Boon of Seaweed Liquid Fertilizer in Agriculture

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Abstract— Now-a-days, the synthetic fertilizers are commonly using in agriculture when compared with organic fertilizers. The continuous use of chemical fertilizers are diminishing soil fertility, soil erosion, health threads to human, livestock and also microbial community present in the soil. To overcome this problem and to increase the efficiency of plant cultivation, seaweed extracts can be used as fertilizers in sustainable agriculture. The seaweed liquid fertilizer (SLF) or suspensions or extracts obtained from algae gain a commercial importance and it can be an alternative treatment especially for organic farming. The application of seaweed fertilizers for different crop plants is of great importance to substitute/supplementary to the inorganic fertilizers and to reduce the cost of production. The current research indicates that the extract from seaweeds are found to be supplementary to chemical fertilizer due to high level of organic matter, micro and macro elements, vitamins, fatty acids and growth regulators. Therefore, the usage of SLF can minimize the quantity chemical fertilizers for sustainable yield of various crop plants.

Key words: Seaweeds, SLF, Sustainable, Crop Response

I. INTRODUCTION

In India, the cropping system involves the usage of inorganic and organic fertilizers to improve soil health and soil fertility. However, the mismanagement and excessive use of inorganic fertilizers creates problems in soil fertility and the environment. Currently, there is widespread interest in developing sustainable agricultural systems that are less dependent on external inputs, especially fertilizers and herbicides, to reduce impacts on the environment and conserve and improve soils. The use of agrochemicals has been the main option for increasing agricultural production in world. Fertilizers and pesticides are widely used by farmers in the forested zone where the population density fuels the demand for food. The intensive use of agrochemicals may lead to soil degradation, residues of agrochemicals in crops or groundwater and to negative effects on the health of agricultural workers, especially in intensive commercial horticulture, particularly in vegetable production [1] [2] [3].

A. Seaweeds

Seaweeds are marine macro algae and it is a one of the major important marine renewable resource [4]. There are about 9,000 species of macro algae broadly classified into three main groups namely green (Chlorophyceae), brown (Phaeophyceae) and red (Rhodophyceae) based on their pigments such as chlorophylls, carotenoids and phycobiliproteins. The Indian coast line of about 7500 km long including two groups of Islands harbor around 840 seaweed species, comprised of 68 families and 217 genera, that includes 216 Chlorophyta, 191 Phaeophyta and 434 Rhodophyta species. There are number of localities along the Indian coastline with luxuriant seaweed growth with high species diversity notably Gujarat, Maharashtra, Tamil Nadu, Lakshadweep and Andaman and Nicobar groups of Islands [5].

To date, India possesses 434 species of red seaweeds, 194 species of brown seaweeds and 216 species of green seaweeds India and more than 60 species were commercially utilized for agar, carrageenan, algin and pharmaceutical especially in agricultural application for crop developments. Seaweed Mari culture is a significant and profitable livelihood option for the coastal fishing community especially for fisher women, who with little effort can earn a substantial income for the household. The seaweed potential in India was estimated at 1,005,000 tones in six states of India comprising 250,000 tones in Gujarat, 250,000 tones in Tamil Nadu, 100,000 tones in Kerala, 100,000 tones in Andhra Pradesh, 5,000 tones in Maharashtra and 300,000 tones in Andaman and Nicobar Islands [6].

Seaweeds occur in the intertidal, shallow and deep waters of the sea up to 180 m depth and also in estuaries and backwaters. They grow on dead corals, rocks, stones, pebbles, other substrates and as epiphytes on sea grasses. Several species of green, brown and red algae with luxuriant growth occur along the Southern Tamil Nadu Coast from Rameswaram to Kanyakumari covering 21 Islands of Gulf of Mannar. Rich seaweed beds are present at Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam, Visakhapatnam and coastal lakes of Pulicat and Chilka. Seaweeds also occur abundantly in Lakshadweep, Andaman and Nicobar Islands. More than 10,000 species of marine algae have been reported all over the world. In India, about 220 genera and 740 species of marine algae were recorded of which 60 species are of economic value. In Mandapam area, 180 species of seaweeds are growing, of which about 40 species are economically important [7].

II. SEAWEED FERTILIZER

Seaweed fertilizers are having nitrogen, phosphorus, potash trace elements and metabolites similar to plant growth regulators. The application of seaweed fertilizers for different crops was of great importance to substitute the commercial chemical fertilizers and to reduce the cost of production. Liquid fertilizers derived from seaweeds are found to be superior to chemical fertilizers due to high level of beneficial compounds that useful for plant growth and development [8].

Seaweed fertilizer is a natural bioactive material; water soluble derived from marine macro algae. Seaweed extract is a new generation of natural organic fertilizers containing highly effective nutrients, increased yield, promotes faster generation of seeds and resistant ability of many crops. Seaweed fertilizer could be absorbed by plant

within several hours after application and safe to human, animals and environment. The growing agricultural practices need more fertilizer for their higher yield to gratify food for human beings. The seaweed extract which contains plant growth hormones, regulators, promoters, auxins, gibberellins and vitamins consequently improves their yield and quality [9].

Seaweed suspensions or extracts obtained from green algae (Cladophora dalmatica, Entromorpha intestinalis, Ulva lactuca, Caulerpa chemnitzia), brown algae (Sargassum wightii) and red algae (Corallina mediterranea, Jania rubens, Pterocladia pinnate) [10]. Seaweed extracts derived from Sargassum wightii (Ochrophyta, Phaeophyceae), Gracilaria corticata (Rhodophyta) and Caulerpa scalpelliformis (Chlorophyta) were effective in increasing the growth parameters [11].

III. Preparation and Mode of Application of Seaweed Liquid Fertilizer (SLF)

The liquid seaweed extracts from seaweeds are usually prepared by hydrolysing the material under pressure, however, the preparation may varies from species to species depending upon the amount of dried material available. It's method of extraction significantly differs from person to person and also the mode of application to crops. Seaweed extracts are used in several ways, such as drench in soil during transplantation, during field preparation, seed treatment [12].

Foliar application is spraying of nutrients to leaves and stems where they are absorbed by the plants. Foliar applications of liquid fertilizer supply the plant with nutrients more rapidly than methods involving uptake by root due to seed/root treatment. Growers, therefore, can apply SLF as foliar treatment to quickly correct nutrient deficiencies. Foliar treatment has some drawbacks, mainly due to the structure of the leaf and the temporary nature of the nutrient supply. Leaves, particularly those with thick cuticle, have low absorption rates. Therefore, multiple applications of liquid fertilizers are necessary to supply a sufficient quantity of the nutrients to the plants. Further, once applied, foliar nutrients may be washed off by rain or irrigation water before the plant absorbs them. To counter this loss, surfactants can be used to increase the efficiency of penetration of the leaf surface and the duration of the sprays on the leaf be increased depending upon the situation. At certain cases application of high nutrient concentrations in foliar spray cause severe leaf damage due to phytotoxicity. To avoid this situation, repeated applications of dilute formulations, therefore, is necessary to supply the plant's nutrient requirements without damaging the foliage. Since there are different types of seaweed extracts available in the market, it is important for the farmer/grower to know the type of species used in preparation of SLF and how to properly use it for specific crops. The timing, dosage and frequency of application are very important when dealing with seaweed extract [13].

The application rate and frequency of SLF may vary based on location, time of season, soil type and crop. Depending on the stage of plant growth and the type of crop, a grower may have different results on which seaweed extract they use. Proper application is important because higher concentration of seaweed extract may damage the plant resulting loss in yields [14] [15].

IV. SLF constituents

Seaweeds contain various fine chemicals and micro nutrients and plant growth promoting hormones, trace elements, vitamins, aminoacids, antibiotics and micronutrients. The presence of huge amount of water soluble potash and other trace elements in seaweeds will readily absorbed by plants and its control the deficiency diseases, and also the carbohydrates and other organic matter from seaweeds improve the nature of soil and moisture retaining capacity [16] and SLF contained macro nutrients, trace elements, organic substances like amino acids and plant growth regulators such as auxins, cytokinins and gibberellins [17].

Seaweeds contain all the trace elements and plant growth hormones required by plants. It was also reported that seaweed manure is rich in potassium but poor in nitrogen and phosphorus than the farm manure. The brown seaweed Sargassum wightii contained higher amounts of cytokinins than the auxins. Analysis of SLF among the macronutrient revealed that potassium was maximum followed by magnesium, calcium, nitrogen and phosphate. In the micronutrients chloride was the maximum followed by iron and ferrous content [18] [19].

Cytokinins have been detected in fresh seaweeds and seaweed extracts. The cytokinins present in seaweed formulations include trans-zeatin, trans-zeatin riboside, and dihydro derivatives of these two forms. Liquid chromatography analysis of 31 seaweed species representing various groups revealed that zeatin and isopentenyl conjugates of cytokinins are the predominant cytokinins. Seaweed concentrates also contained aromatic cytokinins BAP (benzyl amino purine) and topolin (6-[3-hydroxybenzyl-amino] purine) derivatives) [20].

V. Crop response of seaweed liquid fertilizer

Seaweeds contains considerable amount of micronutrients and some plant growth hormones which helps plant growth and also in germination. When its concentration increases it will lead to toxicity and inhibits plant growth. The seaweed liquid fertilizer was prepared from Gracilaria edulis, Enteromorpha intestinalis and Chaetomorpha linum showed increased germination and growth on low concentration, but when the concentration increases, it inhibits the rate of germination due to its toxicity in Solanum lycopersicum [21]. SLF of Sargassum vulgare and Codium tomentosum significantly increased the shoot length, root length, fresh and dry weights of seedlings as compared with the control. The chlorophyll and carotenoid contents in leaves also showed maximum enhancement, in response to application of the SLF of each of the two seaweeds under investigation, particularly S. vulgare. The relatively high concentrations of SLF in either of the studied two algae showed a decreasing trend with respect to germination and seedling growth criteria of wheat [22].

SLF obtained from seaweeds have recently gained importance as foliar sprays for several crops because the

extract contains growth promoting hormones (IAA and IBA), cytokinins, trace elements (Fe, Cu, Zn, Co, Mo, Mn, Ni), vitamins and aminoacids. Seaweed extracts have been reported to stimulate the growth and yield of plants, develop tolerance to environment stress, increase nutrient uptake from soil and enhance antioxidant properties [23]. The seeds of five treated plants with 1.0% SLF of Ulva lactuca and Sargassum wightii have an increased on germination and protein profile. Earlier study reveals that SLF of Ulva reticulata could be used as foliar spray at low concentration 2% to maximize the growth and yield of Vigna mungo and also increase the number of stomata in the leaf [24]. SLF of Sargassum wightii and Hypnea musciformis were shown a great plant growth promoting activity effect in Cyamopsis tetragonoloba (Cluster bean) seeds and they observed maximumof shoot length and root length. It was found the maximum effect by Sargassum wightii, Padina boergesenii and Ulva fasciata Seaweed Liquid Fertilizer (SLF) and the results were mostly similar to them, and it observed maximum of shoot length and root length and also we observed maximum fresh weight in green gram (Vigna radiate) [25].

The seaweed extracts, viz., Kappaphycus alvarezii and Gracilaria edulis were applied to the foliage twice at diverse concentrations (0, 2.5, 5.0, 7.5, 10.0 and 15.0% v/v) during crop growth period. Control plot was sprayed with water. Foliar application of either Kappaphycus or Gracilaria at flowering stage and pod development stage resulted in significant increase in plant height, branches per plant, number of pods per plant, test weight and grain yield over the control. It was found that both the extracts were very effective and enhanced the growth and yield. The seed yield had increased with foliar application of Kappaphycus and Gracilaria respectively when applied at 10% concentration over the control [26]. Marigold seedlings treated with seaweed concentrates were more robust and healthier in appearance than the control. The extract of Laurencia obtusa, Jania rubens, Corallina elongata (Rhodophyta) treated with maize plant to increase the leave number and plant height [27] [28] and plant length, number of leaves, leaf area, and number of branches and fresh weight of shoot, responded positively and significantly to the application of seaweed extract with a gradual effect relative to the applied concentration [29].

Use of seaweed fertilizer stimulated root volume, plant growth and even promoted fruit development thus resulted in the production of high quality agricultural products [30]. Further it was revealed that the use of seaweed fertilizer improved germination and disease resistant capacity in plants. Water and alkaline extracts of Ascophyllum nodosum has given tomatoes of appreciable mass and also yielded good quality fruits. Seaweed extracts and fertilizers have given promising turnouts in agriculture for which it is a main stay in the catalogue of commonly preferred soil nourishers. The effect of Seaweed liquid fertilizer (SLF) of Gracilaria textorii and Turbenaria arnata applied as a foliar spray (2.5%, 5%, 10%, 20% concentrations) on Brinjal, Chilly indicated that the growth and yield of plants as well as quality of product was greatly influenced by application of SLF. The effect of The SLF was found to be effective in increasing the growth and yield in low doses (2.5% and 5%) than the control and higher concentrations of seaweed liquid fertilizer. The effect was due to the SLF contain many growth promoting hormones like auxins, gibberellins, trace elements, vitamins, aminoacids and micro nutrients. The seaweed extract was found effective in increasing the biomass growth of roots and shoots, number of leaves, flowers and fruits, maturity time and yield [31].

The water extracts of red algae Grateloupia divaricata, Chondrus pinnulatus, Ahnteltiopsis flabelliformis, Neorhodomela larix, Tichocarpus crinitus; the brown algae Stephanocystis crassipes, Coccophora langsdorfii, Sphaerotrichia divaricata, Saccharina japonica, Sargassum pallidum, Chorda filum and green algae Ulva fenestrata and Codium fragile on the growth of seedling roots of buckwheat (Fagopyrum esculentum) was screened. It was showed that low and ultra-low concentration of aqueous seaweed extracts may stimulate roots elongation of the buckwheat seedlings. The most perspective for use as biostimulants are red algae Ahnfeltiopsis flabelliformis, Neorhodomela larix and brown alga Stephanocystis crassipes. Extracts of these algae in a studied range of concentrations increased growth of the seedling roots over control. The extracts of the other examined algae showed a weak or no stimulatory effect on the growth of seedling roots. SLF from red algae Neorhodomela larix, Tichocarpus crinitus, of brown algae Saccharina japonica, Sargassum pallidum, and green algae Ulva fenestrata and Codium fragile showed a positive effect on the length of the roots of soybean seedlings. The highest stimulatory effect showed extracts of the green alga Codium fragile than the control roots [32] [33].

The seaweeds resources are intensively used to improve harvest quantity and quality in agriculture and horticulture. The beneficial effects of seaweed products on the cultured plants are well documented. They improve seeds germination, seedlings development and increase plant tolerance to environmental stresses [34] and enhance plant growth and yield [35] [36]. More over seaweeds are used as soil amendment and plant disease management [37]. Liquid extracts obtained from seaweeds have gained importance as foliar sprays and soil drench for many crops including various grasses, cereals, flowers and vegetable species. Also they apply to stimulate seedling germination and rooting.
Seaweed liquid fertilizer promoted seed germination and enhanced early seedling growth in black gram and green gram. Whereas, highest concentration of SLF was inhibited both shoot length and number of lateral roots in black gram [38] [39]. Seaweed products promote root growth and development. The root-growth stimulatory effect was more pronounced when extracts were applied at an early growth stage in maize and the response was similar to that of auxins, an important root growth promoting hormone [40]. Seaweed extract derived from Ulva lactuca, Caulerpa scalpelliformis, the brown algae, Sargassum plagiophyllum, Turbinaria conoides, Padina tetrastromatica, Dictyota dichotama are effective in increasing the growth promoting hormones and nutrients in more quantities in the seaweed extract can be applied to pulse crop, green gram of South India recommended to the growers for attaining better germination, growth and yield of cultivable plants [41]. The

seaweed extract from Turbinaria decurrens could be used as the concentration for seed soaking to enhance germination, growth and yield of crop plant and highest total leaf area was also observed at low concentration in cow pea observed [42].

The effect of liquid extracts of two seaweeds, Caulerpa peltata and Gracilaria corticata on Green gram (Vigna radiata L.) showed better results in growth parameters such as shoot length, root length, number of flowers and fruits of the plant. The pigment content such as Chl. a, Chl. b and total chlorophyll showed maximum results observed at higher concentrations of Gracilaria corticata. In general, it was observed that the seaweed liquid fertilizers prepared from the red algae, Gracilaria corticata when applied to crop plants gave better results in all aspects of growth to yield and soil nutrient contents when compared to the seaweed liquid fertilizer prepared from the green algae, Caulerpa peltata. The foliar application of seaweed (Sargassum crassifolium) had significant effects on tested parameters of tomato over the control. Seaweed extract with 20% of foliar application increased shoot dry weight, root dry weight, fruit number, fruit yield per hectare along with total soluble solids and total acidity 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 [43] [44].

Rice plants treated with various dilutions of seaweed extract Myanmar brown seaweed (Sargassum spp.) showed good growth parameters such as plant height, number of panicles, grain weight and nutritive values of grains. Moreover, the highest dilution of seaweed extract 3.2% v/v gave the best value of protein content [45]. The low concentrations of seaweed extracts showed higher percentages of germination, while at increased concentrations of the extract germination was inhibited. The increased germination percentage at low concentrations might be due to the presence of growth promoting substances such as indole-3-acetic acid (IAA) and indole butyric acid (IBA), gibberellins, cytokinins, micronutrients (Fe, Cu, Co, Zn, Mn, Mo and Ni), vitamins and aminoacids. Same results were obtained with Cajanus cajan [46], Zea mays, Elusine coracona and Vigna sinensis [47] [48].

The seaweed extracts derived from Sargassum wightii (Ochrophyta, Phaeophyceae), Gracilaria corticata (Rhodophyta) and Caulerpa scalpelliformis (Chlorophyta) were effective in increasing the growth parameters. Seaweed bio-fertilizers are better than other fertilizers and very economical. Effect of seaweed extracts have been studied on different range of agriculture and horticulture plants. Seaweed products exhibit growth-stimulating activities, and the use of seaweed formulations as biostimulants in crop production is well established. Seaweed ingredients include macro and microelement nutrients, amino acids, vitamins, cytokinins, auxins, and abscisic acid that affect cellular metabolism in treated plants, leading to enhanced growth and crop yield. In addition, seaweeds contain precursors of elicitor compounds that promote germination, growth, and maintenance of plant health. Another possibility is the presence of polysaccharides in the extract, as sugars that are known to improve plant growth in a similar way to hormones [49]. Zeatin is another candidate for induction of rooting in plants by seaweed [50].

There was a significant increase in chlorophyll content in leaves under different treatments of SLF. The higher chlorophyll concentrations in the leaves resulting from application of the seaweed extract could be achieved also by using the solution of betaines. Leaf chlorophyll contents produced by the use of seaweed extracts are due to the betaines contained in them. It appears probable that the activity of the seaweed extract and the betaines is the result of slowing down the degradation of leaf chlorophyll rather than increasing its content [51]. The total carbohydrate content increased in seaweed treated plants. This may be due to increasing of chlorophyll which can improve photosynthesis so it would increase production of carbohydrate and alternative explanation is that organic molecules such as organic acids, methionine in SLF can increase nutrient absorption in plants by chelating to the available nutrients, thereby increasing their absorbance and so can increase carbohydrates [52].

The application of a low concentration of Ascophyllum nodosum extract to soil or on foliage of tomatoes produced leaves with higher chlorophyll content than those of untreated controls. This increase in chlorophyll content was a result of reduction in chlorophyll degradation, which might because in part by betaines in the seaweed extract. Glycine betaine delays the loss of photosynthetic activity by inhibiting chlorophyll degradation during storage conditions in isolated chloroplasts [53]. The liquid extract of Ulva fasciata, Sargassum ilicifolium and Gracilaria corticata influenced the photosynthetic pigments, carbohydrate, proteins and free aminoacids content of Trigonella foenum – Graecum L. Different concentrations of liquid extract of Ulva lacuta, Caulerpa scalpelliformis, Padina tetrastromatica and Sargassum linearifolium increased the amount of protein, carbohydrate, and aminoacid of Brassica nigra [54]. The liquid extract from Ulva lacuta and Sargassum sp. applied to the soil promoted the photosynthetic pigment composition, soluble protein and starch, aminoacid content of Phaseolus mungo, Zea mays and Cyamopsis tetragonoloba [55]. The biochemical composition of Vigna radiata was increased by applying 10% liquid extract of Sargassum wightii. Seaweed extract of Gracilaria edulis showed an increase in the pigment concentration, protein and enzyme activity of Abelmoschus esculentus and in a comparative study on the impact of the liquid extract of seaweed and sea grasses of Mandapam coast found promoting the chlorophyll content of Zea mays [56][57]. Liquid extract of Padina pavonia helped in increasing the pigment, total soluble sugar, protein and lipid content of Cyamopsis tetragonoloba [58].

The biochemical composition of the green alga Ulva rigida (Ulvophyceae) was investigated by determination of moisture, protein, carbohydrate, total lipid, phenol and chlorophyll content. The green alga Ulva rigida was characterized by its high carbohydrate and lipid content followed by phenol and moisture content. Protein and total free aminoacids were found to be minimum than the other biochemical parameters [59]. Seaweed extracts exhibit growth stimulating property on crop plants. Hence its formulation can be used as a bio-stimulant in agriculture.

Bio-stimulant is defined as a 'material' other than fertilizer that promotes the growth and yield attribute property of the plants when applied in a small quantity during a crop cycle. The bio-stimulant present in seaweed extract increase the vegetative growth, the leaf chlorophyll content, the stomata density, photosynthetic rate and the fruit production of the plant [60].

The application of seaweed extract for different crops was a great importance due to contain high levels of organic matter, micro elements, vitamins and fatty acids and also rich in growth regulators such as auxins, cytokinins and gibberellins. The beneficial effect of seaweed extract application is as a result of many components. Seaweeds are a known source of plant growth regulators, organic osmolites (e.g. betaines), aminoacids, mineral nutrients, vitamin and vitamin precursors [61]. A number of commercial seaweed extract products are available for use in agriculture and horticulture and can be used as liquid extracts applied as foliar spray, soil drench, or in granular/powder form as soil conditioners and manure. These extracts are marketed as liquid biostimulants because a chemical analysis of seaweeds and their extracts has revealed the presence of a wide variety of plant growth-promoting substances such as auxins, cytokinins, and betaines. These substances can influence shoot and root system development [62].

VI. Conclusion

Seaweed liquid fertilizer derived from commonly available seaweeds act as an effective fertilizer in increasing the growth and biochemical and yield characters of many crop plants. Further, SLF also improve the soil fertility and sustainable yield. Hence, this simple practice of application of eco-friendly seaweed liquid fertilizers to economically important plants India is recommended to the growers for attaining better growth and sustainable yield. Sustainable agriculture is the booming executive of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources. Seaweed extracts which are important components of organic farming are a promising avenue for yield maximization through their biostimulatory role on crop plants. Seaweeds extracts are integral to sustainable farming because of their multifarious utility in various fields of agriculture including nutrient and crop management, plant growth and yield.

Acknowledgement

The author is thankful to the Management and the Principal of Ayya Nadar Janaki Ammal College, Sivakasi, Tamil Nadu, India for their help.

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