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Seaweed: An Alternative Liquid Fertilizer for Plant Growth

Shikha Singh[1*], Dhananjay Tiwari[1], Satyendra Singh Gautam[2], M. K. Singh[3] and S. K. Pal[3]

[1]*Department of Agronomy, NAI, SHUATS, Prayagraj (UP), India*
[2]*Department of Chemistry, Govt. College, Pendra (C.G), India*
[3]*Department of Agronomy, BAU, Kanke, Ranchi (JH), India*

**Corresponding author*

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A B S T R A C T

The indiscriminate use of agrochemicals since green revolution resulted in adverse effect on the soil fertility, crop productivity, quality of produce and more specifically on the environment system. The current scenario under such situation firmly emphasizes the need to adopt eco-friendly agricultural practices for food production by considering the sustainability of soil and environment. The use of Seaweed is considered as low cost input for plant growth and development due to presence of many nutrients as well as plant growth hormones which encourage the growth of the plants.

Introduction

Ever increasing and fast growing population is mounting tremendous pressure on food production in the country. To meet out this increasing demand, farmers use more and more chemical fertilizer to enhance the crop production. Excessive use of chemical fertilizers affects adversely soil physico-chemical and microbial properties and consequently factor productivity declining. In this situation, the application of seaweed fertilizer is of great importance to substitute the commercial chemical fertilizers. Seaweed extract is a new generation of natural organic fertilizer containing highly effective nutrients, promotes growth and yield as well as enhance the resistant ability of many crop from biotic and abiotic stress. Unlike chemical fertilizers, extract derived from seaweeds are biodegradable, non-toxic, non-polluting and non-hazardous to humans, animal and birds (Dhargalkar, 2005). Seaweed extract also contains alginates which bound the soil particles and form aggregates and resulting in better soil structure to grow crop. It may contribute to cure ills of modern chemical agriculture. Seaweed has been preferred not only due to their nitrogen, phosphorus, potash and micronutrients content, but also because of the presence of metabolites similar to plant growth regulators (Crouch and Staden, 1993) like indole compounds which help the development of plant roots and buds. Seaweed sap also a good source of potassium and phosphorus, potassium helps in regulating the water status of the plants and controls the opening and closing of stomata and help in photosynthesis, whereas phosphorus helps in root growth. Through foliar spray it directly assimilates by crop foliage within few hours after application, as well as it is used as green manure, compost etc. as seed primer it improve the establishment of the crop that can increase the vigour and germination rate. In recent years, marine bioactive substances extracted from marine algae are used as supplement to the inorganic fertilizer. These substances, recently gained importance as foliar spray for many crops, which enhances yield and quality of crops due to presence of chemical complex polysacharide compounds like laminarian, fucoidan, alginate, beneficial nutrients and growth hormones like cytokinins, auxins, betains, and sterols which promote plant growth. Many chemical components of seaweed extracts and their modes of action remain unknown, but it is possible that these components exhibit synergistic activity (Fornes *et al.,* 1995). Realising the potential use of seaweed sap for enhancing the productivity of crops, *Kappaphycus alvarezii*, *Gracilaria edulis* and other seaweeds *has* proven potentiality as a foliar bio-stimulant to increase productivity of many crops across varied agro-ecological locations for research, development and commercialization. Seaweed extracts posses several growth hormones besides macro and micro nutrients which play an important role and it has been observed that application of seaweed sap significantly influenced the different parameters of growth in several crops. Foliar application of *Gracillaria corticata* and *Kappaphycus alvarezii* extracts on *Phaseolus mungo* and *Pennisetum typhoides* (Murugalakshmi Kumari *et al.,* 2003), wheat (Singh, 2016) and maize (Singh *et al.,* 2015a) has been found to increase growth. Application of 15% *Kappaphycus alvarezii* and *Gracilaria edulis* extract accelerate the growth attributes of rice (Pramanick *et al.,* 2014). Minimum germination rate was reported with higher concentration (10% conc.) of seaweed sap and control (Divya *et al.,* 2015). This may be due to presence of plant growth regulator *i.e*. Cytokinines, gibberellins, trace elements (Challan and Hemingway, 1966), Phenyl acetic acid (PAA) and high salt index of seaweed extract that inhibit growth (Abetz, 1980).

Effect of seaweed extract on plant growth

Effect on Dry matter Accumultaion

Application of powder as well as liquid formulation of *Sargassumwightii*, *Gracilaria corticata* and *Caulerpascal pelliformis* on wheat increased dry matter accumulation by 15-25% over control (Rama Rao, 1991). SLF (Seaweed liquid fertilizer) also increased number of leaves and leaf area which is an important factor because leaves are the photosynthetic structure, which promote better translocation of water and nutrients (Jeevanjyoti *et al.,*1993). Foliar application of 15% *Kappaphycus alvarezii* and *Gracilaria edulis* extract along with recommended dose of chemical fertilizer has been found to increased all the growth attributes of soybean (Rathore *et al.,* 2009), green gram (Pramanick *et al.,* 2013) and rice (Pramanick *et al.,* 2014 ; Devi and Mani 2015).

Wheat seeds soaked for 24 hrs with 20% (0.2 mg SW ml^{-1}) concentration of *Sargassum wightii*, increased dry matter accumulation (DMA), due to high value of growth attributes like plant height, number of tillers m^{-2}, and leaf area index (LAI), (Kumar and Sahoo

2011). Growth and development of green gram increased with increasing concentration of SLF (*Ulva reticulate*) upto certain level (2%), thereafter, it declined at higher concentration (Selvanand Siva Kumar, 2013).

In maize dry matter accumulation was significantly increased by increasing concentration of *Kappaphycus alvarezii* and *Gracilaria edulis* extract upto 7.5% K sap and 5% G sap, thereafter it declined. Application of 7.5% K sap and 5% G sap along with RDF accumulated 29.8 and 11% more dry matter over control (RDF+water spray), respectively (Singh *et al.,* 2015b). This physiological response of crop dry matter increases due to the existence of biologically active cytokinine which promote cell division (Miller, 1961).

Besides, the foliar application of sea weed sap also improved nutrient mobilization and partitioning, thereby resulted in increased leaf area, dry matter production, and crop growth rate (Zodope *et al.,* 2009). Foliar application of *Kappaphycus alvarezii* extract at 10% concentration significantly increased shoot and root dry weight of black gram by 57 and 21%, while, 15% G sap increased it by 65 and 28%, respectively over control (Jadhao *et al.,* 2015). Similar findings were also reported in rice (Bai *et al.,* 2011). Seaweed sap application in rice gradually increased dry matter accumulation at maturity with increasing concentration of seaweed sap upto 10% K sap, thereafter it declined (Singh *et al.,* 2015b). Hence, dry matter accumulation in various crop was significantly influenced (30 to 58%) by seaweed sap concentration, which may be due to presence of several phyto hormones as well as macro and micronutrients in seaweed, which accelerate the rate of photosynthesis and facilitate mobilization of photosynthates from source to sink. Singh (2016), observed that Dry matter production increased with crop age and reached its peak at maturity. Dry matter accumulation in wheat increased with increasing K sap concentration up to 7.5%, thereafter it gradually declined. Application of 7.5% K sap produced maximum dry matter with spray of sap alone and seed soaking along with spray respectively), which were 32 and 29% higher than wheat grown without application of K sap in both the cases (with spray of sap alone and seed soaking along with foliar spray) respectively. Out of the total dry matter 50.4 and 50.0 % was accumulated in spike, 38.3 and 38.8% in stem and 11.3 &11.2% in leaf.

At maturity maximum total dry matter of wheat (1669.9 and 1746 g m^{-2} with spray of sap alone and seed soaking along with foliar spray respectively) was accumulated with application of 7.5% K sap along with 100%RDF,which were 34 and 32% higher than application of water along with 100% RDF in both the cases respectively. Out of the total dry matter 50.8 and 51.2% was accumulated in spike, 39.3 and 38.3% in stem and 9.9 and 10.5% in leaf.

Wheat fertilized with 50% RDF along with application of 7.5% K sap accumulated similar dry matter (1256.35 and 1305.65 g $m^{-2}$with spray of sap alone and seed soaking along with foliar spray respectively) as that of crop fertilized with 100%RDF alone (1247 and 1317.75 g m^{-2} with spray of sap alone and seed soaking along with foliar spray respectively).

Effect on plant height

Plant height is a varietal character, but it also influenced by several external factor like soil moisture and nutrient level. Foliar spray of 1% *Padina boergesnii* extract significantly increased the shoot length in *Rhizophora mucronata* (Nedumarn *et al.,* 2009). Application of 15% *Kappaphycus alvarezii* sap has been found to increased plant height of several crops like soybean (Rathore *et al.,* 2009), *Cajanus cajan* (Mohan *et al.,* 1994), *Vigna sinensis* (Sivasankari *et al.,* 2006) and rice (Pramanick *et al.,* 2014). In pigeon pea 3% of *Gracilaria corticata* extract increased plant height (Kamaladhasan and Subramaniam, 2009). Whereas, 5% concentration of *Kappaphycus alvarezii* increased plant height of tomato by 34.44% over control (Zodope *et al.*,2011). Application of *Kappaphycus alvarezii* and *Gracilaria edulis* sap increased plant height of wheat with increasing concentration of seaweed sap and maximum was recorded with 7.5% K sap and 5% G sap, which were 12.06 and 8.45% higher over control respectively (Shah *et al.,* 2013). Similarly in maize it increased by 110 and 103% higher over control (100%RDF +water spray) at maturity respectively, while application of *Gracilaria edulis* at any concentration along with 100% RDF could not influence plant height of maize (Singh *et al.,* 2016). Similar observation was recorded in *Cajanus cajan* (Mohan *et al.,* 1994), maize, sorghum, ragi (Rajkumar Immanual and Subramaniam, 1999), *Vigna catajung* and *Dolichus biflorus* (Ananthraj and Venkateswarulu, 2001 and 2002). Plant height increases due to enhanced biological activity of auxins and cytokinins, which elongate the internodes and promote the cell division. Hence, here was enough evidence that application of seaweed sap significantly increased the plant height of various crop due to presence of growth hormones which promotes elongation of internodes as well as faster cell division.

Effect on tiller number

In cereals tillers is the most important parameter which influences the crop yield. Application of seaweed (*Hydroclathrus* spp.) extract in rice produced more tillers (Sunarpi *et al.,* 2010). Similarly application of 15% K sap along with 100% RDF in rice produced more tillers per unit area (Pramanick *et al.,* 2014). Whereas, in wheat *Kappaphycus alvarezii* and *Gracilaria edulis* extract along with RDF increased total tillers with increasing concentration of sap and maximum was recorded with 7.5% K sap and 5% G sap which were 9.23 and 7.49 % higher over control respectively (Shah *et al.,* 2013). This is probably due to presence of carbohydrates (Veera *et al.*,2012), phenyl acetic acid (Taylor and Wilkinson, 1997), macro and micro elements (Sharma *et al.,* 2012 and Rathore *et al.,* 2009), plant growth regulators like cytokinin (Mondal *et al.,* 2014) and gibberellins (Strik and Van staden, 2006) in sea weed extracts.

Singh (2016) observed that maximum tillers was recorded with application of 7.5% K sap which were 19 and 18% higher than crop grown without application of K sap in with spray alone and seed soaking along with spray respectively.

Effect on crop growth rate

Crop growth rate gradually increases with crop age up to certain stage and thereafter it declines. It is also influenced by several external factors like soil nutrient and moisture. Application of seaweed extract significantly influenced the crop growth rate of maize with increasing concentration of sap upto 7.5%K and 5% G sap along with 100% RDF thereafter it gradually declined, and magnitude of increase was 46 and 58% respectively over control (Singh *et al.,* 2015b). Similarly in green gram, *Kappaphycus alvarezii* and *Gracilaria edulis* extract significantly increased growth rate during 21 to 42 days after sowing (DAS), the best result was recorded with 15% G sap followed by 15% K sap along with RDF, which were 31 and 31% higher, over control respectively (Pramanick *et al.,* 2013). Singh (2015a,b) reported that, rice sprayed with 10% K sap along with 100% RDF recorded 59.7% more crop growth rate than control (100% RDF with water spray), whereas, spraying of 7.5% G sap along with 100% RDF recorded 37.8% more crop growth rate than control (without sap).

Singh (2016) observed that crop growth rate of wheat gradually increased with crop age and attained its peak during 70-90 days of crop age and thereafter it declined sharply as the crop proceeded towards maturity. Crop growth rate of wheat increased with increasing K sap concentration up to 7.5% and thereafter it gradually declined with spray alone and seed soaking along with sap spray both, Maximum crop growth rate was recorded with application of 7.5% K sap spray alone and seed soaking along with sap spray both respectively, which were 34 and 29% higher than crop grown without application of K sap spay alone and seed soaking along with spray respectively.

Effect of seaweed sap on root growth

Root is responsible for extracting nutrient and moisture from the soil besides providing anchorage to the plant. Root growth is also influenced by several external factors like soil moisture and nutrient. Seaweed is a better organic resource, which contains macro and micro nutrients, auxins, cytokinins and other growth promoting substances (Spinelli *et al.*, 2010).

Lower concentration of seaweed extract is probably required for initiation and development of roots, whereas at higher concentration it declined (Kumari *et al.*, 2011). It may be due to the presence of auxins like substance in seaweed extract which play an important role in cell enlargement and cell division (Jeanin *et al.*, 1991). Such a response is also common with hormones, often promoting physiological process at low concentration and inhibitory effect at high concentration (Crouch and Van Staden, 1993).

Seed treated with 20% concentration of *Sargassum wightii* and *Rosen vingea* intricate extract with or without chemical fertilizer increased root length and number of lateral roots in wheat and decline at higher concentration (Kumar and Sahoo, 2011). Similarly, in *Vigna radiata* application of 1:6 dilution of SLF showed enhanced root and shoot length than control (Bai *et al.*, 2011). Foliar spray of 1% *Padina boergesnii* extract significantly increased the root length and number of roots in *Rhizophora mucronata* (Nedumarn *et al.*, 2009). Seaweed extract increased growth potential due to presence of carbohydrates (Booth, 1965), micro and macro elements (Challan and Hemingway, 1965) and phenyl Acetic acid (Taylor and Wilkinson, 1977). Soaking of wheat seeds with *Sargassum wightii* for 24 hrs at 20% (0.2 mg SW ml^{-1}) concentration increased lateral roots by 63 per cent and root length by 50% (Kumar and Sahoo, 2011). It may be due to presence of plant hormones like, auxins, cytokinins, gibberllins and ABA, which regulate the stimulating and inhibitory effect of marine algae (Prasad *et al.*, 2010; Yokoya *et al.*, 2010, Tokezawa *et al.*, 2011).

Application of *Gracilaria corticata* at 3% concentration in pigeon pea also increased root length (Kamaladhasan and Subramaniam, 2009). Whereas, in tomato 5% concentration of *Kappaphycus alvarezii* extract increased root length by 45.05 % over control (Zodope *et al.*, 2011). Jadhao *et al.*, (2015) reported that application of 10% concentration of *Kappaphycus alvarezii* extract increased root dry weight by 21%, whereas 15% G sap increased by 28% over control. Singh (2016) observed that application of 7.5% K sap gradually increased root length and dry weight, thereafter it gradually decreased in both the cases *i.e.* with sap spray alone and seed soaking along with spray. Wheat grown with application of 7.5% K sap recorded maximum root length and root dry weight.

Effect of seaweed sap on chlorophyll content in plant

Chlorophyll is the green pigment which is responsible for light absorption and photosynthesis (Nelson and Cox, 2004) and photosynthesis is necessary to provide energy for plant growth and reproduction (Marschner, 1995). Seaweed liquid fertilizer increased total chlorophyll and carotenoids content in *Cyamopsis tetragonaloba* at lower concentration (20%) of SLF with or without chemical fertilizer (Thirumaran *et al.*, 2009) which might be due to the presence of plant growth substances in sea weed extract applied (Mostafa and Zeekh, 1999).

In *Vigna unguiculata* application of 0.25% *Ulva lactuca* SLF increased chlorophyll a, b and total content by 142, 160, and 110% over control respectively (Sekhar *et al.*, 1995). Similarly, *Ulva* and *Enteromorpha* SLF also increased magnesium content in fababean by 66 and 96% respectively which ultimately influenced the chlorophyll content (EL-Sheikh and EL-Saied, 1999).

At lower concentration of *Gracilaria edulis* sea weed liquid fertilizer with or without chemical fertilizer increased total chlorophyll and carotenoids contents in *Vigna unguiculata* and *Phaseolus mungo* (Lingakumar *et al.*, 2002), whereas in *Cyamopsis tetragonaloba*, *Caulerpa scaterpelliformis* and *Gracilaria corticata* extract increased leaf chlorophyll content (Thirumalthangan *et al*., 2003).

In sorghum chlorophyll a, b and total chlorophyll content, increased with increasing concentration of SLF upto 1.5% thereafter it showed inhibitory effect (Vijayanand *et al.*, 2004). In *Cyamopsis tetragonoloba*, 20% concentration of seaweed liquid fertilizer enhanced photosynthetic pigment and carotenoids whereas it decreased with increasing concentration beyond 20% (Thirumaran *et al*., 2009). It might be due to the presence of cytokinin and magnesium, which play a vital role in photosynthesis. An enhancement of chlorophyllase activity was observed in chlorotic leaf substrate, when Fe, Cu and Zn were supplemented to the chlorotic leaf (Lange, 1975; Srivastava and Srivastava, 2004), which might be the case with application of seaweed extract also. Similar findings were also reported in maize by Mondal *et al*., (2015), who observed that *Kappaphycus alvarezii* extract enhanced net photosynthesis rate and other gas exchange parameters in maize, due to the presence of gibberellins and choline in substantial amounts, which are known to play an important role in enhancing photosynthetic activity by maintaining higher level of photosynthetic pigments (Blunden *et al.,* 1996 and Guinn *et al.*, 2011). The groundnut treated with four different concentration of SLF (*Sargassum wightii*) viz. 0.25, 0.5, 1.0 and 1.5% enhanced concentration of photosynthetic pigments. Crop receiving 1% SLF and 25% recommended dose of chemical fertilizer contained maximum chlorophyll a, b and total and were 40, 36 and 56% higher to RDF (Sridhar and Rengasamy, 2011). It might be due to the presence of betains (Blunden *et al.,* 1997), Fe and Mg content in seaweed extract, which increased number and size of the chloroplast and better grana development (Menon *et al.,* 1984). Further, application of *Ulva reticulate* at lower concentration enhanced flowering periods in *V. mungo* than control (Selvam and Siva Kumar, 2013), but at higher concentration (above 4%) maturity period was shorter than lower concentration of SLF (Selvam and Sivakumar, 2013), due to reduced amount of leaf chlorophyll a, b and total (a+b) as phenol and peroxidase degrade chlorophyll content as the harvest was nearer as well during senescence the activity increases with ageing process. Wheat crop sprayed with 7.5% K sap along with RDF produced significantly higher chlorophyll (a, b and total) content, which increased with increasing crop age from 2 to 9 days after flowering and thereafter it declined due to senescence of leaf (Singh *et al*., 2016). They also observed that application of 7.5% K sap along with reduced fertilizer dose (50% RDF) was able to maintain similar chlorophyll content in wheat flag leaf fertilized with 100% RDF alone, indicating that 7.5% K sap was capable enough to compensate the 50% fertilizer requirement with regard to chlorophyll production of wheat crop. Application of seaweed extract significantly increased the chlorophyll and other pigments in various crops due to presence of glycine betaines which are responsible for slowing down the degradation of chlorophyll rather than increasing its content, can play an important role in maintaining greenness of the plants for a longer period and delay the photosynthetic activity (Singh, 2016).

In general Chlorophyll (a, b and total) content of wheat flag leaf increased with increasing crop age from 2 to 9 DAF thereafter it gradually decreased Maximum total chlorophyll content was recorded with application of 7.5% K sap (35.9 and 32.3 mg g^{-1} with spray alone and seed soaking along with sap spray respectively), which were 31 and 27% higher than crop grown without application of K sap with spray alone and seed soaking along with sap spray respectively.

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