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Role of seaweed extract on growth, yield and quality of some agricultural crops: A review

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ABSTRACT

Seaweed and seaweed-derived products have been widely used as bio stimulants in crop production due to presence of multiple growth regulators such as cytokinin, auxins, gibberellins, betaines, as well as presence of macronutrients such as Ca, K, P, and micronutrients like Fe, Cu, Zn, B, Mn, Co and Mo, which are necessary for plant growth and development. Numerous studies have revealed a wide range of beneficial effects of seaweed extract on plants, such as early seed germination and establishment, better crop performance and yield, inducing resistance to biotic and abiotic stress and many more. This paper is an effort to review the importance of seaweed extract on germination, production, improvement of nutritional quality of agricultural crops which helps in further study of sea weed in agriculture.

Key words: Foliar spray, Nutritional quality, Resistant to stress, Sea weeed extract.

With the increasing population the demand for food and fiber per unit area are increasing as a result the demand for chemical fertilizer is also increasing for producing more yields from limited area. The excessive use of chemical fertilizer cause serious health hazards as well as pollute the environment. Therefore, in recent years many plant extracts have been used in agriculture. Out of these, use of natural seaweeds as fertilizer has allowed the gradual substitution of conventional synthetic fertilizers (Hong *et al*. 2007). These natural fertilizers are biodegradable, non toxic in nature, non polluting and non hazardous to human, animal and birds (Dhargalkar and Pereira, 2005).

Seaweeds are the macroscopic marine algae. They are used as food for human, fodder for cattle, as a substitute of chemical fertilizer and source of various fine chemicals. Besides this, it is used for obtaining many industrial products such as agar, alginate (Khan *et al.* 2009). In recent years, natural seaweeds are being used as substitute of synthetic fertilizer fertilizers. Seaweed extracts are marketed as liquid fertilizers and bio-stimulants because they contain multiple growth regulators such as cytokinins (Durand *et al.* 2003), auxins (Sahoo, 2000), gibberellins (Strik and Staden, 1997) and various macro and micronutrients necessary for plant growth and development. Moreover, it helps in promoting the growth of beneficial soil microorganisms (Khan *et al*. 2009), developing tolerance to environmental stress (Zhang *et al.* 2003), and increasing nutrient uptake from soil (Turan and Kose, 2004) and enhancing antioxidant properties (Verkleij, 1992). In recent years, the use of seaweed extracts is gaining popularity due to their potential use in organic and sustainable agriculture (Russo and Beryln, 1990), especially in rainfed crops, as a means to avoid excessive fertilizer applications and to improve mineral absorption and because of its organic and bio-degradable properties.

In India about 700 species of marine algae are found in both intertidal and deep-water regions of the Indian coast and out of these nearly 60 species are found to be commercially important. The dominating sea weed producing states are Tamil Nadu, Gujarat, Maharashtra, Goa, Lakshadweep, Andhra Pradesh and Karnataka Andaman and Nicobar Islands, few species are also found in West Bengal and Orissa (Tandel *et al*. 2016). However, a very few species are used in agricultural purpose. The beneficial effect of sea weed extract in some agricultural crop are listed below.

Significance of sea weeds extract in agriculture: At present, seaweed extracts are used in agricultural practice and are already commercialized. Such as, seaweed liquid fertilizers (SLF) are available as manure, foliar spray, soil conditioners and soil drench (Thirumaran, 2009).

Different formulations of sea weed such as LSF (Liquid Seaweed Fertilizer), granular and powder are available in market. The whole or finally chopped powered algal manure have been used and all of them have been reported to produce beneficial effects on cereals, pulses, and many flowering plant. The advantage of seaweed manure is that it is free from weed seeds and other pathogenic fungi.

The liquid extracts obtained from seaweeds have recently gained importance as foliar sprays for many crops including various grasses, cereals flowers and vegetable species

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(Crouch and Staden, 1992). The foliar spray induces faster growth and increased yield in cereals, vegetables, fruit plants and horticultural crops (Elansary *et al*. 2016). Foliar spray of seaweed extract is a common practice to increase yield in many commercial crop (Khan *et al.* 2009). Foliar application of mineral nutrients offers a quicker method of supplying nutrients to higher plants than other soil application method (Shah *et al.* 2013; Nedumaran and Arulbalachandran , 2015). This may be due to active uptake of nutrients through stomatal pores instead of cuticular uptake (Fernandez and Brown, 2013). On the other hand, Bokil *et al*. (1974) has reported that seaweed extracts are bioactive at low concentrations (diluted as 1:1000 or more). The recent research is to introduce new methods for different seaweed preparation such as mixed consortium for the application to the agricultural field and for the gainful yield. The liquid extracts of brown algae are being sold as bio-stimulants or biofertilizers in various brand names. In recent years the seaweed extracts are made commercially available under different names, such as Maxicrop (Sea born), Algifert (marinure), Goemar GA14, Kelpak 66, Seaspray, Seasol, SM3, Cytex and Seacrop 16 (Gandhiyappan and Perumal, 2001) *etc*.

Role of sea weed extract on germination: The positive effects of sea weed on germination of agricultural crops have been reported by many researchers.

However germination is very much dependable on concentration of sea weeds. Some scientist have reported higher germination percentage with low concentration of sea weed extract. Layek *et al.* (2017) reported that when rice seeds were soaked in lower concentrations of seaweed extracts recorded higher germination percentage, shoot and root length as well as seedling vigour index. Similar result was also reported in case of maize. When seeds were soaked in lower concentrations (5%) of both the seaweed saps (*Kappaphycus* and *Gracilara* species) showed the higher rate of germination, while the higher concentration (15%) of the extracts inhibited the germination (Layek *et al.* 2016). The higher germination percentage in sea weed sap treated maize is also reported by Rajkumar and Subramanian, (1999). In case of arhar (*C. cajan*), padina induced maximum seedling growth at a lower concentration (Mohan *et al*. 1994).

Higher germination percentage and seedling vigour was also reported in case of green gram (*Vigna radiata*) (Venkataraman and Mohan, 1997) and cowpea (*Vigna sinensis*) (Sivasankari *et al*.2006). The increase in germination and seedling vigour at low concentrations of seaweed extracts may be due to the presence of growth promoting substances like auxins , gibberellins, phenyl acetic acid (Sivasankari *et al*. 2006) and other micro-nutrients (Layek *et al*. 2014).

Application of seaweed sap at 15% concentration of either *Kappaphyccus* or *Gracilara* sap significantly increased the germination in wheat. But, when the concentration is either reduced to 2.5% or increased to 20%, significant reduction in the germination was noticed (Dilvarnaik *et al*. 2017). Reduction in germination percentage at higher concentrations of *Kappaphyccus* or *Gracilara* seaweed sap might be due to inhibition of germination due to presence of high salts concentration at seaweed saps. Salt stress induced inhibition of seed germination, seedling growth and metabolic processes in maize (Azevedo *et al*. 2004) and wheat (Brini *et al*. 2009). The increased germination percentage at lower concentrations could be due to growth promoting factors like IAA and IBA Gibberlins (A & B), micronutrients, vitamins and amino acids which have a marked influence on the germination of crop. Whereas, retardation of growth at higher concentration can be attributed due to excessive hormones or presence of high concentration of minerals (Challen and Hemingway, 1966). Whereas, soaking of seeds with 60% solid liquid fertilizer prepared from marine algae *E. intestinalis* collected form Mandapam coast of Gulf of Mannar, Tamil Nadu also recorded100% seed germination in soybean (Chetna *et al*. 2015**)**.

Effect of sea weed on crop growth: Three times spraying of *Kappaphyccus* extract at the rate of 15% along with recommended dose of fertilizers recorded higher yield attributes such as number of panicles m^{-2} (507.60), filled grains $panicle^{-1}$ (143.83), panicle length (28.97 cm) and 1000 grain weight (21.23 g) and there by increased the grain (6.55 t/ha) and straw yield (8.25 t/ha) followed by spraying of 15% *Gracilaria* sap along with the recommended dose of fertilizers in rice. Besides this, enhanced the uptake of N and P by grain because of application both *Kappaphyccus* sap and *Gracilaria* sap of same concentration (Pramanick *et al.* 2014). The yield attributing characters of rice such as number of panicles $hill^{-1}$ and number of effective grains $panicle^{-1}$ also increased with higher concentration of seaweed extract, and the highest value was obtained for 15% K sap which was statistically *at par* with that for 10 and 5% K sap concentrations (Layek *et al*. 2017).

It has been reported that application of sea weed not only improved the growth of the crop but also helped in increasing the number of functional nodules as compared to control. This might be due to presence of several cytokinins that are found in brown algal extracts, including, *trans*-zeatin riboside, and their dihydro derivatives (Saravanan *et al*. 2003). It has been also reported that the bioactive compounds present in *Ascophyllum nodosum* extract and its organic sub-fractions have affected the legume–rhizobia signaling processes, resulting in more functional nodules and overall improvement in growth of alfalfa plants (Khan *et al*. 2013). Applications of 15% seaweed extract from *Kappaphycus*

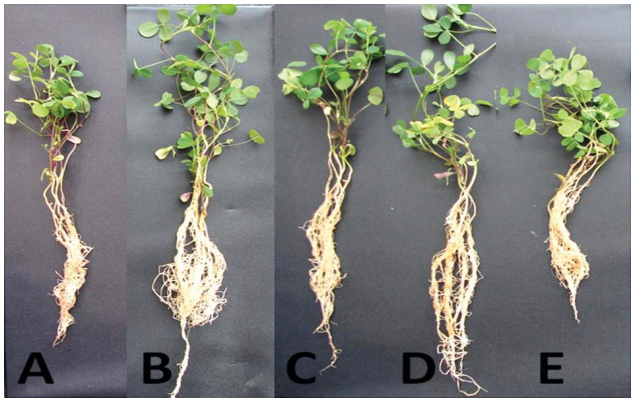

Fig 1: Effects of 1 g L-1, *Ascophyllum nodosum* extract (ANE) and its organic sub-fractions on root nodulation growth and development of alfalfa plants 6 weeks after the treatment: (a) control, (b) *Ascophyllum nodosum* extract (ANE) (c) methanol extract, (d) chloroform, and (e) ethyl acetate. (Khan *et al.* 2013).

alvarezii recorded 57% higher grain yield in soybean due to increased plant height, number of pods plant^{-1}, number of grains plant^{-1}, number of branches and also improved the nutrient uptake by plant (Rathore *et al.* 2009). Whereas, application of 10% *Kappaphyccus alvarezii* resulted 30.11% higher seed yield in maize due to increase in yield of pods, weight of pods as well as seed yield per plant and 100 seed weight (Zodape *et al.* 2010).

Effect of sea weed extract on yield: Seaweed fertilizer was found to be superior to chemical fertilizer. The presence of high level of organic matter aids in retaining moisture and minerals in upper soil that is available to roots (Sivasankari *et al*. 2006). Significant increase in yield of different crops due to foliar application of sea weed extracts has been reported by Arthur (2003), Zodape *et al.* (2008). The foliar applications of seaweed extracts could be a promising option for yield enhancement under rainfed soybean production (Rathore *et al.* 2009). The application of seaweed also significantly increased oil content, oil yield, K, Na and crude protein of sunflower seed. It was reported that application 0.6 % concentration of *Gracilaria dendroides* and *Ulva lactuca* recorded 34.05 and 30.55%, higher oil content in sunflower, respectively (Hannan and Salem, 2011).

In case of green gram the maximum straw yield was also achieved with the application of 15% seaweed extract (Pramanick *et al*. 2013). They also reported that applications of 15% *Kappaphykus* sap along with the recommended dose of fertilizer (RDF), followed by 15% *Gracilaria* - sap along with recommended dose of fertilizer (RDF) recorded 38.97 and 33.58% higher grain yield, respectively compared to the control in green gram and enhanced the nutrient uptake by this grain legume crop. The presence of micro-elements and plant growth regulators, especially cytokinins (Zodape *et al*. 2009) in *Kappaphycus* and *Gracilaria* extracts is responsible for the increased yield and improved nutrition of green gram receiving foliar application of the aforesaid two saps. Application of seaweed extract enhanced the early growth and yield attribute properties in legume plants and recorded12-25% higher yield than that of control (Sethi and Adhikary, 2008).The application of 10% concentration of *Kappaphyccus Alvarezii* and *Gracilaria edulis* extracts increased the grain yield of black gram by 47.52% and 42.52%, respectively as compared to control (Jadhao *et al.* 2015). The average yield of bean was increased by 25% due to foliar spray of sea weed (Temple and Bomke, 1989).

Prajapati *et al*. (2016) reported that supplemen tation of recommended dose of fertilizer along with extract of either *Kappaphycus alvarezii* (K sap) and *Gracilaria edulis* (G sap) at 10% concentration could be followed to improve the growth and yield of potato. They also reported that application of both 10% G sap + RDF and 10% K sap + RDF produced higher tuber yield of 32.88 t/ha and 31.30 t/ha, respectively than control. Moreover, seaweed extract sprays had markedly enhanced marketable tuber yield and minimized non marketable and damage tuber yields of potato over control. Sarhan (2011) corroborated similar findings and opined that seaweed extracts exerted positive effect on growth of the potato plant and thus significantly improved the total yield of potato, both qualitative and quantitatively. Abetz and Young (1983) also concluded that seaweed extract could improve the yield of potato crop. However, the stages of the crop at which the seaweeds are sprayed play an important role. The spraying of seaweed extract at 30 and 60 days interval after planting recorded higher tuber yield, improved nitrogen, total soluble solids and protein contents of the potato tubers (Haider *et al*.2012).

In case of rice 18.0 % increased in rice grain yield with the application of either 15% *Kappaphyccus* (K) or *Gracilaria* (G) sap as compared to control was reported by Layek *et al.* (2017). They recommended that application of either 10% concentration of K or G sap spray along with 100% recommended dose of fertilizer is a feasible option to obtain high yield and grain quality of rice in North eastern region of India. Similar results in rice are also reported by Patel *et al.* (2015) and Singh *et al.* (2015). The beneficial effects of seaweed extract on growth and yield of wheat (*Triticum aestivum* L) was also reported. The yield of wheat grain increased significantly by 19.74% and 13.16% with the application of 7.5% and 5.0% concentrations of *K. alvarezii* and *G. edulis* sap, respectively, over the control (Shah *et al.* 2013). Similar results have also been reported for wheat with the application of *K. alvarezii* extract (Zodape *et al*.2009).

Nutritional quality of grains: Application of 15% K or G saps significantly increased the protein content in rice grain (Layek *et al.* 2017). It has been also reported that application

of 7.5 and 5.0% concentrations of K and G saps increased the protein content by 15.64 and 13.09% in wheat (Shah *et al*. 2013). Increase in protein content with the application of seaweed extracts has also been reported in *Vigna catajung* (Anantharaj and Venkatesalu, 2001). This might be due to promotive effects on root proliferation and higher uptake of N, P and sulphur needed for protein synthesis (Shah *et al*. 2013). Application of seaweed extract also increased the micro-nutrient content in rice grains like Cu and Zn up to 10% concentrations and Fe and Mn upto 5% concentrations (layek *et al*. 2017). Similar results were also reported in okra and wheat (Zodape *et al*. 2009; Shah *et al*. 2013). Seaweed extract contains chelating compounds (i.e. mannitol) that can increase availability of some micro-nutrients to plants (Shah *et al*. 2013). They also reported that application of 7.5% concentration of *K. alvarezii* sap significantly increased fat content by 30.49% and protein content by 15.64% in wheat. Where as in case of green gram, foliar application of 10. 0% *K. alvarezii* extracts increased the carbohydrate content by 5.17% and protein content by 7.07%. Mineral content in seed also increased as compared to control (Zodape *et al*. 2010). Foliar spraying of 15% K sap along with 100% RDF also enhanced the carbohydrate content (63.9%) in Maize (Sikha *et al*. 2015).

Kalaivanan *et al.* (2012) reported that application of *C. scalpelliformis* solid liquid fertilizers at 20% level stimulate the photosynthetic pigments, amino acid, reducing sugar and total sugar content of *Vigna mungo*. Whereas, Selvam & Sivakumar (2013) reported that lower concentration of *Ulva reticulata* (2%) treatment on *V. mungo* resulted in increased photosynthetic pigments, protein, starch, reducing and non-reducing sugars. Moreover, when seeds of *Cajanus cajan* was treated with solid liquid fertilizers of the *S. wightii* chlorophyll, carotenoid, amino acid, protein, lipid and total sugar content of seeds were enhanced at lower concentration of 20% as compared to *Chaetomorpha linum* and *Grateloupia lithophila* (Sathya, 2010). Application of 0.6 % *G. dendroides* recorded the highest oil content (34.05%), oil yield, K and crude protein of sunflower seed and the highest Na content was found in sunflower treated with 0.4 % *U. lactuca*. (Hannan and Salem 2011).

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