Agronomy Research **21**(S1), 291–305, 2023
https://doi.org/10.15159/AR.23.011

Red seaweed liquid fertilizer increases growth, chlorophyll and yield of mungbean (*Vigna radiata)*

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Received: October 29th, 2022; Accepted: February 12th, 2023; Published: April 3rd, 2023

Abstract. The demand for chemical fertilizers in Bangladesh is increasing by the day. Seaweed extracts are high in a variety of bioactive substances that can be used as a biostimulant as an alternative to agricultural plants. To assess the impact of foliar spraying of red seaweed (*Gracilaria tenuistipitata* var. *liui*) extracts at 5, 10, 15, 20 and 25% concentrationsin comparison to the control condition (water spray only) and soil application of recommended doses of fertilizer (RDF) as basal on growth, chlorophyll and yield of mungbean variety BU mug5, a pot experiment was conducted at the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh during *Kharif-1* season (March to May 2021). Seven (7) treatments: T_1 – Control (foliar spray using water), T_2 – Recommended doses of fertilizers (RDF) as basal, T_3 – Foliar spray of 5% seaweed extracts, T_4 – Foliar spray of 10% seaweed extracts, T_5 – Foliar spray of 15% seaweed extracts, T_6 – Foliar spray of 20% seaweed extracts and T_7 – Foliar spray of 25% seaweed extracts were imposed following completely randomized design (CRD) with three replications. The results revealed that seaweed liquid fertilizer at 20% concentration increased leaf area, total dry matter and chlorophyll (SPAD value) by 25.00, 40.21 and 9.11% over the control and 15.42, 8.27 and 2.08% compared to RDF, respectively. Seed yield increased by 93.14% when compared to a control with 20% seaweed foliar spray, and by 9.04%, when compared to RDF. Foliar application of 20% seaweed liquid fertilizer performed best among the treatments in terms of mungbean growth and yield, according to findings of the experiment. The results of this study suggest that red seaweed extracts from *Gracilaria tenuistipitata* var. *liui* may be used as a fertilizer to reduce the chemical fertilizer to boost mungbean yield.

Key words: bio-stimulant, mungbean, red algae, yield.

INTRODUCTION

Seaweeds are one of the important marine bio-resources which are now-a-days termed as fantastically promising organic source of nutrient. The major uses of seaweeds are (i) production of phyto-chemicals such as agar-agar, carrageen and alginate (Kaliaperumal & Uthirasivan, 2011) and (ii) as food for human consumption as green vegetable, salad and also in the form of jelly, jam, chocolates and pickles (Chennubhotla et al., 1981) and medicines (Maeda et al., 2007). Seaweed extracts has been found rich in nutrients like nitrogen, phosphorus and higher amount of water soluble potash, other minerals, also rich in vitamins, amino acids, trace elements (Fe, Cu, Co, Ni, Zn and Mn) and plant growth hormones IAA and IBA growth stimulators such as auxin, gibberellins and cytokinin required by plants (Zodape et al., 2001; Zodape et al., 2010). Seaweed extracts are considered biostimulants as opposed to fertilizers because they encourage the plant's defensive and growth responses when applied (Ruso & Berlyn, 1990; Ali et al., 2021a). And nterestingly, seaweed extracts have repeatedly been shown to contribute to plant growth promotion, increased yields (Khan et al., 2013; Patel et al., 2016; Parađiković, 2019). The bio-stimulant present in seaweed extracts increase the vegetative growth, the leaf chlorophyll content, the stomata density, photosynthetic rate, increase water retention capacity in plants (Subramanian et al., 2011) and the fruit production of the plant (Blunden et al., 1996; Spinelli et al., 2009). According to Pascual et al. (2021) the use of seaweed biostimulant dramatically increased the rate of assimilation of rice beans, leading to an increase in height, heavier pods, and more seeds per pod. Foliar application of seaweed extracts has also been reported to enhance the yield of different crops significantly (Zodape et al., 2008; 2009). Seaweed extracts have also delayed of fruit senescence, improved overall plants vigour, improved yield quantity and quality (Featonby-Smith & Van Staden, 1983); improve nutrient uptake by roots (Briceño-Domínguez et al., 2014) resulting in improved water and nutrient use efficiency, thereby enhancing plants growth and vigour (Crouch et al., 1990), and develop tolerance to environmental stress (Zhang & Ervin, 2004). Moreover, manures of seaweeds are also used as a soil amendment in agriculture in many parts of the world (Eyras et al., 1998).

The productivity of the mungbean crop is very low (0.90 ton ha^{-1}) in Bangladesh (BBS, 2021). The low productivity may be attributed to lack of suitable genotypes, adequate nutrient supply (Azadi et al., 2013), improper fertilizer management (Anjum et al., 2006), and so on. Though chemical fertilizers are used in great quantities to compensate nutrient deficiencies and increase yield of mungbean, application of organic fertilizer like seaweed extracts may become a worthy effort to alternate the synthetic fertilizers increasing the yield of mungbean and this may be the most practical means of solving protein malnutrition in Bangladesh in a sustainable way. However, No study has so far been conducted on the effect of *Gracilaria tenuistipitata* var. *liui* (a red seaweed species) on growth, yield and nutritional quality of mungben and its concentration and doses of application have not been standardized. Thus, considering each and every corner of the above discussion, an experiment was conducted on the growth and yield of mungbean aiming to assess the efficacy of foliar application of different doses of seaweed extracts from *G. tenuistipitata* var. *liui*as liquid fertilizer. So, the research work was undertaken with the objectives to study the effects of seaweed extracts on growth, leaf chlorophyll and yield of mungbean crop and to identify suitable doses for mungbean crop.

MATERIALS AND METHODS

Experimental site

The experiment was carried out in pots in a polythene indoor controlled environment at the Department of Agronomy of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh (24° 5′ 23″ N and 90° 15′ 36″ E) in *Kharif-1* season (March to May 2021). The day and night temperatures were 28.5 ± 1.6 and 13.6 ± 1.3 °C, respectively. The plants were grown in plastic pots (0.30 m deep and 0.25 m in diameter), each containing 11 kg of soil. The experimental soil was sandy loam with a field capacity of 28% and a pH of 6.71 (53.12% sand, 33.12% alluvium, and 13.76% clay). The exchanged soil organic carbon, available P, total N, K, cation exchange capacity (CEC), and electrical conductivity (EC) were 0.59%, 0.07 mg per 100 g, 0.06%, 0.76 cmol per kg dry soil, 12.85 cmol per kg dry soil, and 0.03 dS per m, respectively.

Plant materials and seaweed extracts

A high-yielding mungbean variety, BU mug4 developed by Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) was used in this study. Red seaweed species *Gracilaria tenuistipitata* var. *Liui* under family Gracilariaceae is available in Bay of Bengal, Bangladesh was first identified and recorded by Aziz & Alfasane (2020). Fresh seaweed was collected in the morning from the coastal area of the Moheshkhali Channel of the Bay of Bengal (21° 30′ 0″ N and 92° 5′ 0″ E). The seaweed was washed with seawater and tap water, respectively to remove unwanted impurities and transported to the BSMRAU campus. After that, fresh seaweed was dried in the sun and homogenized by a grinder with stainless steel blades at ambient temperature and subsequently utilized for extraction of liquid fertilizer using the method described by Rao & Chatterjee (2014). Hundred (100) g of powdered seaweed suspended in one liter of deionized water was heated to 100 °C in hot water bath for one hour. The extracts was filtered through a muslin cloth and measured and stored in a refrigerator. Considering this as stock solution, seaweed liquid extracts was used to prepare 5%, 10%, 15%, 20% and 25% concentrations by diluting with deionized water. Then the diluted extracts in different concentrations was preserved at room temperature (15 –20 °C) before the spraying. Proximate composition of the seaweed powder from *Gracilaria tenuistipitata* var. *Liui* are presented in Table 1. The crude protein, crude lipid and crude fiber content were determined by the Micro-Kjeldahl method (Guebel et al., 1991), Mehlenbacher (1960) & using the AOAC (2000) method, respectively. To measuring one gram of powdered sample was placed onto the tray of the automatic moisture meter (Model PB-1D2, 544205, Kett Electric laboratory, Made in Japan) for 10–15 minutes while the moisture content was measured. Ash content was determined by following AOAC (1990) method. Following Sarkiyayi & Agar (2010), the percentage of total carbohydrate content was calculated using the formula [Percentage of total carbohydrate content] = 100 - (% moisture + % crude fiber + % crude protein + % crude lipid + % ash). The formula [available energy = (9.3 x fat) + (4.1 x carbohydrates) + (4.1 x protein)] described by Eneche (1991), Chinma & Igyor (2007), and Nwabueze (2007) was used to calculate available energy. The mineral contents (Ca, Mg, Fe, Cu, and P) and heavy metal (Pb) were determined by atomic absorption spectrophotometer (Shimadzu, Model-AA. 610s) following Hitachi, Ltd. (1986). To determine the amount of arsenic in seaweeds, an improved and verified inductively coupled plasma mass spectrometry (ICP-MS) technique was utilized. A sample of about 0.5 g was put into the digestion vessel, and the sample was washed with 100 mL of distilled water until it reached the bottom of the vessel. After gently stirring the liquid, wait roughly until the vessels are warm to the touch before carefully venting the remaining digestive pressure. The analysis results were then gathered using the NexION 5000 ICP-MS, an inductively coupled plasma mass spectrometry (Wilschefski & Baxter, 2019). According to Nagata et al. (1992), the amount of β-carotene in the fresh sample was quantified and the vitamin C was calculated described by method Pleshkov (1976).

Table 1. Chemical composition of the seaweed extracts from *Gracilaria tenuistipitata* var. *liui*

Constituents	Concentration
Crude protein (%)	24.06 ± 0.03
Crude fiber (%)	5.15 ± 0.09
Crude lipid (%)	0.19 ± 0.06
Carbohydrates (%)	49.50 ± 0.25
Ash (%)	10.02 ± 0.10
Moisture (%)	11.88 ± 0.06
Phosphorus (mg per 100 g dry weight)	579.05 ± 5.36
Calcium (mg per 100 g dry weight)	129.14 ± 1.01
Magnesium (mg per 100 g dry weight)	2.90 ± 0.11
Iron (mg per 100 g dry weight)	75.18 ± 0.15
Copper (mg per 100 g dry weight)	3.29 ± 0.30
Pb (mg per kg dry weight)	0.044
Arsenic (mg per kg dry weight)	5.019
β-carotene (mg per 100 g)	9.21 ± 0.28
Vitamin C (mg per 100 g)	2.12 ± 0.21
Total energy (kcal per 100 g)	303.34 ± 0.89

Treatments and cultural practices

The experiment was consisted of seven (7) treatments: T_1 – Control (0% seaweed extracts, spray with water), T_2 – Recommended doses of fertilizer (RDF) (0% seaweed extracts, spray with water), T_3 – 5.0% seaweed extracts, T_4 – 10.0% seaweed extracts, T_5 – 15.0% seaweed extracts, T_6 – 20.0% seaweed extracts and T_7 – 25.0% seaweed extracts. Ten seeds of mungbean were sown in each pot and well-watered to ascertain uniform germination. Once the plants are fully established, thin them out to keep only six healthy plants in each pot. Different concentrations of seaweed extracts were applied as foliar spray at seedling (15 days after germination) and flowering (30 days after germination) stages. A 50–60 mL seaweed extracts was sprayed on per four plants in a pot. The recommended fertilizers (0.310, 0.421, and 0.365 g urea, triple superphosphate, and muriate of potash, respectively) were mixed uniformly in each pot (T_2) before seed sowing, corresponding to 50–70–60 kg urea, triple superphosphate, and muriate of potash per hectare (FRG, 2018). Required intercultural operations like weeding, insecticides application and irrigation were applied as per requirements.

Experimental design

The experiment was performed using a completely randomized design (CRD) with three replications.

Growth and agronomic measurement

At 15 days after the 2nd time foliar application of seaweed extracts solution three plants were harvested from each pot. Plant growth-related parameters viz. number of leaves per plant, number of branches per plant, individual leaf area, and dry weight of leaf, stem and roots were measured. At the physiological maturity stage, the rest three plants from each pot were harvested and grain yield and yield contributing traits were recorded.

Measurement of chlorophyll (SPAD values) in leaf

Fully developed three leaves in upper side of one plant in each pot were selected and SPAD values were measured using SPAD meter (SPAD-502Plus KONICA MINOLTA, Japan) at 15 days after the 2nd time foliar application of seaweed extracts.

Statistical analysis

The recorded data underwent an analysis of Completely Randomized Design (CRD) (Gomez & Gomez, 1984) using CropStat statistical software version 7.2. All treatments were compared using Least Significance Difference (*LSD*) test at 5% level of significant.

RESULTS AND DISCUSSION

Effect of seaweed extracts on number of branches per plant, number of leaf per plant and leaf area of mungbean

The foliar application of seaweed extracts significantly influenced the number of branches per mungbean plant. The number of branches per plant had been doubled due to the application of seaweed extracts by compared to the control condition (Table 2). The maximum number of branches was 2.67 per mungbean plant found in plant treated with 20% seaweed extracts. The plants treated with water only provided on an average number of branches (0.83) in mungbean plants. The branches number per plant 2, 1.17, 1.17 and 1.0 were recorded at 15, 25, 10 and 5% seaweed extracts application, respectively. Whereas, the number of branches per plant 2.17 was found in the basal application of chemical fertilizer as recommended this showed 161% more number of branches per plant than the control. The number of branches per plant increased 221, 140, 41, 40 and 20% over the control were when plants were sprayed with 15, 25, 10 and 5% seaweed extracts, respectively. Even the seaweed extracts showed 23.04% higher number of branches per plant in 20% extracts relative to the recommended fertilizer doses.

Table 2. Effect of seaweed extracts on number of branch per plant, number of leaf per plant and leaf area of mungbean

Treatments	Number of branches per plant	Number of leaf per plant	Leaf area (cm^2)
Control	0.83b	10.0c	28.0f
RDF	2.17a	10.83bc	36.26bc
5% Seaweed extracts	1.0b	10.17c	30.16ef
10% Seaweed extracts	1.17b	10.67bc	32.08de
15% Seaweed extracts	2.0a	11.67ab	37.07ab
20% Seaweed extracts	2.67a	12.50a	39.26a
25% Seaweed extracts	1.17b	10.50bc	33.87cd
CV (%)	2.6	7.0	4.8

RDF – Recommended doses of Fertilizers. Means followed by diverse letters in each parameter differ significantly by *LSD* at $p < 0.05$.

The seaweed extracts also influenced the number of leaf per plant remarkably (Table 2). The number of leaf of mungbean plant had been increased by up-to 25% relative to the control condition by 20% seaweed extracts application. The highest number of leaves found 12.5 when the mungbean plant was treated with 20% seaweed extracts and lowest number was 10 found in control condition. The number of leaf per plant was 10.83 when plants were grown with recommended doses of fertilizers. The number of leaf were found 11.67, 10.67, 10.50 and 10.17 in mungbean plants treated with 15, 10, 25 and 5% seaweed extracts, respectively whichshowed 25, 16.67, 6.67 and 1.67% more leaves compared to control. In relation to recommended fertilizer dose, mungbean showed 8.30% more leaves than the control, at 20% seaweed concentration mungbean produced 15.42% more leaves when mungbean was grown in recommended doses of fertilizers.

Leaf area is an important morphological feature that act as major photosynthetic parts in plant body and influenced the plant growth and development. Maximum plant leaf area were 39.26 cm^2 found in at 20% seaweed extracts application followed by 37.07, 34.20, 32.08, 30.16 and 28.00 cm^2 in mungbean plant treated with 15, 25, 10 and 5% seaweed extracts, respectively. Minimum leaf area 28 cm^2 was recorded in control treatment. In the application of fertilizer as per recommendation, mungbean showed 36.26 cm^2 leaf area which less than that of is found in 20% seaweed extracts treatment and more than that of in 15% seaweed extracts application. In 20, 15, 25, 10 and 5% seaweed extracts application showed 40.21, 32.37, 22.14 14.5 and 7.71% higher leaf area than the control. In comparison between seaweed fertilizer and chemical fertilizer, it was observed that seaweed liquid fertilizer produced 8.27% more leaf area than the chemical fertilizer application.

So, it is clear that the number of branch per plant, number of leaf per plant and leaf area of mungbean were influenced by foliar application of seaweed extracts. Seaweed also showed better growth than the usage of chemical fertilizer. Similar results were also reported by Mohan et al. (1994) in *Cajanus cajan* (L.) *Mill* sp and Sivasankari et al. (2006) in *Vigna sinensis* L. as well as Kamaladhasan & Subramanian (2009) in Red gram. The increased leaf numbers and leaf area along with increased biomass was observed in tomato plants treated with red, brown, and green seaweed extracts reported by Ali et al. (2019) and Ramkissoon et al. (2017). The growth promotion of plants by the application of seaweed extracts have also been reported in several plants viz., marigold (Aldworth & Van Staden, 1987; Russo et al., 1993), strawberry (Battacharyya et al., 2015), maize, and tomato (Alam et al., 2013; Ali et al., 2016; Trivedi et al., 2018a, 2018b), where there was an increase in vegetative growth by the foliar spray of seaweed extracts (Athithan, 2014). *S*eaweed extracts have been shown to positive effect of soybean plant growth at all stages up to harvest (Ali et al., 2019 and 2021b). The maximum number of branches per plant were observed in the plant treated with low concentration of seaweed extracts which also supported by Sridhar & Rengasamy (2010a) found in *Tagetes erecta* (marigold) plant treated with crude extracts from the brown seaweed *Sargassum wightii*. In an another study of *Arachis hypogaea,* it also recorded highest number of branches and leaf area when the plant treated with seaweed liquid extracts than the basal application of recommended fertilizer. Crouch & van Staden (1991) reported that plant leaf area of young tomato plants was improved by seaweed extracts application. The increased growth of the crop may be due to the presence of some growth promoting substances present in the seaweed extracts (Mooney & Van Staden, 1986; Blunden, 1991). In addition, the growth enhancing potential of the seaweed extracts might be attributed to the presence of macro and micronutrients. The growth regulatory substances (seaweed oligosaccharides) induced the biosynthesis of hormones such as phyto-hormones abscisic acid, cytokinin, and auxin in treated plants

(Khan et al., 2009; Aremu et al., 2016; Patel et al., 2018; Ali et al., 2019; Renaut et al., 2019; Mukherjee & Patel (2020) that can promote crop growth.

Effect of seaweed extracts on leaf dry weight, stem dry weight, root dry weight and total dry weight of mungbean

The growth promoting attributes of seaweed extracts on mungbean plants accelerate the dry weight of different plant parts in vegetative stage remarkably. Due to the application of seaweed, the leaf dry weight of mungbean leaves had been increased up-to 94.23% in vegetative stage of plants compared to the control condition (Table 3). At 15 days after the foliar application of seaweed extracts, the highest dry weight of mungbean leaf was estimated as 7.40 g in 20% seaweed extracts application. Whereas, in this similar condition and stage, the plants treated with water only (control) had provided 3.81 g dry weight of leaves in mungbean plants. The second highest 6.03 g of leaf dry weight was observed due to the foliar application of 15% seaweed extracts followed by 4.91, 4.41 and 3.96 g at 25, 10 and 5% seaweed extracts application, respectively. Leaf dry weight (5.85 g) was found in the basal application of chemical fertilizer as recommended which showed 53.54% more dry weight than control. A 58.36, 28.78, 15.75, and 3.94% increment in leaf dry weight over the control was observed with 15, 25, 10, and 5% seaweed application, respectively. Even the seaweed extracts showed 26.5% higher leaf dry weight at 20% extracts compared to the recommended fertilizer.

Table 3. Effect of seaweed extracts on leaf dry weight, stem dry weight, root dry weight and total dry weight of mungbean

Treatments	Leaf dry weight (g)	Stemdry weight (g)	Root dry weight (g)	Total dry weight (g)
Control	3.82e	4.21e	0.47e	8.50d
RDF	5.85bc	6.15ab	0.78b	12.78b
5% Sea weed extracts	3.96de	4.61de	0.60d	9.17d
10% Sea weed extracts	4.41de	4.68de	0.66cd	9.75
15% Sea weed extracts	6.03b	5.16cd	0.73bc	11.92b
20% Sea weed extracts	7.40a	6.86a	0.95a	15.21a
25% Sea weed extracts	4.91cd	5.73bc	0.69bcd	11.33bc
CV (%)	10.8	9.6	8.1	8.6

RDF – Recommended doses of fertilizers, Means followed by diverse letters in each parameter differ significantly by *LSD* at $p < 0.05$.

Dry weight of mungbean stem at vegetative stage had been increased by 62.82% due to the beneficial effect of seaweed extracts compared to the control condition (Table 4). The highest amount of stem dry matter of mungbean was 6.86 g, achieved by the foliar application of 20% seaweed extracts. Conversely, the lowest dry weight of mungbean stem was only 4.21 g found in the untreated plants. Dry weights of mungbean stems, 5.73, 5.16, 4.78, and 4.61 g, were recorded by applying seaweed extracts at concentrations of 25, 15, 10, and 5%, respectively, and 36.11, 22, 39, 13.45, and 9.49% higher than control treatment. When chemical fertilizers were applied in soil, mungbean produced 6.15 g of stem dry weight, which was 45.97% higher than the control, and 20% seaweed extracts produced 11.55% higher stems compared to the recommended fertilizer doses.

The root dry weight of mungbean had been increased up-to 93.75% in vegetative stage of plants compared to the control condition (Table 3). At 15 days after the foliar application of seaweed extracts, the highest root dry weight of mungben was estimated as 0.93 g in 20% seaweed extracts application. In this similar condition and stage, the plants treated with water only provided 0.48 g dry weight of roots in mungbean plants. The second highest 0.71 g of root dry weight was observed due to the foliar application of 15% seaweed extracts followed by 0.69, 0.67 and 0.67 g at 25, 10 and 5% seaweed extracts application, respectively. Root dry weight 0.78g was calculated with the recommended chemical fertilizer application, showing 62.50% more dry weight than the control. At 15, 25, 10, and 5% extracts, root dry weights increased by 47.92%, 43.75%, 39.58%, and 29.17%, respectively, over controls. Even the seaweed extracts showed 19.23% higher root dry weight at 20% extracts compared to the recommended dose.

Total dry weight is one of attributes that indicate the plant growth and development in the vegetative stage. Total dry matter accumulation of mungbean plant was largely influenced by different level of seaweed extracts which is increased up-to 78.94% relative to control (Table 4). The highest amount of total dry weight (15.21 g) of mungbean was measured in 20% seaweed extracts. The second highest total dry weight found in RDF was 12.78 g which was 50.35% higher than that of plant sprayed with water only (control). When the plants were treated with 15, 25, 10, and 5% sea weed extracts solution, the estimated total dry weight of the mungbean plants was 11.92, 11.33, 9.75, and 9.17 g, which was 40.24, 33.29, 14.71, and 7.88% higher than the control. Seaweed demonstrated a 19% higher total dry weight of munbean plants when compared to RDF. Similar findings have demonstrated that adding green and red seaweed extracts, as well as commercial seaweed extracts with compost enhances cucumber vegetative growth, dry and fresh weight, and yield (Ahmed & Shalaby, 2012). Xu & Leskover (2015) reported increased leaf fresh weight and leaf dry weight in spinach plant with the application of seaweed extracts, even if, under the stressed condition. Increment in fresh and dry weight might be due to nitrogen availability and improving soil physical properties as well as improved soil microorganism's activity on the account of seaweed application.

Table 4. Effect of seaweed extracts on number of pods per plant, number of seeds per pod, 100-seed weight and seed yield of mungbean

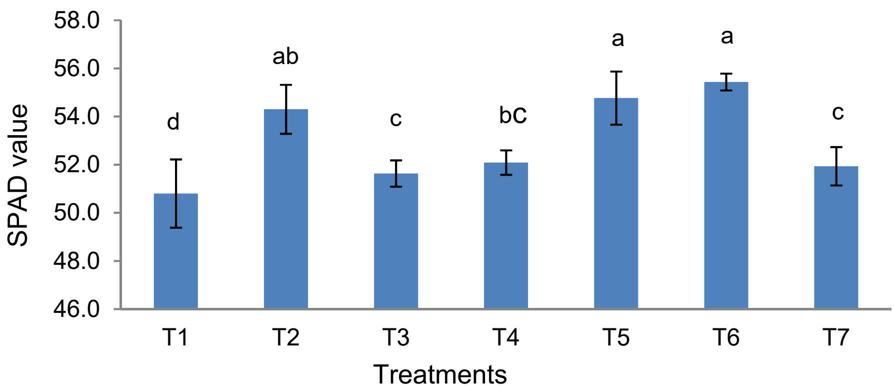
Treatments	Number of pods per plant	Number of seeds per pod	100-seed weight (g)	Seed yield per plant (g)
Control	12.67d	9.87b	4.87f	6.04e
RDF	18.67ab	10.21ab	5.78b	10.69b
5% Sea weed extracts	14.00cd	9.96ab	5.06e	7.05de
10% Sea weed extracts	15.00cd	10.06ab	5.26d	7.9cd
15% Sea weed extracts	16.33bc	10.24a	5.72b	9.63bc
20% Sea weed extracts	20.00a	10.30a	6.21a	11.66a
25% Sea weed extracts	15.67c	10.13ab	5.51c	8.76c
CV (%)	4.9	8.9	5.0	9.7

RDF – Recommended doses of fertilizers, Means followed by diverse letters in each parameter differ significantly by *LSD* at $p < 0.05$.

Seaweed based fertilizers improve plants growth by providing more nitrogen, phosphorus, and potassium, as well as supplying micronutrients and secondary metabolites (Karthick et al., 2013). After using seaweed extracts indicated that fresh and dry weight and leaf area increased probably due to increased nitrogen concentration and improving soil physical conditions through providing more energy for microorganisms helps to improve availability and absorption of mineral nutrients. There have been prior reports of increases in fresh weight, dry weight, root length, stem length, and chlorophyll content due to seaweed extracts (Sridhar & Rengasami, 2011).

Effect of seaweed extracts on chlorophyll (SPAD value) of mungbean

SPAD value which indicates the greenness of plant leaf thereby an indirect idea about the chlorophyll content of the leaves can be obtained it. SPAD value is significantly influenced by the application of seaweed extracts as organic fertilizer (Fig. 1). A SPAD value of 55.43, 9.11% higher than the control, was found at 20% seaweed extracts foliar application, followed by 54.77 at 15%, 7.81% higher than the control. The lowest SPAD value of 50.8 was recorded in the control (water spray only).



T_1 – Control; T_2– RDF; T_3– 5% seaweed extracts; T_4 – 10% seaweed extracts; T_5 – 15% seaweed extracts; T_6 – 20% seaweed extracts & T_7 – 25% seaweed extracts. Bars indicates (±*SE*).

Figure 1. Effect of seaweed extracts on SPAD value of mungbean.

The recommended fertilizer dose resulted in a 54.3 SPAD value, which is 6.89% higher than the control, followed by 52.09, 51.93, and 51.63 in the application of 10, 25, and 5% seaweed extracts, which resulted in 2.54, 2.22, and 1.63% more SPAD value than the control, respectively. SPAD values increased from 5% to 20% seaweed extracts application and then decreased at 25% seaweed concentration. Even a 20% concentration of seaweed extracts shows a SPAD 2.09% higher than the recommended fertilizer dose. According to Iswarya et al. (2019), the highest SPAD values were found when mungbean plants were treated with SWE spray (0.25%) to 25 DAS and 35 DAS. Rosa et al. (2021) found that treatment with *Ascophyllum nodusum* on water stressed soybean have higher SPAD value than plants without application and increased pigment concentration was observed using sesweed liquid fertlizer by Arumugam & Anantharaman (2009). Increment of SPAD value in mungbean may be due to the significantly enhanced the growth and nutrient uptake by the foliar applications of seaweed extracts.

Effect of seaweed extracts on yield and yield contributing characters of mungbean

Number of pods per plant

The number of pods per plants is considered as one of most important yield components of mungbean plants. The foliar application of seaweed extracts has a great influence to the number of pods in a mungbean plant. Application of seaweed extracts to mungbean plants increased the number of pods per mungbean plants by 50% compared to control conditions (Table 4). At 15 days after the foliar application of seaweed extracts, the highest number of pods was estimated as 19 in 20% seaweed extracts application. In this similar condition and stage, the plants treated with water only provided on an average 12.67 number of pods in mungbean plants. The number of pods per plant 16.33, 15.67, 15.00 and 13.16 were recorded at 15, 25, 10 and 5% sea weed extracts application, respectively, whereas the number of pods per plant 18.67 was found in the basal application of chemical fertilizer as recommended which showed 47.36% higher than the control. Increases of 28.95, 23.68, 18.42 and 39.47% number of podsper plants over control were observed with seaweed applications of 15, 25, 10 and 5%, respectively. Even the seaweed extracts showed 7.55% higher number of pods per plant in 20% extracts relative to the recommended doses.

Number of seeds per pod

The number of seeds per pod is directly related with the final yield content of mungbean plants. The average numbers of seeds per pod of mungbean were varied due to the inducement of seaweed extracts to the mungbean plants. The application of sea weed extracts to the mungbean plants caused 4.36% higher number of seeds per pod compared to the control condition (Table 4). The highest number of seeds per pod were 10.3 found in at 20% sea weed extracts application followed by 10.24, 10.13, 10.05 and 10.21 in mungbean plant treated with 15, 25, 10 and 5% seaweed extracts,respectively. Minimum number of seeds per podwas recorded in control (9.87) in the application of fertilizer as recommendation, mungbean showed 10.21 numbers of seeds per pod which is 3.44% higher than the control and less than that of found in 20% sea weed application. In 15, 25, 10 and 5% sea weed extracts application showed 3.75, 2.63, 1.82 and 0.91% increased number of seeds per pod over the control, respectively.

100-seed weight

Seed weight is significantly influenced by the application of seaweed extracts as organic fertilizer. The maximum mungbean weight of 100 seed was 6.21 g with 20% seaweed extracts, 27.3% more than the control (4.87 g), followed by 5.72 g in with 15% seaweed extracts which was 17.42% more than with control (Table 4). The lowest weight of 100-seeds was 4.87 g recorded in control (water spray only). 5.78 g 100 kernel weight mungbean found using the recommended dose of fertilizer was 18.47% more than the control.In the application of 25, 10 and 5% seaweed extracts showed 5.51, 5.26 and 5.06 g weight of 100-seed which were 13.3, 8.21 and 3.91% more than the control, respectively.

Seed yield

The yield is one of the most vital components of any crop which defines the productivity of that crop. The foliar application of seaweed extracts has a great influence to the final yield of mungbean plant. The seed yield of mungbean had been increased due to the application of seaweed extracts by 93.14% compared to the control condition (Table 4). The maximum yield was 11.66 g per mungbean plant found in plant treated with 20% sea weed extracts. The plants treated with water only provided on an average 6.04 g seed in mungbean plants. The yield per plant 9.63, 8.76, 7.90 and 7.05 g were recorded at 15, 25, 10 and 5% seaweed extracts application, respectively. Whereas the yield per plant 10.69 g was found in the basal application of chemical fertilizer as recommended which showed 77.13% more yield per plant than the control. About 59.63, 45.17, 30.96 and 16.74% increased seed yield per plant over the control were observed due to 15, 25, 10 and 5% seaweed application, respectively. Even the seaweed extracts showed 9.04% higher yield per plant in 20% extracts relative to the recommended doses. According to Ramamoorthy et al. (2006), the foliar application of aqueous extracts of *Ulva lacuta*, *Turbinariaconoides* and *Sargassum polycystum* gives positive result on the growth and yield of pea and black gram. The foliar application of liquid extracts of *Kappaphycus alvarezii* triggers the yield potency of *Lycopersicon esculentum* (Zodape et al., 2011). Bai et al. (2011) coincide with our findings in the application of liquid extracts of *Pandina pavonia* provides maximum yield of pulses. Kumar & Sahoo (2011) reported higher yield in *Triticum aestivum* upon foliar application of 20% extracts of *Sargassum wightii*. Similar kinds of result are also showed by Xavier et al. (2007); Zodape et al. (2008); Sridhar & Rengasamy (2010b); Thevanathan et al. (2005); Sivasankari et al. (2006) in several crops. Increased in yield may also be related to some nutritional elements, especially iron, zinc and manganese in compost and potassium, calcium, magnesium, sulfur and iron in our used seaweed extracts, which is supported by Zodape et al. (2009) who found increased yield of green gram using *Gracilaria* extracts. These elements can stimulate vegetative growth, chlorophyll biosynthesis and photosynthesis, which in turn affect flowering and fruit production (Ahmed & Shalaby, 2012).

CONCLUSIONS

The foliar application of seaweed extracts derived from *Gracilaria tenuistipitata* var. *liui* in mungbean plants had a positive impacts on number of leaves per plant; number of branches per plant; individual leaf area dry weight of leaf, stem, roots and whole plant; leaf chlorophyll content and yield of mungbean. The application of 20% seaweed extracts increased the grain yield of mungbean plants by 93.14 compared to control (water spray only) conditions and 9.04%, than the recommended fertilizers doses. Among the different concentration of seaweed extracts applied, 20% concentration showed the best performance in the improvement of growth and yield of mungbean plants even when plants were grown as recommended doses of fertilizers. Further study is required, though, to determine more physiological and molecular pathways to boost the development and production of mungbean utilizing the seaweed *Gracilaria tenuistipitata* var. *liui*.

ACKNOWLEDGEMENTS. The authors acknowledges to the Ministry of Science and Technology, Government of Bangladesh for funding the research.

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