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PROSPECTS OF SEAWEED LIQUID FERTILIZERS IN ENHANCING THE AGRICIURAL PRODUCTIVITY

S. Babu[*, 1, 2] and R. Rengasamy[2]

[1] Research and Development Division, Mahathi Biotech, Kalaignar Karunanidhi Nagar, Chennai – 600062, India

[2] Centre for Advanced Studies in Botany, University of Madras, Guindy Campus,Chennai-600025, India

[3] Hydrolina Biotech Pvt Ltd, Jafferkhanpet Chennai, 600083

*Correspondence: mahathibiotech@gmail.com

Abstract

Seaweed extracts are well known biostimulants. They are characterized by high efficiency in plants cultivation what was proved by many papers, besides they are environmentally friendly due to biological origin of material. In the present study, effect of the Seaweed Liquid Fertilizer (SLF) of *Kappaphycus alvarezii* on the efficacy of germination, growth potential, biochemical changes during seedling growth and yield response in Paddy (*Orysa sativa L.*), *Arachis hypogea L.* (Groundnut) and *Capsicum annum L.* (Chilli) was investigated at different concentrations viz., 1%, 2%, 5% and 10%. The treatment increased plumule and radicle growth markedly in addition to their fresh weight in the seedlings of the plants. Growth of plumule, radicle and fresh weight of the seedlings of Paddy and Chilli registered a significant increase to an extent of 44%, 63% and 75% and 43.2%, 95% and 64% respectively, in response to 2% K. alvarezii SLF treatment. Groundnut recorded an increase of 44.4%, 43.6% and 65% against 1% SLF treatment for the same parameters of growth. The yield of paddy and chilli were significantly increased up to 27% and 23% under glass house condition by 2% SLF supplemented with 100% recommended rate of chemical while groundnut recorded 30.6% increase in yield with 1% SLF supplemented with 100% recommended rate of chemical fertilizer. The study revealed that the SLF of *K. alvarezii* can be effectively used at low concentrations to promote germination, growth and yield in crop plants.

Keywords: seaweed, SLF, germination and seedlings

INTRODUCTION

In India, nearly 70% of the total population lives in rural areas and agriculture is their only source of income. Modern day intensive crop cultivation requires the use of chemical fertilizers which are not only in short supply but are also very expensive in developing countries like India. Therefore, there is a need to utilize the possibility of supplementing chemical fertilizers with organic ones such as Seaweed Liquid Fertilizers (SLFs) which are cost effective and within the reach of the poor farmers. Seaweeds are one of the most important marine resources of the world and have been nurtured for several years as fertilizer additives with beneficial results (K. Jayaprakash *et al.,* 2017). The use of chemical fertilizers and pesticides resulted spectacular increase in food production but their applications decreased the fertility of soil. So, search for bio-organic inputs for sustainable crop productivity has been emphasized. Liquid fertilizers derived from seaweeds are one such organic input which showed proven capability to increase the growth and yield of various crops (Immanuel and Subramanian, 1999; Anantharaj and Venkatesalu, 2002; Rama-subramanian *et al.,* 2004; Ramamoorthy *et al.,* 2007; Ramamoorthy and Sujatha, 2007). The extracts from a variety of seaweeds available in the coastal regions of India have been studied for their fertilizer potential and they have been recommended for application as seed treatment or as foliar spray (Venkatraman Kumar and Mohan, 2000; Thevanathan *et al.,* 2005; Ramamoorthy and Sujatha, 2007; Xavier). Foliar application of fertilizers like seaweed extract on the plants provides more effective utilization of nutrients (Pulschen, 2004).

MATERIALS AND METHODS

Collection of Sample

The seaweed Liquid Fertilizer (SLF) prepared at pH 7.2 and 4.0 from the red seaweed *Kappaphycus alvarezii* (Doty) Doty ex Silva obtained from a multinational company, PepsiCo. Pvt. Ltd., Tuticorin in December 2005 were used for the present investigation.

Preparation of different concentrations of SLF

The sample obtained from the company was considered as 100% SLF. Different concentrations of SLF *viz.*, 1.0%, 2.0%, 5.0%, and 10.0% (V/V) were prepared from the above stock by using distilled water and used for different experiments.

Experimental plants

Three different agricultural crops namely *Oryza sativa* L. (Paddy), *Arachis hypogea* L. (Groundnut) and *Capsicum annum* L. (Chilli) were selected as test plants for the present study. The effect of different concentrations of *K. alvarazii* SLF on the plants was made

with reference to their growth, biochemical characteristics and yield. Mature seeds of the test plants were obtained from Tamil Nadu Agro Service Centre at Chengalpattu near Chennai.

Laboratory studies

The effect of different concentrations of SLF on seed germination and early growth of seedlings of the three different plants was made under laboratory conditions (30 μE m^{-2} s^{-1} light intensity, 12 h/12 h light/ dark cycle and 24 ± 1°C). Twenty seeds of each plant were surface sterilized with 0.1% mercuric chloride for one minute and washed thoroughly in sterilized distilled water. Then they were soaked in different concentrations of SLF *viz.*, 1%, 2%, 5% and 10% for 6 h, 12 h and 24 h durations separately.

After the treatments the seeds of paddy and chilli were placed on sterilized moist handmade filter paper in Petriplates and kept under laboratory conditions. Every day, 2mL of distilled water was added on the filter paper in order to compensate the loss of evaporation. The length of radical and plumule and fresh weight of paddy seedlings were recorded on 5^{th} day. The above different parameters were recorded on chilli seedlings on 10^{th} day since they showed delayed germination and growth.

The effect of different concentrations of SLF on germination and early growth of groundnut was treated in acid washed river coarse sand. The sand was initially washed thoroughly twice with tap water followed by treating with conc. HCl and washed thoroughly in running tap water for 30 minutes in order to remove the acid and nutrients. Then the acid washed sand sample was dried at room temperature. Three hundred gram of the sand sample was taken in plastic cups (7.5 cm diameter and 9.5 cm height) and a pinhole was made at the bottom in order to avoid stagnation of water. To each cup five SLF treated seeds (at different concentrations and durations) were placed just 2 cm below the surface and moistened with distilled water and kept under laboratory condition. The growth characteristics such as length of radical and plumule and fresh weight of seedlings were recorded at the end of 7^{th} day.

Glass house study

Experiments were conducted in earthen pots (12' x 12') in a glass house at the Centre for Advanced Studies in Botany, University of Madras. Thirteen different treatments were followed for all three test plants (Table 1).

Paddy

This study was conducted for a period of 120 days. The seeds of rice cv. ADT 43 were soaked in tap water for 24 h and sown in earthen pots. Each pot contained 6 kg garden

soil, 500 g FYM and 3.5 g DAP as basal fertilizer.

The 30 days old paddy seedlings grown in earthen pots were transplanted into 13 different experimental pots. To each experimental pot, 8 seedlings were transplanted at two places at equal interval (*i.e.* 4 seedlings in each place).

The experimental plants were applied with chemical fertilizers as per the agriculture practice at different days (Agricultural crops, 2005-2006) (Table 2). Application of different concentrations of SLF was also made corresponding to the days of chemical fertilizers application. On zero day, the SLF was applied by soil drench, whereas the SLF was applied as foliar spray on 30^{th}, 50^{th} and 70^{th} day old plants.

One hundred mL of different concentrations of SLF such as 1%, 2%, 5% and 10% were applied to the respective experimental pots.

Thirty days and 60 days old experimental plants were uprooted and recorded for different parameters *viz.,* height, fresh weight and dry weight of shoot, root and total plant; number of tillers of third young leaf. The third young leaf was analyzed for different biochemical parameters *viz.,* Chlorophyll a, Chlorophyll b, total Chlorophyll, total protein; carbohydrate and lipid content.

Yield

At the end of 90^{th} day after transplantation, the paddy plants were harvested and recorded for different biometric parameters such as number of tillers, number of panicles, number of spikelets, grains, filled and unfilled grains, total weight of filled and unfilled grains, total yield and straw weight.

Groundnut

The study was conducted for a period of 105 days. The seeds of groundnut cv. TVM 7 were soaked in tap water for 24 h. To each pot, two seeds were sown just 2 cm below the surface at equal interval in earthenware pots and irrigated. Thirteen different treatments were followed as mentioned for the paddy. Application of chemical fertilizers was made as per the agriculture practice(Table 3).

One hundred mL of different concentrations of SLF such as 1%, 2%, 5% and 10% as mentioned in the Table 1 was added to the respective experimental pots. The application of SLF was made on zero day by soil drench and 30^{th}, 45^{th} and 60^{th} day by foliar spray on groundnut.

Thirty days and 60 days old plants of groundnut were uprooted and recorded for different parameters : height, fresh weight and dry weight of shoot, root and total plant; number of branches and area of third young leaf. The biochemical parameters of the third young leaf namely, Chlorophyll a, Chlorophyll b, total Chlorophyll, total

protein; carbohydrate and lipid content were also recorded.

Yield

The 105 days old plants were uprooted and the pods were separated by handpicking and fresh weight was recorded.

Chilli

This study was conducted for a period of 120 days. The seeds of chilli cv. VRI-1 were used for the present experiment. They were soaked in tap water for 24 h and sown in earthen pots contained 6 kg garden soil and 500 g FYM and 3.5 g DAP as basal fertilizer in order to raise the seedlings.

The 30 days old seedlings were uprooted from the above earthen pots and transplanted into the thirteen different experimental pots (Table 1). To each pot 4 seedlings were transplanted at two places (*i.e.* 2 each). Application of chemical fertilizers was made as per the agriculture practice (Table 4). The different concentrations of 100 mL of SLF were applied on zero day as soil drench whereas the foliar spray of SLF was made on 30, 60, and 90 days old plants. Thirty days and 60 days old plants were uprooted and recorded for different parameters namely, height, fresh weight and dry weight of shoot, root and total plant; number of branches and third young leaf area. The biochemical parameters of the third young leaf such as Chlorophyll a, Chlorophyll b, total Chlorophyll, total protein, carbohydrate and lipid content were also recorded.

Yield

Three pickings of red chilli (*C. annum*) were made on 60, 75 and 90 days and their fresh weight (g) was recorded. For the above experiments two replicates were maintained for each experiment.

RESULTS

The effect of Seaweed Liquid Fertilizer (SLF) of *Kappaphycus alvarezii* on the germination and early growth of seedlings under laboratory and green house conditions son the three different agricultural crops such as *Oryza sativa* L. (Paddy), *Arachis hypogea* L. (Groundnut) and *Capsicum annum* L. (Chilli) was made in the present investigation.

Laboratory Studies

Effect of *K. alvarezii* SLF on germination and growth of seedlings

***Oryza sativa* (Paddy)**

The seeds treated with 1.0%, 2.0%, 5.0% and 10.0% of *K. alvarezii* SLF for 6 h, 12 h and 24 h durations showed enhanced growth characteristics of *Oryza sativa* seedlings (Fig. 7). The fresh weight and length of radicle and plumule were increased due to SLF treatments on 5th day. Among the treatments, maximum of 4.03 and 3.26 cm length of radicle and plumule, respectively, were recorded when the seeds soaked with 2.0% SLF for 24 h duration

(Table 9). The increment was more than 44% and 63%, respectively, when compared to control. The fresh weight of the seedlings was also increased by 75% due to the above SLF treatment.

The length of plumule, radicle and fresh weight of seedlings of O. sativa were significantly increased at 2.0% level when the seeds of O. sativa were treated at 2.0% K. alvarezii SLF. The one way ANOVA (P=5%; LSD) revealed that the plants received 2.0% of SLF has exhibited significantly higher seedlings length and fresh weight (Table 5).

***Arachis hypogea* (Groundnut)**

The data recorded on the effect of K. alvarezii SLF on Arachis hypogea are presented in Table 10. The seeds soaked at four different concentrations and three different durations in K. alvarezii SLF showed enhanced seedlings growth characteristics (Figs 2 and 2).

The seedlings recorded at 6 h duration in 1.0% SLF showed maximum growth. At this condition the length of radicle and plumule were increased up to 43.6% and 44.4%, respectively, over control. The fresh weight of seedling was 1.3 g as against only 0.79g in control. The one way ANOVA (P=5%; LSD) has revealed that the plants received 1.0% of SLF exhibited significantly higher seedlings length and fresh weight (Table 6).

***Capsicum annum* (Chilli)**

The growth of seedlings of chilli was enhanced when the seeds were treated with different concentrations and durations of K. alvarezii SLF. Among the treatments, seedlings grown at 2% SLF for 6 h duration showed maximum growth (Fig. 3). The length of radicle and plumule increased upto 95% and 43.2%, respectively, when compared to control. The fresh weight of seedlings in the above condition was 0.052 g as against 0.031g in control. The one way ANOVA (P=5%; LSD) revealed that the plants received 2% of SLF has exhibited significantly higher seedlings length and fresh weight (Table 7).

Glass house experiments

Paddy

Thirteen different experiments were conducted on paddy under glass house conditions (vide Materials and Methods) and they are

1. T1- Normal level of CF (Chemical Fertilizer) + FYM (Farm Yard Manure) + 1% SLF
2. T2- CF + FYM + 2% SLF
3. T3- CF + FYM + 5% SLF
4. T4- CF + FYM + 10% SLF
5. T5- FYM + 1% SLF
6. T6- FYM + 2% SLF
7. T7- FYM + 5% SLF
8. T8- FYM + 10% SLF
9. T9- FYM
10. T10- CF

11. T11–50% CF + FYM + 5% SLF
12. T12– CF + FYM and
13. T13– without any application (Table 1). Thirty and 60 days old paddy (after transplantations) were uprooted and recorded the following observations

Paddy

Effect of SLF treatments on the growth of paddy at 30 days after transplantation

The paddy treated with 100% recommended dose of Chemical fertilizers and FYM at normal level (T2) and 2% SLF showed maximum plant height of 50.4 cm, followed by T1 47.5 cm whereas the paddy recorded at T12 (agricultural control) exhibited only 42.0 cm whereas the paddy received with only water exhibited 23.0cm total plant height (T13). Shoot length was maximum of 37.8 cm in T2 plants followed by T1 (35.0 cm). The length of fibrous roots recorded at T2 and T1 showed similar values which were more than 40.0% to that of control (T12). The total fresh weight of paddy recorded at T2 (5.8 g) was also maximum followed by T1 (5.2 g) and T3 (4.2 g). Similarly, the values of total dry weight recorded at T2 (1.2 g) and T1 (0.9 g) were maximum. The T1 and T2 paddy experimental plants showed a maximum of 9 tillers whereas the control exhibited (T12) only 6 tillers. The one way ANOVA (P=5%; LSD) revealed that all the growth parameters were significantly higher in the 2% SLF treated paddy plants (Table 8).

Effect of SLF treatments on the growth of paddy at 60 days after transplantation

The experimental plants of T2 showed maximum growth parameters when compared to control as well as other treatments. The T2 plants showed maximum 97.3 cm of height followed by T1 (86.5 cm) whereas in agricultural control (T12) and universal control (T13) the heights were only 74.4 and 55.0 cm, respectively. The shoot and root lengths of paddy at T2 were also increased up to 31.5% and 23.9% when compared to T12 plants (control). Maximum fresh weight of 91.4 g and dry weight of 20.4 g recorded at T2 were more than 30.3% and 63.2%, respectively, to that of control (T12). Total number of tillers recorded at T1 was 13.3 and T2 was 14.0, whereas in agricultural control (T12) and universal control (T13) they were only 10.0 and 5.6, respectively. In general the SLF treatments considerably increased the number of tillers in paddy under glasshouse condition. . The one way ANOVA (P=5%; LSD) revealed that all the growth parameters were significantly higher in the 2% SLF treated paddy plants (Table 9).

Effect of SLF treatments on the growth and yield of paddy at 90 days after transplantation

Different parameters such as number of panicle, number of spikelets, total number of grains, total number of filled and unfilled grains, grain weight and yield were recorded in the paddy plants at 90th day after transplantation.

The experimental paddy of T2 had maximum panicles of 14/tiller and T1 had 13/tiller. The T2 paddy exhibited maximum number of spikelets up to 96/tiller followed by T1, T3 and T6 plants, whereas in agricultural control (T12) it was only 63.3/tiller and in universal control it was 34/tiller. Similarly total numbers of filled grains recorded at T2 was 1212. Among the treatments the T2 plants produced less number of unfilled grains (45 unfilled grains/hill). Maximum total grain weight of 13.8 g/hill was recorded in T2 plants followed by 13.2 g/hill in T1 plants which were more than 26.6% and 21.1% to that of control (T12) (Fig. 4; Table 10). Among the experimental paddy plants, the T2 plants recorded maximum yield of 52.3 g/pot followed by 48.4 g/pot in T1 plants compared to control (36.0 g/pot), (T12). The increments of the yield recorded at T2 and T1 were more than 45.3% and 34.0%, respectively. All the yield related parameters were significantly (one way ANOVA; P=5%) higher in the 2.0% SLF treated paddy plants under glass house condition (Table 11).

Effect of SLF treatments on the growth of groundnut

Thirteen different experiments were conducted on groundnut as similar to paddy. Different growth parameters recorded under glass house condition on 30 and 60 days old plants revealed the following observations.

Effect of SLF treatments on the growth of groundnut on 30th day

Maximum plant height of 31.0 cm was recorded in T1 plants followed by T2 (30.5 cm). Maximum shoot length of 22.0 cm and 21.5 cm, respectively were recorded in T1 and T2 plants. Similarly T1 and T2 plants showed maximum root length (each 9 cm). Maximum total fresh weight of 12.0 g and dry weight 2.85 g were recorded in T1 plants. The total number of leaves of T1 and T2 were 68 and 65, respectively, which were more than 41.6% and 35.4% to that of agricultural control (T12). The one way ANOVA (P=5%; LSD) revealed that all the growth parameters were significantly higher in the 1.0% SLF treated paddy plants under glass house condition (Fig. 5; Table 12).

Among the experimental plants, the T1 plants showed maximum total plant height

of 44.0 cm followed by T2 (41.5 cm), and the values were more than 64.14% and 54.8%, respectively, to that of control (T12). The values of fresh and dry weights of groundnut also showed maximum at T1 plants (65.7 and 14.4 g). Maximum number of branches were recorded at T1 (23) and T2 (22) experimental plants. The leaf area was also maximum in both T1 and T2 plants (15 cm^2 and 14.5 cm^2 respectively). Maximum numbers of leaves were recorded in both T1and T2 plants (120 and 117, respectively). The one way ANOVA (P=5%; LSD) has revealed that all the growth parameters were significantly higher in the 1% SLF treated groundnut plants under glass house condition (Table 13).

Effect of SLF treatments on the yield of groundnut on 105th day

Among the experimental plants, the T1 plants recorded maximum yield of groundnut of 170.6 g/pot followed by 158.3 g/pot in T2 plants which were more than 30.6% and 21.2% respectively when compared to agricultural control (130.6 g/pot). All the yield related parameters were significantly (one way ANOVA; P=5%) higher in the 1% SLF treated groundnut plants under glass house condition (Table 14).

Experimental conditions are the same as described for paddy and groundnut.

Effect of SLF treatments on the growth of chilli at 30 days after transplantation

As observed for paddy and groundnut, the T1 and T2 plants of chilli showed maximum total plant height of 41.8 cm and 42.8 cm, respectively, under glass house conditions followed by T3 (37.5 cm). The dry weights of shoot and roots were maximum in T2 plants (2.6 g and 0.6 g) followed by T1 (2.5 g and 0.4 g). The number of branches recorded at T2 (14) and T1 (13) plants were more than 55.5% and 44.4%, respectively, to that of agricultural control (T12). The leaf area of T2 plants showed a maximum of 8.1 cm^2 whereas in agricultural control it was only 6.2 cm^2. The one way ANOVA (P=5%; LSD) revealed that all the growth parameters were significantly higher in the 2% SLF treated chilli plants under glass house condition (Table 15).

Effect of SLF treatments on the growth of chilli at 60 days after transplantation

Maximum total plant height, shoot and root lengths, fresh weight of shoot and root, total dry weight, dry weight of shoot and root, number of branches, leaf area and total number of leaves were recorded at T1 and T2 plants and their values were found similar. The T2 and T1 showed the plant heights of 60.2 cm and 57.4 cm, which were more than 49.8% and 42.7%,

respectively, when compared to agricultural control (T12). Maximum number of branches (19.6) recorded in T2 plants were more than 78.2% to that of control T12. Similarly T2 plants had maximum number of leaves (61) followed by T1 and T3. The T2 plants had 25 fruits when compared to only 7 fruits in control (T12). The one way ANOVA (P=5%; LSD) revealed that all the growth parameters were significantly higher in 2% SLF treated chilli plants under glass house condition (Table 16).

Effect of SLF treatments on the yield of chilli at different periods (60, 75 and 90 days after transplantation)

Since chillies are harvested 3 times, the experiment also is designed for three harvests to determine the yield. Among the experimental plants the T2 plants showed maximum yield of chilli of 464.9 g/pot followed by T1 plants of 429.4 g/pot when compared to agricultural control (368.2 g/ pot) (T12). The increment was more than 26.3% and 16.6% respectively to that of control. All the yield related parameters were significantly (one way ANOVA; P=5%) higher in the 2.0% SLF treated chilli plants under glass house condition (Fig. 6; Table 17).

Discussion

Seaweeds are marine macro-algae which constitute one of the commercially important renewable living resources. Use of seaweeds as manure is a common practice in coastal areas throughout the world. Recent researchers proved that Seaweed Liquid Fertilizers (SLFs) is better than other chemical fertilizers (Gandhiyappan and Perumal, 2001; Selvaraj *et al.*, 2004; Lingakumar *et al.*, 2006). Seaweed Liquid Fertilizer contains plenty of essential nutrients especially trace elements, proteins, lipids, polysaccharides, vitamins, enzymes and other bioactive substances. Large red algae have rich potassium content (Jacqueline, 2002). Accoding to Crouch and Van Staden (1993) the seaweed products can substitute conventional synthetic fertilizers. Application of SLF has been shown by many to play a significant role in improving the yield of crop plants by 20-30%. Seaweed manures are applied either directly or in the form of compost. The minerals and trace elements present in the seaweeds are readily absorbed by plants and they control diseases caused by mineral deficiencies (Crouch and Vanstaden, 1993). Carbohydrates and other organic matter present in seaweeds alter the nature of soil and improve its moisture retaining capacity. Application of seaweed extracts to commercial crops increases the yield of

crops, promotes seed germination, increases the resistance to frost, protects crops from fungal as well as insect attacks and aids in the uptake of inorganic constituents as well (Crouch and Vanstaden, 1993). In the present study, the effect of SLF obtained from the red seaweed *Kappaphycus alvarezii* was investigated on the growth, biochemical characteristics and yield of *Oryza sativa, Arachis hypogea* and *Capsicum annum* under both glass house conditions and in field trials. Two sets of SLF preparations with initial pH 4.0 and 7.2, respectively. The pH of the two samples decreased during the experimental period of six months to 3.2 and 6.7, respectively.

Table 1. Application of different concentrations of SLF and chemical fertilizers on test plants

Treatments	Chemical Fertilizer	Farm Yard Manure (FYM)	Seaweed Liquid Fertilizer (SLF)
T 1	At normal level	At normal level	1%
T 2	At normal level	At normal level	2%
T 3	At normal level	At normal level	5%
T 4	At normal level	At normal level	10%
T 5	No chemical fertilizer	At normal level	1%
T 6	No chemical fertilizer	At normal level	2%
T 7	No chemical fertilizer	At normal level	5%
T 8	No chemical fertilizer	At normal level	10%
T 9	No chemical fertilizer	At normal level	No SLF
T 10	At normal level	No FYM	No SLF
T 11	At 50 % normal level	At normal level	5%
T 12 (Agricultural control)	At normal level	At normal level	No SLF
T 13	No chemical fertilizer	No FYM	No SLF

Table 2. Normal level of chemical fertilizer application on *Oryza sativa*

Days (After transplantation)	**Normal level of chemical fertilizer/ pot**	**Normal level of chemical fertilizer / ha.**
0 day	Urea - 0.25 g Super phosphate - 0.28 g Potash - 0.07 g	Urea - 36 Kg Super phosphate - 40 Kg Potash - 10 Kg
30th day	Urea - 0.25 g Potash - 0.07 g	Urea - 36 Kg Potash - 10 Kg
50th day	Urea - 0.25 g Potash - 0.07 g	Urea - 36 Kg Potash - 10 Kg
70th day	Urea - 0.25 g Potash - 0.07 g	Urea - 36 Kg Potash - 10 Kg

Normal level of FYM = 500 g / plot

Table 3. Normal level of chemical fertilizer applications on *Arachis hypogea*

Days	Normal level of chemical fertilizer/ pot	Normal level of chemical fertilizer / ha.
0 day	Urea - 0.12 g Super phosphate - 0.24 g Potash - 0.38 g	Urea - 17 Kg Super phosphate - 34 Kg Potash - 54 Kg
45th day	Calcium phosphate - 1.414 g	Calcium phosphate - 200 Kg

Normal level of FYM = 500 g / pot

Table 4. Normal level of chemical fertilizer application on *Capsicum annum*

Days (After transplantation)	Normal level of chemical fertilizer/ pot	Normal level of chemical fertilizer / ha.
0 day	Urea - 0.25 g Super phosphate - 0.25 g	Urea - 35 Kg Super phosphate - 35 Kg
30th day	Urea - 0.53 g	Urea - 75 Kg
60th day	Urea - 0.25 g	Urea - 36 Kg
90th day	Urea - 0.25 g	Urea - 36 Kg

Fig. 1. Effect of *Kappaphycus alvarezii* SLF on the early growth of paddy on 5th day under laboratory conditions

a. Control, b. 1.0% SLF, c. 2.0% SLF, d. 5.0% SLF, e. 10.0% SLF

Table 5. Effect of *Kappaphycus alvarezii* SLF on the seedling growth of *Oryza sativa*

Parameters	Duration of soaking	SLF concentrations					CD (0.05)
		Control	1%	2%	5%	10%	
Length of plumule (cm)	6h	1.5 ± 0.12^{bc}	1.9 ± 0.24^{ab}	2.1 ± 0.16^{a}	1.8 ± 0.08^{abc}	1.5 ± 0.16^{c}	0.3935
	12h	1.5 ± 0.33^{c}	2.1 ± 0.08^{ab}	2.3 ± 0.16^{a}	2.1 ± 0.14^{ab}	1.8 ± 0.26^{bc}	0.5230
	24h	2.0 ± 0.16^{cd}	3.0 ± 0.40^{ab}	3.3 ± 0.24^{a}	2.6 ± 0.40^{bc}	1.8 ± 0.20^{d}	0.6771
Length of radical (cm)	6h	$2.0\pm0.12b^{c}$	2.4 ± 0.16^{ab}	2.8 ± 0.16^{a}	2.5 ± 0.20^{a}	1.8 ± 0.16^{c}	0.4132
	12h	2.4 ± 0.14^{bc}	2.9 ± 0.09^{ab}	3.3 ± 0.57^{a}	3.3 ± 0.21^{a}	2.1 ± 0.12^{c}	0.6486
	24h	2.8 ± 0.28^{cd}	3.9 ± 0.48^{ab}	4.0 ± 0.12^{a}	3.4 ± 0.18^{bc}	2.6 ± 0.36^{d}	0.6635
Fresh weight (g)	6h	0.05 ± 0.001^{b}	0.02 ± 0.001^{a}	0.03 ± 0.002^{a}	0.03 ± 0.002^{a}	0.01 ± 0.004^{b}	0.0067
	12h	0.01 ± 0.003^{c}	0.03 ± 0.002^{b}	0.04 ± 0.001^{a}	0.03 ± 0.003^{ab}	0.01 ± 0.002^{c}	0.0065
	24h	0.02 ± 0.001^{c}	0.03 ± 0.003^{b}	0.04 ± 0.002^{a}	0.03 ± 0.002^{a}	0.01 ± 0.002^{c}	0.0049

Note: Values are means of triplicates with ± SD. Values in the column with same alphabets are not significantly different as analyzed by ANOVA (5% level; LSD)

Fig. 2. Effect of *Kappaphycus alvarezii* SLF on the early growth of groundnut on 7th day under laboratory conditions
a. Control; b. 1.0% SLF; c. 2.0% SLF; d. 5.0% SLF; e. 10.0% SLF

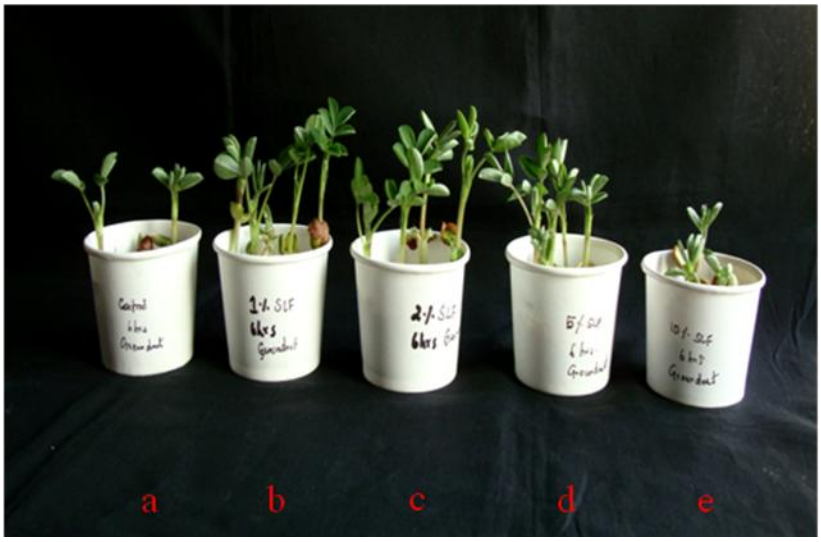

Fig. 2. Effect of *Kappaphycus alvarezii* SLF on the early growth of groundnut on 10th day under laboratory conditions
a. Control; b. 1.0% SLF; c. 2.0% SLF; d. 5.0% SLF; e. 10.0% SLF

Table 6. Effect of *Kappaphycus alvarezii* SLF on the seedling growth of *Arachis hypogea*

Parameters	Duration of soaking	SLF concentrations					CD (0.05)
		Control	1%	2%	5%	10%	
Length of plumule (cm)	6h	2.7±0.42^{bc}	3.9±0.23^{a}	3.7±0.23^{a}	3.3±0.47^{ab}	2.2±0.08^{c}	0.7574
	12h	2.5±0.16^{c}	3.3±0.23^{a}	3.0±0.16^{ab}	2.6±0.18^{bc}	1.8±0.12^{d}	0.4147
	24h	2.4±0.21^{b}	3.0±0.12^{a}	2.9±0.28^{a}	2.1±0.08^{b}	1.5±0.08^{c}	0.3670
Length of radical (cm)	6h	3.9±0.28^{bc}	5.6±0.40^{a}	4.7±0.23^{a}	4.2±0.20^{b}	3.3±0.23^{c}	0.7037
	12h	2.8±0.16^{b}	4.0±0.30^{a}	3.9±0.28^{a}	3.0±0.16^{b}	2.5±0.24^{b}	0.5824
	24h	2.6±0.36^{b}	3.8±0.21^{a}	3.7±0.04^{a}	2.5±0.09^{b}	2.2±0.24^{b}	0.5575
Fresh weight (g)	6h	0.79±0.02^{b}	1.3±0.05^{a}	1.2±0.10^{a}	1.1±0.13^{a}	0.6±0.04^{b}	0.1833
	12h	0.7±0.03^{b}	1.1±0.08^{a}	1.0±0.10^{a}	1.0±0.09^{a}	0.6±0.08^{b}	0.2089
	24h	0.6±0.09^{c}	1.0±0.05^{a}	1.0±0.06^{ab}	0.9±0.008^{b}	0.5±0.04^{d}	0.1540

Note: Values are means of triplicates with ± SD. Values in the column with same alphabets are not significantly different as analyzed by ANOVA (5% level; LSD)

Fig. 3. Effect of *Kappaphycus alvarezii* SLF on the early growth of chilli on 10th day under laboratory conditions

a. Control, b. 1.0% SLF, c. 2.0% SLF, d. 5.0% SLF, e. 10.0% SLF

Table 7. Effect of *Kappaphycus alvarezii* SLF on the seedling growth of *Capsicum annum*

Parameters	Duration of soaking	SLF concentrations					CD (0.05)
		Control	1%	2%	5%	10%	
Length of plumule (cm)	6h	3.7±0.24^{c}	5±0.16^{a}	5.3±0.07^{a}	4.5±0.21^{b}	2.8±0.16^{d}	0.5337
	12h	3.3±0.21^{c}	4.5±0.16^{ab}	4.9±0.32^{a}	4.0±0.16^{b}	2.6±0.24^{d}	0.5522
	24h	2.6±0.28^{b}	3.9±0.32^{a}	4.1±0.24^{a}	3.1±0.24^{b}	2.5±0.32^{b}	0.7381
Length of radical (cm)	6h	4.0±0.24^{c}	7.2±0.29^{b}	7.8±0.08^{a}	6.8±0.08^{b}	3.5±0.20^{d}	0.4713
	12h	4.0±0.18^{c}	6.3±0.24^{a}	6.5±0.16^{a}	5.9±0.40^{b}	3.0±0.16^{d}	0.5869
	24h	3.2±0.24^{c}	5.5±0.08^{a}	5.7±0.21^{a}	5.1±0.16^{b}	2.7±0.16^{d}	0.4210
Fresh weight (g)	6h	0.03±0.006^{b}	0.04±0.007^{ab}	0.05±0.005^{a}	0.04±0.005^{abc}	0.03±0.003^{d}	0.0140
	12h	0.03±0.008^{bc}	0.04±0.002^{ab}	0.04±0.004^{a}	0.03±0.004^{ab}	0.02±0.005^{d}	0.0102
	24h	0.02±0.003^{bc}	0.03±0.003^{a}	0.03±0.002^{a}	0.03±0.002^{b}	0.02±0.005^{c}	0.0078

Note: Values are means of triplicates with ± SD. Values in the column with same alphabets are not significantly different as analyzed by ANOVA (5% level; LSD)

Table 8. Effect of *Kappaphycus alvarezii* SLF on the growth of *Oryza sativa* under glass house conditions on 30th day after transplantation

Treatment	Total plant height (cm)	Shoot height (cm)	Root height (cm)	Total fresh weight (g)	Shoot fresh weight (g)	Root fresh weight (g)	Total dry weight (g)	Shoot dry weight (g)	Root dry weight (g)	Number of tillers
T1	47.5±2.04^{ab}	35.0±3.58^{a}	12.5±0.86^{a}	5.2±1.40^{ab}	3.8±0.40^{a}	1.4±0.26^{ab}	0.9±0.42^{abc}	0.7±0.10^{a}	0.2±0.05^{acde}	9.0±1.00^{a}
								^{b}	^{f}	
T2	50.4±0.45^{a}	37.8±1.83^{b}	12.6±2.53^{a}	5.8±0.95^{a}	4.0±1.50^{a}	1.8±0.30^{a}	1.2±0.58^{a}	0.8±0.10^{a}	0.4±0.24^{a}	9.0±1.00^{a}
T3	43.0±7.54^{bc}	34.0±2.00^{bc}	9.0±3.60^{bc}	4.2±0.87^{abc}	2.5±1.15^{b}	1.7±0.61^{a}	0.9±0.41^{ab}	0.6±0.13^{a}	0.3±0.08^{abc}	7.0±1.00^{b}
			^{d}					^{bc}		
T4	26.5±4.37^{fg}	20.0±3.04^{hij}	6.5±0.86^{de}	2.5±1.44^{cde}	1.6±0.36^{bcd}	0.9±0.10^{bcd}	0.7±0.46^{bcd}	0.4±0.10^{d}	0.3±0.10^{bcd}	4.0±1.00^{d}
								^{e}		
T5	39.7±5.22^{cd}	29.0±2.17^{de}	10.7±1.54^{abc}	3.5±1.80^{bcd}	2.2±1.71^{bcd}	1.3±0.20^{ab}	0.8±0.05^{abc}	0.4±0.13^{cd}	0.4±0.10^{ab}	5.0±1.00^{cd}
								^{e}		
T6	37.0±2.64^{cd}	25.5±2.38^{efg}	11.5±2.72^{ab}	3.5±2.33^{bcd}	2.5±1.92^{b}	1.0±0.44^{bc}	0.8±0.16^{abc}	0.5±0.13^{bc}	0.2±0.02^{bcde}	6.0±1.00^{bc}
							^{d}	^{d}		
T7	30.0±4.58^{ef}	22.0±4.58^{ghi}	8.0±0.50^{cd}	3.2±0.82^{cde}	2.3±0.53^{bc}	0.9±0.51^{bcd}	0.6±0.46^{bcd}	0.3±0.10^{ef}	0.3±0.10^{bcd}	5.0±1.00^{cd}
								^{g}		
T8	20.5±1.27^{g}	16.5±2.42^{j}	4.0±2.49^{e}	1.5±1.48^{e}	1.2±0.61^{cd}	0.3±0.10^{e}	0.4±0.20^{cd}	0.2±0.10^{fg}	0.2±0.10^{def}	4.0±1.00^{d}
T9	25.3±2.90^{fg}	21.1±1.03^{ghi}	4.2±0.87^{e}	1.8±1.82^{de}	1.4±0.72^{bcd}	0.4±0.20^{de}	0.3±0.17^{d}	0.2±0.10^{fg}	0.1±0.03^{fg}	4.0±1.00^{d}
T10	30.3±3.65^{ef}	23.9±1.21^{fgh}	6.4±2.26^{de}	2.0±0.70^{de}	1.5±1.26^{d}	0.5±0.26^{cde}	0.4±0.17^{cd}	0.3±0.19^{ef}	0.05±0.01^{g}	4.0±1.00^{d}
T11	35.6±2.66^{de}	26.6±2.19^{ef}	9.0±3.22^{bc}	2.2±0.20^{de}	1.6±1.06^{bcd}	0.6±0.46^{cde}	0.5±0.17^{bcd}	0.4±0.10^{d}	0.1±0.05^{fg}	5.0±1.00^{cd}
			^{d}					^{e}		
T12 (c)	42.0±3.00^{bc}	33.0±3.00^{dc}	9.0±2.98^{bc}	3.0±0.50^{cde}	2.0±0.24^{bcd}	1.0±0.10^{bc}	0.7±0.40^{bcd}	0.4±0.08^{cd}	0.2±0.10^{cde}	6.0±1.00^{bc}
			^{d}					e		
T13	23.0±4.52^{g}	18.5±2.88^{ij}	4.5±1.00^{e}	1.6±1.05^{de}	1.2±0.62^{cd}	0.4±0.10^{de}	0.3±0.10^{d}	0.1±0.05^{g}	0.1±0.05^{efg}	4.0±1.00^{d}
CD (0.05)	6.2622	4.5482	3.1848	1.9143	1.1019	0.5444	0.5432	0.1987	0.1429	1.7331

Note: Values are means of triplicates with ± SD. Values in the column with same alphabets are not significantly different as analyzed by ANOVA (5% level; LSD)

Table 9. Effect of *Kappaphycus alvarezii* SLF on the growth of *Oryza sativa* under glass house conditions on 60th day after transplantation

Treatment	Total plant height (cm)	Shoot height (cm)	Root height (cm)	Total fresh weight (g)	Shoot fresh weight (g)	Root fresh weight (g)	Total dry weight (g)	Shoot dry weight (g)	Root dry weight (g)	Number of tillers
T1	86.5±2.18^{b}	78.5±2.18^{ab}	8.0±0.50^{ab}	85.6±2.15^{b}	68.1±3.85^{ab}	17.5±2.69^{ab}	18.8±0.60^{b}	16.4±0.20^{b}	2.4±0.20^{bc}	13.3±0.58^{a}
T2	97.3±2.36^{a}	88.5±8.10^{a}	8.8±0.10^{a}	91.4±4.20^{a}	72.8±2.10^{a}	18.6±2.08^{a}	20.4±0.60^{a}	17.2±0.40^{a}	3.2±0.20^{a}	14.0±1.00^{a}
T3	85.5±2.18^{b}	78.5±2.17^{ab}	7.0±1.00^{bc}^{d}	78.3±3.29^{c}	65.1±4.30^{bc}	13.2±2.16^{cde}	14.5±0.30^{bc}	12.4±0.53^{c}	2.1±0.26^{cd}	11.3±0.58^{b}
T4	67.7±1.99^{e}	62.9±2.00^{bcd}	4.8±0.35^{g}^{hi}	63.4±3.20^{ef}	53.8±3.10^{de}^{f}	9.6±2.73^{fgh}	8.4±0.20^{d}^{h}	7.0±0.50^{g}	1.4±0.10^{fg}	7.0±1.00^{f}
T5	79.9±4.16^{c}	73.5±2.17^{abc}	6.4±0.60^{cd}^{e}	75.4±4.44^{c}	60.8±6.16^{bc}^{d}	14.6±20.46^{bc}^{d}	15.2±0.20^{cd}	12.7±0.20^{c}	2.5±0.20^{b}	10.6±0.58^{bc}
T6	83.5±2.18^{bc}	76.5±2.17^{ab}	7.0±1.00^{bc}^{d}	78.6±5.70^{c}	63.4±3.90^{bc}	15.2±0.27^{bc}	15.8±0.50^{c}	12.8±0.44^{c}	3.0±0.26^{a}	11.0±1.00^{bc}
T7	72.3±2.36^{d}	66.3±2.36^{e}	6.0±1.00^{de}^{f}	70.3±5.06^{d}	58.7±6.40^{cd}	11.6±1.77^{defg}	11.5±0.40^{f}	10.3±0.44^{d}	1.2±0.26^{gh}	8.3±0.58^{e}
T8	55.4±2.27^{g}	51.2±5.44^{de}	4.2±0.36^{hi}	48.5±5.20^{h}	40.7±3.46^{gh}	7.8±1.97^{hi}	6.9±0.50^{i}	6.1±0.20^{h}	0.8±0.10^{i}	5.6±0.58^{g}
T9	62.3±2.36^{f}	57.1±3.15^{cde}	5.2±0.40^{fg}^{h}	55.3±4.35^{g}	46.7±5.47^{fg}	8.6±2.21^{ghi}	8.5±0.20^{h}	7.6±0.30^{g}	0.9±0.20^{hi}	6.3±0.58^{fg}
T10	71.2±1.56^{de}	65.6±2.08^{bcd}	5.6±0.61^{ef}^{g}	59.8±3.20^{fg}	50.4±3.80^{ef}	9.4±1.94^{ghi}	9.6±0.35^{g}	8.3±0.30^{f}	1.3±0.20^{fg}	9.3±0.58^{de}
T11	71.5±2.17^{de}	64.5±2.17^{bcd}	7.0±1.00^{bc}^{d}	66.5±3.00^{de}	55.0±5.00^{de}	11.5±0.63^{efg}	10.9±0.46^{f}	9.3±0.40^{e}	1.6±0.20^{ef}	10.3±0.58^{bcd}
T12 (c)	74.4±2.27^{d}	67.3±2.36^{bcd}	7.1±0.40^{bc}	70.1±2.95^{d}	58.2±5.99^{cd}	11.9±0.37^{def}	12.5±0.20^{e}	10.7±0.46^{d}	1.8±0.20^{de}	10.0±1.00^{cd}
T13	55.0±5.00^{g}	50.9±4.81^{de}	4.1±0.40^{i}	45.6±4.75^{h}	39.2±5.98^{h}	6.4±1.39^{i}	6.5±1.00^{i}	5.6±0.35^{h}	0.9±0.20^{hi}	5.6±0.58^{g}
CD (0.05)	4.4868	18.6061	1.0957	4.5736	7.3432	3.0004	0.7479	0.6240	0.3474	1.2218

Note: Values are means of triplicates with ± SD. Values in the column with same alphabets are not significantly different as analyzed by ANOVA (5% level; LSD)

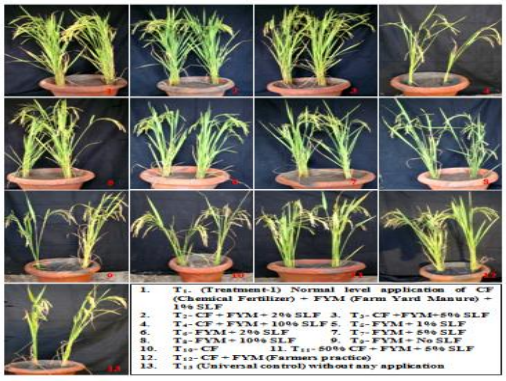

Fig. 4. Effect of *Kappaphycus alvarezii* SLF on paddy under glass house conditions at 90 days after transplantation

Table 10. Effect of *Kappaphycus alvarezii* SLF on the growth of *Oryza sativa* under glass house conditions on 90th day after transplantation

Treatment	Number of panicles / tiller	Number of spikelets / tiller	Total number of grains / hill	Number of filled grains / hill	Number of unfilled grains / hill	Filled grains weight (g) / hill	Unfilled grains weight (g) / hill	Total grains weight (g) / hill
T1	13.0±1.00^{a}	83.0±7.21^{b}	1194.0±50.47^{a}	1140.0±102.01^{b}	58.0±6.08^{f}	12.2±0.50^{a}	1.0±0.20^{gh}	13.2±0.34^{a}
T2	14.0±1.00^{a}	96.0±8.00^{a}	1258.0±47.03^{a}	1212.0±48.86^{a}	45.0±5.56^{f}	13.0±1.00^{a}	0.8±0.05^{h}	13.8±0.65^{a}
T3	10.0±1.00^{b}	77.0±12.52^{b}	1054.0±56.00^{b}	974.0±56.66^{c}	68.0±6.08^{f}	8.2±0.75^{c}	1.4±0.20^{fg}	9.6±0.65^{c}
T4	6.0±1.00^{de}	54.0±7.93^{d}	651.0±60.55^{e}	508.0±26.22^{f}	156.0±11.53^{bc}	5.4±0.60^{fg}	2.5±0.50^{ab}	7.9±0.36^{e}
T5	9.0±1.00^{b}	72.6±6.80^{bc}	955.0±57.10^{c}	839.0±15.87^{d}	115.0±18.68^{de}	8.4±0.36^{c}	1.0±0.10^{gh}	9.4±0.20^{cd}
T6	8.6±0.57^{bc}	83.6±3.21^{b}	1028.0±64.21b^{c}	912.0±23.57^{c}	102.0±10.44^{e}	9.3±0.26^{b}	0.9±0.20^{h}	10.2±0.26^{bc}
T7	6.0±1.00^{de}	64.0±3.60^{cd}	754.0±62.26^{d}	626.0±32.51^{e}	128.0±16.09^{d}	6.7±0.43^{e}	1.5±0.10^{ef}	8.0±1.00^{e}
T8	4.6±0.57^{ef}	37.3±6.43^{e}	524.0±26.00^{f}	349.0±30.00^{hi}	175.0±13.22^{b}	4.5±0.50^{g}	2.0±0.20^{cd}	6.5±0.60^{f}
T9	4.3±0.57^{f}	54.3±3.51^{d}	554.0±38.93^{f}	403.0±21.93^{gh}	178.0±23.51^{b}	6.0±0.46^{ef}	2.4±0.40^{abc}	8.4±010de
T10	5.3±0.57^{ef}	59.0±6.56^{d}	667.0±7.93^{e}	460.0±27.22f^{g}	164.0±12.49^{b}	6.2±0.53^{ef}	2.0±0.20^{cd}	8.2±0.55^{e}
T11	7.3±0.57^{cd}	61.6±3.51^{cd}	787.0±50.86^{d}	623.0±25.53^{e}	175.0±9.53^{b}	7.8±0.40^{c}	1.9±0.20^{de}	9.7±1.13^{c}
T12 (c)	8.6±0.57^{bc}	63.3±7.23^{cd}	811.0±19.15^{d}	667.0±31.51^{e}	135.0±10.00^{cd}	8.8±0.44^{bc}	2.1±0.40^{bcd}	10.9±0.87^{b}
T13	5.3±0.57^{ef}	34.0±2.64^{e}	527.0±17.34^{f}	296.0±24.33^{i}	217.0±28.61^{a}	4.6±0.36^{g}	2.8±0.43^{a}	7.4±0.40^{ef}
CD (0.05)	1.3425	11.6260	80.1399	65.6927	25.3599	0.8761	0.4653	1.0562

Note: Values are means of triplicates with ± SD. Values in the column with same alphabets are not significantly different as analyzed by ANOVA (5% level; LSD)

Table 11. Effect of *Kappaphycus alvarezii* SLF on the yield of *Oryza sativa* under glass house conditions on 90th day after transplantation

Treatment	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12(c)	T13
Yield (g /pot)	48.4	52.3	46.7	30.1	44.8	48.6	41.8	29.6	32.6	35.8	40.3	36.0	28.0

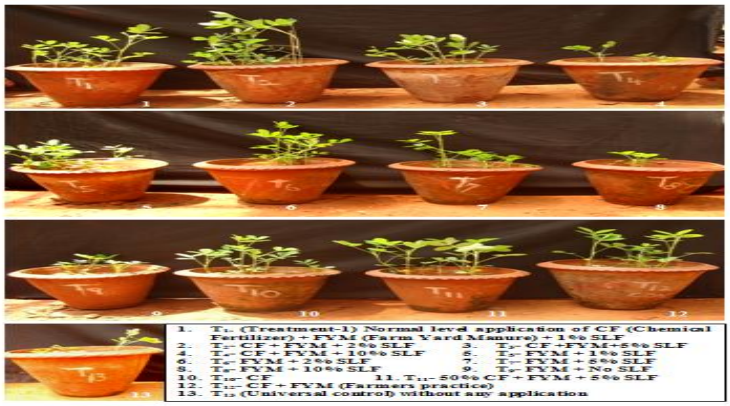

Fig. 5. Effect of *Kappaphycus alvarezii* SLF on 30th day of groundnut under glass house conditions

Table 12. Effect of *Kappaphycus alvarezii* SLF on the growth of *Arachis hypogea* under glass house conditions on 30th day

Treatment	Total plant height (cm)	Shoot height (cm)	Root height (cm)	Total fresh weight (g)	Shoot fresh weight (g)	Root fresh weight (g)	Total dry weight (g)	Shoot dry weight (g)	Root dry weight (g)	Number of branches	Leaf area (cm^2)	Total number of leaves
T1	31.0±3.46^{a}	22.0±3.60^{a}	9.0±0.50^{a}	12.0±1.73^{a}	11.3±2.13^{a}	0.75±0.10^{a}	2.85±0.42^{a}	2.45±0.20^{a}	0.4±0.10^{a}	17.0±2.64^{a}	10.5±1.32^{a}	68±4.58^{a}
T2	30.5±2.17^{a}	21.5±3.00^{a}	9.0±1.50^{a}	11.5±1.80^{ab}	10.8±1.58^{ab}	0.70±0.10^{ab}	2.8±0.40^{a}	2.4±0.17^{a}	0.4±0.10^{a}	16.0±1.00^{a}	10.4±1.92^{a}	65±6.55^{a}
T3	26.0±2.00^{b}	19.5±1.80^{ab}	6.5±0.62^{b}	10.0±1.83^{b}	9.5±1.32^{b}	0.50±0.18^{cdef}	2.4±0.26^{b}	2.05±0.20^{b}	0.35±0.05^{ab}	11.0±2.00^{b}	7.6±0.72^{b}	55±3.00^{b}
T4	18.5±2.29^{def}	13.5±2.00^{d}	5.0±1.32^{cde}	4.2±1.12^{ef}	3.8±0.96^{ef}	0.40±0.15^{def}	1.2±0.20^{de}	1.02±0.12^{ef}	0.18±0.03^{f}	6.0±1.00^{de}	3.9±0.79^{de}	40±4.00^{e}
T5	22.0±2.64^{bd}	17.8±2.36^{bc}	4.2±0.52^{defg}	7.0±1.00^{cd}	6.45±0.80^{cd}	0.55±0.15^{bcd}	1.7±0.20^{c}	1.45±0.20^{cd}	0.25±0.05^{cdf}	11.0±1.72^{b}	5.1±1.05^{cd}	49±6.08^{bcd}
T6	23.0±2.64^{b}	18.4±2.94^{ab}	4.6±0.72^{def}	6.9±1.50^{cd}	6.32±1.01^{cd}	0.58±0.04^{abc}	1.8±0.40^{c}	1.56±0.20^{c}	0.24±0.02^{cdf}	11.0±1.00^{b}	4.6±0.75^{cd}	52±4.00^{bc}
T7	20.5±1.32^{de}	16.5±3.04^{bcd}	4.0±0.30^{defg}	5.1±1.65^{de}	4.73±0.63^{de}	0.37±0.02^{efg}	1.5±0.30^{cd}	1.27±0.06^{d}	0.23±0.06^{cdf}	9.0±1.00^{bc}	4.2±0.43^{de}	43±4.35^{de}
T8	16.5±1.32^{ef}	13.7±1.80^{d}	2.8±0.52^{g}	3.2±0.52^{ef}	2.98±0.27^{f}	0.22±0.02^{g}	0.7±0.20^{f}	0.48±0.13^{g}	0.22±0.04^{cdf}	8.0±1.00^{cd}	3.0±0.50^{de}	32±2.00^{gh}
T9	17.0±2.64^{ef}	13.8±1.73^{d}	3.2±0.91^{fg}	3.7±0.26^{ef}	3.35±1.03^{ef}	0.35±0.15^{f}	1.1±0.20^{e}	0.9±0.05^{f}	0.2±0.02^{df}	7.0±1.00^{cd}	3.9±0.36^{de}	35±3.00^{f}
T10	18.0±3.00^{def}	14.2±1.70^{cd}	3.8±0.75^{efg}	4.0±1.00^{ef}	3.58±0.80^{ef}	0.42±0.11^{cdef}	1.2±0.30^{de}	0.94±0.12^{f}	0.26±0.04^{cdf}	6.0±1.00^{de}	4.2±1.05^{de}	40±5.00^{e}
T11	20.0±4.00^{def}	14.6±1.92^{cd}	5.4±0.79^{bcd}	4.5±1.00^{ef}	4.03±0.95^{ef}	0.47±0.08^{cdef}	1.5±0.17^{cd}	1.22±0.12^{de}	0.28±0.04^{bc}	9.0±2.00^{bc}	5.0±1.00^{c}	47±3.00^{bcde}
T12 (c)	24.0±1.00^{b}	17.8±2.36^{bc}	6.2±1.11^{bc}	7.5±0.86^{c}	6.97±1.10^{c}	0.53±0.03^{bcde}	1.7±0.26^{c}	1.41±0.21^{cd}	0.29±0.04^{bc}	11.0±1.00^{b}	5.9±0.79^{c}	48±3.00^{bcd}
T13	16.0±3.00^{f}	13.1±1.73^{d}	2.9±0.65^{g}	3.0±0.50^{f}	2.79±0.29^{f}	0.21±0.03^{g}	0.6±0.20^{f}	0.42±0.07^{g}	0.18±0.03^{f}	4.0±1.00^{e}	2.7±0.43^{f}	25±2.64^{h}
CD (0.05)	4.2895	3.6653	1.4808	1.9780	1.7319	1.7319	0.3574	0.2493	0.0880	2.4585	1.6668	7.1585

Note: Values are means of triplicates with ± SD. Values in the column with same alphabets are not significantly different as analyzed by ANOVA (5% level; LSD)

Table 13. Effect of *Kappaphycus alvarezii* SLF on the growth of *Arachis hypogea* under glass house conditions on 60th day

Treatment	Total plant height (cm)	Shoot height (cm)	Root height (cm)	Total fresh weight (g)	Shoot fresh weight (g)	Root fresh weight (g)	Total dry weight (g)	Shoot dry weight (g)	Root dry weight (g)	Number of branches	Leaf area (cm^2)	Total number of leaves	Number of pods
T1	44.0±0.50 a	27.5±0.17^{a}	17.0±0.36^{a}	65.7±0.40^{a}	45.1±0.30 a	21.4±0.26^{a}	14.4±0.34a	9.6±0.26^{a}	5.1±0.20^{a}	23.0±2.64 a	15.0±0.65 a	120.0±7.21^{a}	20.0±3.60^{a}
T2	41.5±0.98 b	24.5±0.26^{c}	16.5±0.10^{a}	62.5±0.36^{b}	41.1±0.50 b	20.6±0.26^{b}	13.9±0.60^{a}	8.8±0.26^{b}	4.8±0.10^{a}	22.0±1.00 a	14.5±0.10 a	117.0±1.00^{a}	18.0±1.73^{a}
T3	37.3±0.35 c	26.3±0.23^{b}	11.0±0.87^{b}	48.1±0.30^{c}	31.6±0.26 c	16.5±0.26^{c}	10.8±0.55^{b}	6.6±0.43^{c}	4.2±0.34^{b}	16.0±2.00 b	10.5±0.26 b	87.0±12.52^{b}	12.0±2.64^{b}
T4	20.1±0.43^{i}	14.7±0.43^{i}	5.4±0.17^{f} g	22.6±0.26^{k}	13.3±0.26 k	9.3±0.55 g	5.7±0.17^{gh}	3.5±0.43^{gh}	2.2±0.10^{g}	10.0±2.64 c	6.2±0.20^{gh}	37.0±3.60^{f}	4.0±3.00 de
T5	30.6±0.62 d	22.0±0.46^{d}	8.6±0.26^{c}	39.6±0.26^{d}	26.1±0.26 d	13.5±0.46^{d}	8.9±0.60^{c}	5.4±0.20^{d}	3.5±0.52^{cd}	8.0±1.00^{cd} e	8.2±0.10^{d}	81.0±7.54^{b}	8.0±2.00 bcd
T6	29.4±0.26 e	21.3±0.10^{e}	8.1±0.20^{e}	38.6±0.26^{e}	25.8±0.26 d	12.8±0.10^{e}	8.4±0.26^{cd}	4.8±0.36^{e}	3.6±0.17^{c}	9.0±1.73^{cd}	9.0±0.34^{c}	87.0±17.08^{b}	9.0±3.46 bc
T7	23.0±0.87 h	15.6±0.36^{h}	7.4±0.43^{d}	30.6±0.26^{h}	20.0±0.20 g	10.6±0.26^{f}	7.0±0.10^{e}	4.2±0.17^{f}	2.8±0.17^{f}	7.0±3.60^{cd} e	6.5±0.26^{g}	64.0±3.00^{cd}	8.0±2.00 cd
T8	16.5±0.26 k	11.6±0.34^{k}	4.9±0.26^{g}	20.3±0.26^{i}	12.8±0.10^{j}	7.5±0.26 h	5.1±0.45^{hi}	3.0±0.36^{h}	2.1±0.36^{g}	5.0±1.73^{e}	5.8±0.17^{h}	41.0±2.64^{ef}	3.0±1.00 e
T9	18.5±0.26^{j}	12.3±0.26^{j}	6.2±0.17^{e}	25.1±0.26^{j}	15.5±0.26^{i}	9.6±0.20 g	5.5±0.17^{gh}	3.2±0.20^{gh}	2.3±0.17^{g}	6.0±1.00^{de}	6.7±0.26^{fg}	47.0±9.64^{ef}	3.0±1.00 e
T10	20.0±0.81^{i}	12.9±0.43^{j}	7.1±0.17^{d}	27.6±0.26^{i}	17.8±0.17 h	9.8±0.10 g	6.1±0.36^{fg}	3.6±0.26^{g}	2.5±0.34^{fg}	7.0±1.73^{cd} e	7.1±0.36^{ef}	54.0±4.00^{de}	5.0±3.46 cde
T11	25.1±0.30 g	16.9±0.36^{g}	8.2±0.17^{c}	31.8±0.17^{g}	21.3±0.20^{f}	10.5±0.20^{f}	6.5±0.60^{ef}	3.4±0.26^{gh}	3.1±0.45^{d}	8.0±1.73^{cd} e	7.5±0.17^{e}	62.0±4.00^{cd}	7.0±2.64 cde
T12 (c)	26.8±0.17^{f}	18.4±0.36^{f}	8.4±0.26^{c}	35.4±0.17^{f}	21.8±0.26 e	13.6±0.26^{d}	7.9±0.17^{d}	4.8±0.26^{e}	3.1±0.30^{d}	10.0±1.73 c	8.2±0.36^{d}	75.0±5.29^{bc}	8.0±2.00 bcd
T13	18.5±0.26^{j}	12.7±0.60^{j}	5.8±0.26^{e} f	20.4±0.34^{i}	13.9±0.34^{j}	6.5±0.26^{i}	4.5±0.43^{i}	3.0±0.26^{h}	1.5±0.10^{h}	6.0±1.00d e	5.7±0.36^{h}	43.0±12.49^{ef}	3.0±1.00 e
CD (0.05)	0.9134	0.6262	0.5889	0.4880	0.4705	0.5109	0.6932	0.5239	0.4332	3.1900	0.5400	13.6278	4.1586

Note: Values are means of triplicates with ± SD. Values in the column with same alphabets are not significantly different as analyzed by ANOVA (5% level; LSD)

Table 14. Effect of *Kappaphycus alvarezii* SLF on the yield of *Arachis hypogea* under glass house conditions on 105th day

Treatment	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12(c)	T13
Yield (g/ pot)	170.6	158.3	146	78.6	147.3	135.4	130.3	86.8	98.6	109.7	141.5	130.6	70.6

Table 15. Effect of *Kappaphycus alvarezii* SLF on the growth of *Capsicum annum* under glass house conditions on 30th day after transplantation

Treatment	Total plant height (cm)	Shoot height (cm)	Root height (cm)	Total fresh weight (g)	Shoot fresh weight (g)	Root fresh weight (g)	Total dry weight (g)	Shoot dry weight (g)	Root dry weight (g)	Number of branches	Leaf area (cm^2)	Total number of leaves
T1	41.8±1.40^{a}	32.5±1.56^{ab}	9.3±1.80^{a}	17.0±1.00^{ab}	14.8±0.80^{a}	2.2±0.26^{ab}	2.9±0.26^{ab}	2.5±0.10^{a}	0.4±0.08^{b}	13.0±2.00^{ab}	7.2±0.40^{b}	45.0±4.35^{ab}
T2	42.8±3.46^{a}	35.0±2.00^{a}	7.8±1.47^{ab}	18.5±1.00^{a}	15.9±0.78^{a}	2.6±0.52^{a}	3.2±0.26^{a}	2.6±0.43^{a}	0.6±0.10^{a}	14.0±2.00^{a}	8.1±0.70^{a}	46.0±4.00^{a}
T3	37.5±1.00^{b}	30.5±1.80^{bc}	7.0±1.50^{bc}	15.0±1.00^{bc}	13.0±0.50^{b}	2.0±0.20^{bc}	2.5±0.45^{bc}	2.2±0.20^{ab}	0.3±0.04^{c}	12.0±2.64^{abc}	7.2±0.36^{b}	41.0±5.00^{abc}
T4	26.5±4.58^{ef}	24.0±3.00^{e}	2.5±0.50^{g}	9.0±1.32^{e}	8.0±0.50^{d}	1.0±0.30^{de}	1.8±0.10^{e}	1.6±0.17^{c}	0.2±0.02^{d}	7.0±1.73^{defg}	4.1±0.45^{f}	30.0±5.56^{efg}
T5	32.0±2.00^{cd}	25.0±2.00^{e}	7.0±1.00^{bc}	12.0±1.80^{d}	10.7±0.40^{c}	1.3±0.30^{de}	2.1±0.17^{cde}	1.8±0.10^{bc}	0.3±0.05^{c}	9.0±2.00^{cde}	5.2±0.36^{e}	32.0±5.29^{ef}
T6	33.5±3.00^{c}	27.0±2.00^{de}	6.5±1.00^{bcd}	13.0±1.73^{cd}	11.6±0.60^{c}	1.4±0.50^{d}	2.3±0.36^{cd}	2.0±0.36^{bc}	0.3±0.05^{c}	10.0±1.73^{bcd}	5.3±0.45^{e}	38.0±6.24^{bc}
T7	28.6±4.00^{de}	24.0±2.00^{e}	4.6±0.40^{ef}	11.5±1.00^{d}	10.3±1.17^{c}	1.2±0.26^{de}	2.0±0.17^{de}	1.8±0.26^{c}	0.3±0.02^{cd}	8.0±1.73^{def}	4.5±0.34^{f}	30.0±4.35^{efg}

T8	21.0± 1.73^{gh}	18.0± 1.73^{fg}	3.0±0 .50^{fg}	7.0±0 .50^{ef}	6.2±0 .40^{e}	0.8± 0.20^{e}	0.8±0 .20^{f}	0.7± 0.10^{d}	0.1± 0.02^{e}	6.0±2. 00^{efg}	3.2± 0.20^{g}	24.0± 3.46^{g}
T9	23.1± 2.50^{fg}	19.0± 2.00^{f}	4.1±0 .60^{efg}	7.5±1 .00^{ef}	6.5±0 .50^{e}	1.0± 0.30^{de}	1.2±0 .17^{f}	1.1± 0.20^{d}	0.1± 0.02^{e}	5.0±1. 73^{fg}	4.0± 0.34^{df}	29.0± 2.64^{efg}
T10	33.5± 3.00^{c}	28.5± 2.29^{cd}	5.0±1 .32de	11.5± 1.00^{d}	10.3± 0.30^{c}	1.2± 0.20^{de}	2.0±0 .43de	1.8± 0.30^{c}	0.3± 0.05^{cd}	5.0±1. 73^{fg}	5.5± 0.34^{de}	30.0± 2.64^{efg}
T11	34.5± 2.00^{bc}	29.0± 2.29^{cd}	5.5±1 .00^{cde}	12.5± 1.00^{d}	11.0± 1.73^{c}	1.5± 0.20^{cd}	2.0±0 .30de	1.7± 0.34^{c}	0.3± 0.05^{c}	7.0±1. 00^{defg}	6.0± 0.10^{c}	35.0± 4.35^{ce}
T12 (c)	33.5± 1.73^{c}	27.0± 2.00^{de}	6.5±1 .00^{bcd}	12.0± 1.00^{d}	10.6± 1.00^{c}	1.4± 0.36^{d}	2.2±0 .10^{cde}	1.9± 0.26^{bc}	0.3± 0.04^{c}	9.0±2. 00^{cde}	6.2± 0.34^{c}	36.0± 3.46^{ce}
T13	19.0± 1.00^{h}	15.0± 1.80^{g}	4.0±1 .00^{efg}	6.5±1 .00^{f}	5.7±0 .60^{e}	0.8± 0.20^{e}	1.2±0 .26^{f}	1.1± 0.17^{d}	0.1± 0.02^{e}	4.0±1. 00^{g}	3.0± 0.17^{g}	25.0± 3.60^{fg}
CD (0.05)	3.592 1	3.350 9	1.774 3	2.005 8	1.398 4	0.527 2	0.475 7	0.430 9	0.079 1	3.2240	0.580 3	7.6204

Note: Values are means of triplicates with ± SD. Values in the column with same alphabets are not significantly different as analyzed by ANOVA (5% level; LSD)

Table 16. Effect of *Kappaphycus alvarezii* SLF on the growth of *Capsicum annum* under glass house conditions on 60th day after transplantation

Treatment	Total plant height (cm)	Shoot height (cm)	Root height (cm)	Total fresh weight (g)	Shoot fresh weight (g)	Root fresh weight (g)	Total dry weight (g)	Shoot dry weight (g)	Root dry weight (g)	Number of branches	Leaf area (cm^2)	Total number of leaves	Number of green chilli	Number of chilli
T1	57.4±1.65^{a}	49.1±2.35^{a}	8.3±1.17^{a}	25.7±1.67^{b}	23.7±2.59^{a}	2.0±0.10^{a}	6.5±1.32^{a}	6.2±0.10^{a}	0.3±0.16^{abc}	17.3±2.51^{a}	6.5±0.98^{ab}	55.0±6.08^{ab}	20.0±2.64^{b}	10.0±1.00^{b}
T2	60.2±1.80^{a}	52.0±2.45^{a}	8.2±0.75^{a}	28.3±2.26^{a}	26.1±1.30^{a}	2.2±0.36^{a}	7.0±0.50^{a}	6.5±0.13^{a}	0.4±0.11^{a}	19.6±2.51^{a}	7.0±2.64^{a}	61.0±4.58^{a}	25.0±2.00^{a}	12.0±1.00^{a}
T3	50.9±1.10^{b}	42.7±2.80^{b}	8.2±1.11^{a}	18.4±1.45^{c}	17.4±0.95^{b}	1.0±0.43^{b}	4.9±0.87^{b}	4.5±0.24^{b}	0.3±0.11^{abc}	14.0±1.00^{b}	5.7±0.95^{abc}	47.0±5.29^{bc}	16.0±1.73^{c}	7.0±1.00^{c}
T4	26.3±3.55^{g}	22.0±2.20^{gh}	4.3±0.60^{f}	10.2±0.96^{gh}	9.8±0.81^{fg}	0.4±0.20^{d}	1.9±0.36^{efg}	1.6±0.35^{ef}	0.2±0.07^{bcde}	6.0±1.00^{ef}	2.9±0.88^{e}	28.0±4.00^{efg}	7.0±1.00^{fg}	3.0±1.00^{f}
T5	35.8±0.91^{de}	30.1±3.30^{cde}	5.7±0.26^{cde}	13.6±1.67^{ef}	12.9±2.00^{de}	0.6±0.15^{cd}	3.1±0.81^{cd}	2.8±0.22^{cd}	0.3±0.07^{abcd}	8.0±2.00^{cde}	4.0±1.56^{cde}	35.0±6.08^{de}	15.0±1.73^{c}	6.3±0.57^{cd}
T6	38.6±1.03^{cd}	32.6±3.70^{cd}	6.0±0.20^{bcd}	15.6±1.75^{de}	14.9±1.38^{cd}	0.7±0.21^{cd}	3.4±0.52^{c}	3.0±0.12^{c}	0.3±0.10^{ab}	9.0±1.00^{cd}	4.1±0.79^{cde}	40.0±11.53^{cd}	17.0±1.00^{c}	6.3±0.57^{cd}
T7	31.2±1.90^{f}	25.7±3.91^{efg}	5.5±0.10^{de}	10.3±1.99^{gh}	9.8±1.09^{fg}	0.6±0.08^{d}	1.3±0.52^{g}	1.0±0.07^{g}	0.2±0.02^{cde}	7.3±0.57^{def}	4.0±0.75^{cde}	32.0±5.29^{de}	12.0±1.00^{d}	5.0±1.00^{de}
T8	20.4±2.62^{h}	16.4±2.35^{i}	4.0±0.52^{f}	7.5±0.72^{j}	7.0±1.10^{hi}	0.5±0.07^{d}	1.4±0.36^{fg}	1.3±0.40^{fg}	0.1±0.02^{f}	6.0±1.73^{ef}	3.2±0.96^{de}	20.0±4.58^{g}	6.0±1.73^{g}	3.0±1.00^{f}
T9	27.8±1.05^{g}	23.0±3.10^{fg}	4.8±0.60^{ef}	9.7±1.41^{hi}	9.2±1.59^{gh}	0.5±0.08^{cd}	1.9±0.30^{efg}	1.7±0.17^{e}	0.1±0.02^{ef}	7.0±1.00^{def}	3.7±0.98^{de}	30.0±4.58^{ef}	8.0±2.00^{fg}	4.0±1.00^{ef}
T10	33.4±1.15^{ef}	28.0±3.10^{def}	5.4±0.20^{de}	12.4±1.27^{fg}	11.8±0.60^{e}	0.6±0.07^{cd}	2.3±0.34^{def}	2.0±0.16^{e}	0.2±0.03^{bcde}	8.0±2.00^{def}	4.1±0.79^{cde}	29.0±2.64^{efg}	9.0±1.73^{ef}	4.3±0.57^{ef}
T11	36.5±1.80^{d}	30.0±3.27^{cde}	6.5±0.45^{bc}	14.9±0.87^{de}	14.2±0.96^{cd}	0.7±0.36^{bcd}	2.7±0.26^{cde}	2.5±0.26^{d}	0.2±0.02^{def}	10.0±2.64^{c}	5.0±1.73^{bcd}	32.0±2.64^{de}	11.0±1.73^{de}	5.0±1.00^{de}
T12 (c)	40.2±0.91^{c}	33.4±2.66^{c}	6.8±0.40^{b}	16.3±0.87^{cd}	15.5±1.18^{b}	0.8±0.14^{bc}	3.0±1.00^{cd}	2.8±0.52^{c}	0.2±0.02^{cde}	11.0±1.00^{c}	5.7±0.43^{abc}	37.0±6.24^{de}	11.0±2.00^{de}	7.3±0.57^{c}
T13	20.8±2.30^{h}	16.9±2.90^{hi}	3.9±0.55^{f}	6.5±0.75^{j}	6.1±3.51^{i}	0.4±0.09^{d}	1.2±0.30^{g}	1.1±0.26^{dg}	0.1±0.01^{f}	5.0±1.00^{f}	2.7±0.70^{e}	22.0±5.56^{fg}	7.0±2.00^{fg}	3.0±1.00^{f}
CD (0.05)	3.0909	5.1928	0.9898	2.4589	2.4261	0.3362	0.9787	0.4403	0.1347	2.5741	1.9579	9.0044	2.8301	1.4656

Note: Values are means of triplicates with ± SD. Values in the column with same alphabets are not significantly different as analyzed by ANOVA (5% level; LSD)

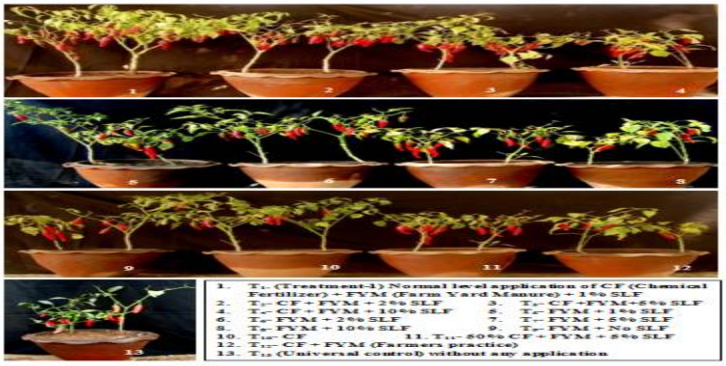

Fig. 6. Effect of *Kappaphycus alvarezii* SLF on chilli under glass house conditions at 90 days after transplantation

Table 17. Effect of *Kappaphycus alvarezii* SLF on the yield of *Capsicum annum* under glass house conditions at different periods.

Treatment	1st picking on 60th day (g/pot)	2nd picking on 75th day (g/pot)	3rd picking on 90th day(g/pot)	Total yield (g/pot)
T1	120.3	182.3	126.4	429.4
T2	127.1	202.6	135.2	464.9
T3	105.2	165.8	115.0	386.0
T4	80.3	115.2	65.0	260.5
T5	105.6	150.6	90.5	346.7
T6	107.8	160.2	100.6	368.6
T7	92.9	140.7	87.3	320.9
T8	72.3	107.3	67.0	246.6
T9	85.1	100.3	78.7	264.1
T10	90.8	119.5	80.4	290.7
T11	120.5	160.0	105.5	386.0
T12 (c)	115.6	155.3	97.3	368.2
T13	75.3	83.2	97.8	256.3

Conclusion

Application of seaweed extracts to commercial crops increases the yield of crops, promotes seed germination, increases the resistance to frost, protects crops from fungal as well as insect attacks and aids in the uptake of inorganic constituents as well (Crouch and Vanstaden, 1993). In the present study, the effect of SLF obtained from the red seaweed *Kappaphycus alvarezii* was investigated on the growth, biochemical characteristics and yield of *Oryza sativa, Arachis hypogea* and *Capsicum annum* under both glass house conditions and in field trials. Two sets of SLF preparations with initial pH 4.0 and 7.2, respectively, were used in the investigation *vide* Materials and Methods. The pH of the two samples decreased during the experimental period of six months to 3.2 and 6.7, respectively.

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