, India. 296 p.

**Parthasarathi, K., M. Balamurugan, K.V. Prashija, L. Jayanthi and S.A. Basha. 2016**. Potential of Perionyxexcavatus (Perrier) in lignocellulosic solid waste managementand quality vermifertilizer production for soil health. *Int. J. Recycl. Org. Waste Agricult.,* **5**: 65–86.

**Patel, V.P., S. Deshmukh, A. Patel and A. Ghosh, A. 2015.** Increasing productivity of paddy (*Oryza sativa* L.) through use of seaweed sap. *Trends Biosci*., **8**: 201–205.

**Pramanick, B., K. Brahmachari and A. Ghosh, A. 2013.** Effect of seaweed saps on growth and yield improvement of green gram. *Afr. J. Agric. Res*., **8**: 1180–1186.

**Rama Rao, K. 1991.** Effect of seaweed extract on *Zyziphus mauratiana* Lamp. *Journal of Indian Botanical Society,* **71**: 19-21.

**Rani Juneius, C.E., M. Sundari, R. Eswaralakshmi and S. Elumalai. 2018.** Seaweed liquid fertilizers: A novel strategy for the biofortification of vegetables and crops. In: Patra, J., Das, G., Shin, H.S. (Eds.), Microbial Biotechnology. Springer, Singapore.

**Rathore, S.S., D.R. Chaudhary, G.N. Boricha, A. Ghosh, B.P. Bhatt, S.T. Zodape and J.S. Patiola. 2009.** Effect of seaweed extract on the growth, yield and nutrient uptake of soybean (*Glycine max*) under rainfed conditions. *S. Afr. J. Bot*., **75**: 351–355.

**Russo, R.O., R.P. Poincelot, G.P. Berlyn. 1994.** The use of commercial organ*ic biostimulant for improved production of marigold cultivars. Journal of Home Consumer and Horticulture,* **1**: 83-93.

**Singh, S.K., R. Thakur, M.K. Singh, C.S. Singh and S.K. Pal. 2015.** Effect of fertilizer level and seaweed sap on productivity and profitability of rice (*Oryza sativa*). *Indian J. Agron*., **60**: 69–74.

**Sivasankari, S., V. Venkatesalu, M. Anantharaj and M. Chandrasekaran. 2006.** Effect of seaweed extracts on the growth and biochemical constituents of *Vigna sinensis. Bioresour Technol*., **97**: 1745–1751.

**Shah, M.T., S.T. Zodape, D.R. Chaudhary, K. Eswaran and J. Chikara. 2013.** Seaweed sap as an alternative liquid fertilizer for yield and quality improvement of wheat. *Journal of Plant Nutrition,* **36**: 192-300.

**Sharma, K. and V.K. Garg. 2018**. Vermicomposting: a green technology for organic waste management. In: Waste to Wealth. Springer, Singapore, pp. 199–235.

**Suthar, S., B. Pandey, R. Gusain, R.Z. Gaur and K. Kumar. 2017.** Nutrient changes and biodynamics of *Eisenia foetida* during vermicomposting of water lettuce (Pistia sp.) biomass: a noxious weed of aquatic system. *Environ. Sci. Poll. Res.,* **24**: 199–207.

**Sylvia, S., M. Baluswami, V.M.D. Parthasarathy and V. Krishnamurthy. 2005**. Effect of liquid seaweed fertilizers extracted from Gracilariaedulis (Gmel.) Silva, Sargassumwightiigreville and Ulvalactuca Linn. On the growth and yield of Abelmoschus esculentus (L.) Moench. *Indian Hydrobiol.,* **7**: 69–88.

**Umamaheswara Rao, M. 1970.** An annotated list of the marine algae of Visakhapatnam (India). *J. Linn. Soc.,* (Botany) **63**: 23–45.

**Umamaheswara Rao, M. 1987**. Key for identification of economically important seaweeds. *Bull. Cent. Mar. Fish. Res. Inst*., **41**: 19–25.

**Verkleij, F.N. 1992.** Seaweed extracts in agriculture and horticulture: a review. *Biol. Agric. Hortic*., **8**(4): 309–324.

**Zhang, X. and E. Ervin. 2008.** Impact of seaweed extract-based cytokinins and zeatinribo-side on creeping bentgrass heat tolerance. *Crop Science,* **48**: 364–370.

**Zodape, S.T., V.J. Kawarkhe, J.S. Patolia and A.D. Warade. 2008.** Effect of liquid seaweed fertilizer on yield and quality of okra (*Abelmoschu sesculentus* L.). *Journal of Scientific and Industrial Research,* **67**: 115–117.

**Zodape, S.T., S. Mukherjee, M.P. Reddy and D.R. Chaudhary, D.R. 2009.** Effect of *Kappaphycus alvarezii* (Doty) Doty e*x silva.* extract on grain quality, yield and some yield components of wheat *(Triticum aestivum* L.) *Int. J. Plant Prod.,* **3**: 97–101.

**Zodape, S.T., A. Gupta, S.C. Bhandari, S.C. Rawat, E.R. Chaudhary, K. Eswaran and J. Chikara. 2011.** Foliar application of seaweed sap as biostimulant for enhancement of yield and quality of tomato. *Journal of Scientific and Industrial Research,* **70**: 215–219.

**How to cite this article?**
**Jayanta Layek, Anup Das, Arup Ghosh, Mesaya Rangsa Marak, Krishnappa R., Ramkrushna, G.I., A.S. Panwar and Shidayaichenbi Devi. 2018.** Evaluation of sea weed saps on performance of tomato (*Lycopersicum esculentum*) under organic production system. *Innovative Farming*, **3**(4): 185-191.