Seaweed: A Novel Organic Biomaterial

Nidhi Verma¹, Anita R. Sehrawat*, Digvijay Pandey² and Binay K. Pandey³

¹Department of Botany, Maharishi Dayanand University, Rohtak, 124001, India.
²Department of Technical Education, IET Lucknow, Uttar Pradesh-224001, India.
³Department of IT, G. B. Pant University of Agriculture and Technology, Uttarakhand, India.

Authors’ contributions

This work was carried out in collaboration among all authors. Author NV designed the study and wrote the first draft of the manuscript. Author ARS guide the work. Authors DP and BKP managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

ABSTRACT

The seaweeds are macroscopic living resources having significant amount of growth regulators, macronutrients as well as micronutrients which are essential for the growth of crop plants. The fertilizers that are derived from seaweeds are known as new generation fertilizers or modern fertilizers which are devoid of harmful effects of chemicals. Seaweeds contains considerable amount of nutrients which are easily absorbed by plants hence beneficial for the positive growth of crop plants. In the present situation seaweeds are found to be more suitable to crop plants to increase growth parameters as compared to chemical fertilizers. The positive effects of seaweed have been observed in many crops like Cajanus cajan, Abelmoschus esculentus, Arachis hypogea, Cyanopsis tetragonoloba, Lablab purpureus, Cicer arietinum etc. This review helps in encouraging the students and research scholars towards the uses of different seaweeds on growth and development of many crop plants.

Keywords: Seaweed; crop plant; fertilizers; nutrients.

*Corresponding author: E-mail: anitarsehrawat@gmail.com;
1. INTRODUCTION

The word seaweed means the large marine algae (macroalgae or seaweed) that grow almost entirely in the shallow water. Seaweeds are the plants having thallloid body (body is not differentiated into root, stem and leaves and not having complex conducting tissues) and synthesis their food through photosynthesis [1]. Because of thallloid or simple body as compared to land plants, these absorb require nutrients from their surrounding water. The seaweeds are classified into mainly three groups on the basis of pigments and synthesizing food namely green algae (Chlorophyta), red algae (Rhodophyta) and brown algae (Phaeophyta). To call these seaweeds are “weeds” is totally incorrect because these are so beneficial in nature and directly more useful to human. Seaweeds are rich in macronutrient as well as micronutrient, proteins, vitamins, lipids, carbohydrates etc. Seaweeds have been used as phycocolloid extraction (agar, alginic acid and carrageenan), cattle feed, food, manure and [2]. In many countries like china and Japan seaweeds are harvested as staple food. Recently seaweeds are used in cosmetics, pet food, stabilizers, emulsifiers, gelling agents, cloth dyeing, to flavour milk, pizza toppings and ingredient of toothpaste and dental moulding [3,4]. From the red seaweeds a jelly like compound “Agar” is obtained that is used as irreplaceable medium in laboratory to culture explants, bacteria and fungi for research programs [5].

2. SEAWEED FERTILIZER

The fertilizers that are derived from seaweeds are known as seaweed fertilizer. The seaweed fertilizers contain growth promoting hormones, vitamins, antibiotics and all essential amino acids that increase seed germination, microbial and insect resistance so quantitatively as well as qualitatively increase yield of crops [6,7,8]. In fertilizers from seaweeds the basic nutrients (N, P and K) are present in adequate amount that make it suitable fertilizer for crop plants. Seaweed acts as excellent activator when added into the soil in the form of mulch and compost heap and changes soil physical and biological properties that are beneficial for plant growth [9, 10,11]. The alginate oligosaccharides in seaweed help in binding of soil particles and trace elements together. The seaweed manure improves the soil texture by increasing water holding capacity and by adequate supply of essential nutrients [12].

The fertilizers that are derived from the seaweed are more superior to chemical fertilizers because chemical fertilizer makes soil acidic so decrease the fertility of soil. On the other the organic fertilizers that derived from seaweed (Ascophyllum, Sargassum, Fucus, Ecklonia maxima etc.) are nontoxic, easily degradable, eco-friendly and favourable to birds, animals and human [13]. In areas where fresh seaweed is not available easily the dried seaweed in the form of 'concentrated liquid meal' is available on cheap prices. In India many brands of seaweed fertilizers are available like Biovita, Kelpak 66, Shaaktizyme, Seagrow, Plentozyme, Maxicrop, Algifert etc [14]. In modern techniques an adequate amount of fertilizer is sprayed on roots and shoots (foliar). There are many methods of preparation of Seaweed Liquid Extract (SLE) from seaweeds. Firstly seaweeds were collected from the coastal regions. These were gathered in netted basket to removal of all sea water. After this the seaweeds were washed with water to remove all impurities, dirt and any contamination. After this the seaweeds were finally chopped and boiled for 50-60 min. Then the material was cooled down and filter through paper or cloth. This concentrated extract was taken as 100% Seaweed Liquid Extract (SLE) [15,16,17,18].

3. EFFECT ON RHIZOSPHERE COMMUNITIES

Besides increasing growth of plants and water holding capacity of soil seaweeds also increase microbial community of soil that are beneficial for plant growth. However limited data is available on beneficial effect of seaweed on soil micro fauna. The alginites of seaweed increase growth of vesicular arbuscular mycorrhizal (VAM) that increase growth in orange seedlings [19]. Red and green algal extracts increase mycorrhizal infection which as a result increases growth in Carica papaya and Passiflora edulis [20].

4. EFFECT OF SEA WEED ON DIFFERENT PLANTS

India is a developing agricultural country approximately; 70% population of rural area makes backbone of Indian economy. The fast-growing population in country develops tremendous pressure on food production. To meet the needs of this increased demand
Table 1. List of different seaweed with their effects on plants

| S. No | Seaweed                        | Common name          | Scientific name               | Effects on plants                                                                 | Reference |
|-------|--------------------------------|----------------------|--------------------------------|----------------------------------------------------------------------------------|-----------|
| 1     | Sargassum tenerrimum           | Horse gram           | Dolichos biflorus             | Better results in all aspects of growth and yield                                 | [21]      |
| 2     | Laurencia obtuse               | Maize                | Zea mays                       | Enhance yield of maize plants                                                    | [22]      |
| 3     | Kappaphycus alvarezi and Hydropuntia edulis (formerly Gracilaria edulis) | Wheat var. ‘GW 496’ | Triticum aestivum              | Increase yield of and nutrient contents in grains                                 | [23]      |
| 4     | Sargassum myriocystum          | Lady's fingers or bhindi | Abelmoschus esculentus         | Increase in organic, photosynthetic and protein content                           | [24]      |
| 5     | Kappaphycus and Gracilaria     | Green gram           | Phaseolus radiata              | Improved crop quality and nutrient uptake                                         | [25]      |
| 6     | Ascophyllum nodosum            | Snap bean            | Phaseolus vulgaris             | Fresh and dry weight of leaf and stem                                            | [26]      |
| 7     | Ascophyllum nodosum            | Tomato               | Lycopersicon spp.              | Increase in Germination and Seedling Growth of Tomato                            | [27]      |
| 8     | Sargassum myriocystum          | Black gram           | Vigna mungo                    | High protein and reducing sugar content in seedling and increased α and β amylase activity in shoots | [4]       |
| 9     | Sargassum wightii Ulva lactuca | soybean              | Glycine max                    | Increased seed germination and growth rate                                         | [28]      |
| 10    | Ulva lactuca                   | chilli pepper, bell pepper or paprika | Capsicum annum                  | Sugar, chlorophyll and protein content increased                                 | [29]      |
| 11    | Ecklonia maxima and Saragassum spp | Maize                | Zea mays                       | Induced seed germination                                                         | [30]      |
| 12    | Sargassum wightii              | Peanut or groundnut  | Arachis hypogea                | Increased biochemical and pigment content                                         | [31]      |
| 13    | Caulerpa recemosa Gracilaria edulis  | Cow pea              | Vigna catajung                 | Increased seedling, fresh and dry weight                                         | [32]      |
| 14    | Dictyota dichotoma             | lady's fingers or bhindi | Abelmoschus esculentus         | increased biomass of leaf, roots, flowers and fruits                            | [33]      |
| 15    | Padina pavonica                | Green gram           | Vigna radiata                  | Increased seed germination, growth and yield                                      | [34]      |
| 16    | Ascoiphylum nodosum            | Cucumber             | Cucumis sativus                | Reduce fungal diseases                                                           | [19]      |
| 17    | KELPAK Ecklonia maxima         | Irish potatoes       | Solanum tuberosum              | increase vigour by increasing rooting system that results more tuberisation      | [10]      |
| S. No | Seaweed                              | Common name        | Scientific name                          | Effects on plants                                                                 | Reference |
|-------|--------------------------------------|--------------------|------------------------------------------|----------------------------------------------------------------------------------|-----------|
| 18    | *Padina tetrastromatica* and *Sargassum linearifolium* | black mustard      | *Brassica nigra*                         | Increased content of amino acid, protein and carbohydrate                        | [35]      |
| 19    | *Sargassum wightii*                   | Sunflower          | *Helianthus annuus*                      | Increased biochemical and antioxidant content                                     | [36]      |
| 20    | *Sargassum wightii*                   | Marigold           | *Tagetes erecta*                         | Increased height as well as number of branches                                    | [37]      |
| 21    | *Kappaphycus alvarezii*               | Green gram         | *Phaseolus radiata*                      | Improved nutritional value and yield                                              | [8]       |
| 22    | *Ascophyllum nodosum*                 | Mouse-ear cress    | *Arabidopsis thaliana*                   | Improved root and shoot growth                                                    | [13]      |
| 23    | *Ulva lactuca*                        | Cowpea             | *Vigna unguiculata*                      | Increase in fresh and dry weight                                                  | [38]      |
| 24    | *Chaetomorpha linum*                  | Tur dal            | *Cajan us cajan*                         | Improved root and shoot length and organic content                                | [39]      |
| 25    | *Sargassum wightii*                   | Asian rice         | *Oryza sativa*                           | Better results of root and shoot                                                  | [40]      |
| 26    | *Rosenvigea intricata*                | Lady's fingers or  | *Abelmoschus esculentus*                 | Increased yield and pigment content                                               | [6]       |
| 27    | *Rosenvigea intricata*                | bhindi             |                                          |                                                                                  |           |
| 28    | *Ulva lactuca* (formerly *Ulva fasciata* and *Caulerpa racemosa*) | Gavar, Guwar or Guvar bean | *Cyanopsis tetragonoloba*               | Improved growth                                                                  | [37]      |
|       |                                      | Common beans       |                                          |                                                                                  |           |
| 29    | *Laurencia obtusa, Padina tetrastromatica* and *Stoechospermum polypodioides* (formerly *Stoechospermum marginatum*) | Tea                | *Camellia sinensis*                      | Increased quality and productivity                                                | [6]       |
| 30    | *Hydroclathratus*                     | Durra or jowari    | *Sorghum*                                | Increased growth                                                                 | [42]      |
| 31    | *Ulva intestinalis* (formerly *Enteromorpha intestinalis*) | Sesame             | *Sesamum indicum*                        | Increased seed germination, chlorophyll and root, shoot length                    | [43]      |
| 32    | *Codium iyengarii* (formerly *Codium iyengarii*) | Gram               | *Cicer arientinum*                       | Increased yield, nutritional values and resistance against diseases               | [44]      |
|       |                                      | Sunflower spinach  | *Helianthus annuus*                      |                                                                                  |           |
|       |                                      |                    | *Spinacea oleracea*                      |                                                                                  |           |
| S. No | Seaweed                                                                 | Common name                   | Scientific name               | Effects on plants                        | Reference |
|-------|-------------------------------------------------------------------------|-------------------------------|-------------------------------|------------------------------------------|-----------|
| 33    | *Cladophora dalmatica, Ulva lactuca, Jania rubens* and *Pterocladiellacapillacea* (formerly *Pterocladia pinnata*) | Broad bean or faba bean       | *Vicia faba*                  | Increased protein content                 | [45]      |
| 34    | *Ulva lactuca, Sargassum wightii* and *Gelidella Acerosa*               | Ragi                          | *Eleusine coracana*           | Induced germination root and shoot growth | [1]       |
| 35    | *Kelpak 66 Ecklonia maxima*                                            | Table beet or red or golden beet | *Beta vulgaris*               | Plants grew significantly better          | [46]      |
| 36    | *Hypnea musciformis, Spatoglossum asperum, Stoechospernum polypodioides* (formerly *Stoechospermum marginatum*) and *Sargassum* | Red pepper                    | *Capsicum frutescens*         | Enhanced the rate of seed germination     | [12]      |
|       |                                                                         | Turnip pineapple              | *Brassica rapa*               |                                          |           |
| 37    | *Sargassum wightii*                                                     | Zunna berry                   | *Ziziphus rugosa*             | Increased fruit yield                     | [18]      |
farmers, use chemical fertilizers to increase the yield of crops. Chemical fertilizers release various toxic metals (arsenic and cadmium) which are stored in plant products and cause many health-related problems through biomagnifications [47]. The fertilizers that are derived from seaweeds act as biostimulants for crop plants. The term ‘biostimulant’ is totally opposite to fertilizer, the biostimulants is also known as ‘metabolic enhancers’ that increase the growth of plants when applied in small quantity [8]. Nowadays, natural seaweed products are used in place of chemical fertilizers that increase plant growth, delay fruit senescence and provide ability to crop plants to withstand against adverse environmental conditions [46]. The effective elicitors that are present in algal polysaccharides provide defence to plant against many plant diseases [17]. In brown seaweeds (Ascophyllum sp., Fucus sp., Saccharina sp.) have laminaran and alginate polysaccharides that play important role in biological activity [48, 20,49].

5. SIGNIFICANCE OF THE STUDY

Seaweed fertilizer is suitable for all crops and for most methods of applications Physiological mechanism of action of compounds present in seaweed can be of immense help to use seaweed as a source of organic fertilizer.

- Increased yield quantity and seed germination
- Improved overall vigour and ability to withstand adverse environmental conditions
- Biodegradable, non-polluting and non-hazardous
- Supply adequate trace elements
- Effective elicitors in seaweed help the plant defence against plant diseases
- Excellent biofertilizers as compared to chemical fertilizers

6. CONCLUSION

A number of researches have been done by many researchers in all parts of world to know various bioactive compounds in seaweeds. These bioactive compounds play active role in plant growth as well as in medicinal, pharmaceutical and industrial uses. The present review gives information of seaweed as an effective fertilizer compared to chemical fertilizer but more research is needed that provide information of seaweed secondary metabolites (flavonoids, steroids, alkaloids) that have many medicinal and insecticidal use.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Haupt Arthur W. Plant Morphology. New York: McGraw-Hill Book company. 1953;7.
2. Chapman VJ, Chapman DJ. Seaweeds and their uses, Chapman and Hall, London. 1980;334.
3. Gupta S, Abu-Ghannam N. Bioactive potential and possible health effects of edible brown seaweeds. Trends. Food Sci. Tech- no! 2011;22:315-326.
4. Joseph T, Baker OBE. Seaweeds in pharmaceutical studies and applications. Hydrobiologia. 1984;29-40.
5. Kumar S, Godiy CB, Siddhanta AK. Carrageenan from Sarconema scinaoides (Gigartinales, Rhodophyta) of Indian waters. Carbohydr. Polym. 2012;87:1657-1662.
6. Tarakhovskaya ER, Maslov YI, Shishova MF. Phytohor-mones in Algae. Russ. J. Plant Physiol. 2007;54:163-170.
7. Erulan VSP, Thirumaran G, Ananthan G. Studies on the effect of Sargassum polycystum extract on the growth and biochemical composition of Cajanus cajan L. J. Agri. Environ. Sci. 2009;6:392-399.
8. Zhang X, Wang K, Ervin E.H. Optimizing dosages of seaweed extract-based cytokinins and zeatin riboside for improving creeping bentgrass heat tolerance. Crop Sci. 2010;50:316-320.
9. Eyras MC, Rostagno CM, Defosse GE. Biological evaluation of seaweed composting. Comp Sci Util. 1998;6:74-81.
10. Moore KK. Using seaweed compost to grow bedding plants. BioCycle. 2004;45:43-44.
11. Khan W, Ravishankar P, Alan TC, Donald LS, Yousef P, Balakrishan P. Ascophyllum nodosum extract and its organic fractions stimulate rhizobium root nodulation and growth of Medicago sativa (Alfalfa). Communications in Soil Science and Plant Analysis. 2013;44 (5):900–908.
12. Dhargaikar VK, Untawale AG. Indian J. Mar. Sci. 1983;12:210-214.
13. Ramya SS, Vijayanand N, Rathinavel S. Influence of seaweed liquid fertilizers on
growth, biochemical and yield Parameters of Cluster Bean Plant. 2012;1(1):19–32.
14. Jeanin I, Lescure JC, Morot Gaudy JF. The effects of aqueous seaweed sprays on the growth of maize. Botanica Marina. 1991; 34:469-473.
15. Immanuel R, Subramaniam SK. Effect of fresh extracts and seaweed liquid fertilizer on some cereals and millets. Seaweed Res. Utltn. 1999;21:91–94.
16. Xavier G, Anthony S, Jesudass LL. Effect of seaweed extract on cluster bean. Seaweed Res. Utltn. 2007;29:85-87.
17. Kamaladhasan N, Subramaniam SK. Influence of seaweed liquid fertilizers on legume crop. Red gram. Journal of Basic and Applied Biology. 2009;21-24.
18. Pise NM, Sabale AB. Effect of seaweed concentrates on the growth and biochemical constituents of Trigonella Foenum- Graecum L. Journal of Phytology. 2010;2:50–56.
19. Ishii T, Akijawa J, Kirino S, Kitabayashi H, Matsumoto I, Kadoya K. Effects of alginate oligosaccharide and polyamines on hyphal growth of vesicular-arbuscular mycorrhizal fungi and their infectivity of citrus roots. In: Proceedings of the 9th International Society of Citriculture Congress, Orlando, FL, 3–7 December. 2000;1030–1032.
20. Kuwada K, Utamura M, Matsushita I, Ishii T. Effect of tangle stock ground extracts on in vitro hyphal growth of vesicular arbuscular mycorrhizal fungi and their in vivo infections of citrus roots. In: Proceedings of the 9th International Society of Citriculture Congress, Orlando, 2000;1034–1037.
21. Rayorath P, Narayanan JM, Farid A, Khan W, Palanisamy R, Hankins S, Critchley AT, Prithiviraj B. Rapid bioassays to evaluate the plant growth promoting activity of Ascophyllum nodosum (L.) Le Jol. Using a model plant, Arabidopsis thaliana (L.) Heynh. J Appl Phycol. 2008; 20:423-429.
22. Rioux LE, Turgeon SL, Beaulieu M. Characterization of polysaccharides extracted from brown seaweeds. Carbohydrate Polym. 2007;69:530–537.
23. Sathy B, Indu H, Seenivasan R, Geetha S. Influence of seaweed liquid fertilizer on the growth and biochemical composition of legume crop. Cajanus Cajan (L.). Mill Sp. Journal of Phytology. 2011;2(5):50–63.
24. Balamurugan G, Sasikumar K. Effect of seaweed liquid fertilizer of Sargassum myricostem of Abelmoschus esculentus L. International Journal of Current Research and Development. 2013;1:33-37.
25. Brahmachari K, Ghosh A. Effect of seaweed saps on growth and yield improvement of green gram. African Journal of Agricultural; 2013.
26. Abou El-Yazied A, El-Gizawy AM, Ragab MI, Hamed ES. Effect of seaweed extract and compost treatments on growth, yield and quality of snap bean. Journal of American Science. 2012;8.
27. Basher A, Alalwani N, Mohammed A, Jebor Teeb A, Hussai I. Effect of seaweed and drainage water on germination and seedling growth of tomato (Lycopersicon spp.). Euphrates Journal of Agriculture Science. 2012;4:24-39.
28. Rama Rao K. Effect of seaweed liquid fertilizer on the yield of Zizyphus rugosa (Bores). International Symposium on Marine Algae. Indian Ocean eg., India, Abstarcts. 1979:27.
29. Sridhar S, Rengasamy R. Influence of seaweed liquid fertilizer on growth and biochemical characteristics of Arachis hypogea L. under field trial. Journal of Ecobiotechnology. 2011;3:18-22.
30. M Lakshmi S, Sundaramoorthy P. Response of vigna unguiculata on liquid seaweed fertilizer. International Journal of Current Research. 2010;2:039-042.
31. Shah H, Ifikhar M. Growth, yield and quality response of three wheat (Triticum Aestivum L.) Varieties to Different Levels of N, P and K. 2011;1:2–5.
32. Anandharaj M, Venkatesalu V. Effects of seaweed liquid fertilizer on Vigna catajung. Seaweed Research and Utilization. 2001; 23(1&2):33–39.
33. Sangeetha V, Thevanathan R. Biofertilizer potential of traditional and panchagavya amended with seaweed extract marsland press. The Journal of American Science. 2010;6:61-67.
34. Bai NR, Christi RM, Kala TC. Effect of seaweed concentrate of Padina pavonia on the growth and yield of a pulse crop. Plant Archives. 2011;11:117-120.
35. Kalaivanan C, Venkatesalu V. Utilization of seaweed Sargassum myricostem extracts as a stimulant of seedlings of Vigna mungo (L.). Hepper Spanish Journal of Agricultural Science. 2012;10.
36. Akila N, Jeyadoss T. The potential of seaweed liquid fertilizer on the growth and antioxidant enhancement of Helianthus
37. Sridhar S, Rengasamy R. The effects of seaweed liquid fertilizer of Ulva lactuca on Capsicum annum Algological Studies. 2012;38:75–88.
38. Lane CE, Mayes C, Druehl LD, Saunders GW. A multi-gene molecular investigation of the kelp (Laminariales, Phaeophyceae) supports substantial taxonomic reorganization. J Phycol. 2006;42:493–512.
39. Sasikumar K, Govindan T, Anuradha C. Effect of seaweed liquid fertilizer of Dictyota dichotoma on growth and yield of Abelmoschus esculentus L. Journal of Chemistry. 2010;26:1353-1360.
40. Safinaz AF, Ragaa AH. Effect of some red marine algae as biofertilizers on growth of maize (Zea mayz L.) plants. International Food Research Journal. 2013;20:1629-1632.
41. Thirumaran TG, Arumugam M, Arumugam R, Anantharaman P. Effect of seaweed liquid fertilizer on growth and pigment concentration of Cyamopsis tetrogonolaba. American-Eurasian Journal of Agronomy. 2009;2:50-56.
42. Ashok V, Vijayanand N, Rathinavel S. Bio-fertilizing efficiency of seaweed liquid extract of Hydroclathrus clathratus on Sorghum vulgare. Seaweed Res. Utiln. 2004;26:181-186.
43. Thirumaran G, Arumugam M, Arumugam R, Anantharaman P. Effect of seaweed liquid fertilizer on growth and pigment concentration of Abelmoschus esculentus (l) medikus. American- Eurasian Journal of Agronomy. 2009;2:57-66.
44. Zahid BP. Preparation of organic fertilizer from seaweed and its effect on the growth of some vegetables and ornamental plants. Pakistan Journal of Biological Sciences. 1999;1274-1279.
45. El-Sheekh MM, el-Saied A el-D. Effect of seaweed extracts on seed germination, seedling growth and some metabolic processes of Faba beans (Vicia faba L) Cytobios. 1999;101:23-35.
46. Featonby Smith BC, Van -Staden J. The effect of seaweed concentrate and fertilizer on the growth of Beta vulgaris. Z. Pflanzenphysiol. Bd. 1983;112:155-162.
47. Hansra BS. Transfer of agricultural technology on irrigated agriculture. Fertilizer News. 1993;38(4):31-33.
48. Oyoo J, Nyongesa M, Mbiyu M, Lungho C. Organic farming: Effect of kelpak and earthlee on the yield of irish potatoes. Scientific Conference Proceedings; 2010.
49. Renuka Bai N, Mary Christi R, Christy Kala T. Growth and yield characteristics of dolichos biflorus linn. as influenced by seaweed liquid fertilizer. Plant Archives. 2013;13:163-166.