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Efficacy of *Kappaphycus* and *Gracilaria* sap on growth and yield improvement of sesame in new alluvial soil

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ABSTRACT

A field experiment was conducted during pre-kharif season of 2012 and 2013 with the focal objectives of studying the efficacy of seaweed saps derived from two marine algae viz. Kappaphycus and Gracilaria on growth and yield improvement of sesame;, nutrient uptake by the crop and monetary advantage. The foliar spray was performed thrice at different concentrations (0, 2.5, 5.0, 10.0 and 15.0% v/v) of seaweed extracts. Such application of seaweed extracts significantly enhanced the growth and yield parameters. The highest seed yield was evidenced with the combined applications of 15% Kappaphykus sap and 75% recommended dose of fertilizer (RDF) and this treatment was closely followed by the application of 15% Gracilaria sap along with 75% RDF. The maximum net monetary return (₹28650) and benefit: cost ratio (1.99) were documented with this treatment. Nutrient uptake (N, P and K) was also increased with seaweed extract applications.

Key words: Gracilaria sap, growth, kappaphycus sap, sesame, yield

Under the present situation, one needs to develop such a sustainable system of cultivation that has least harmful environmental impact. One such approach is the use of bio-stimulants, which can enhance the effectiveness of conventional mineral fertilizers. To meet increasing demand of organic manures, among many viable options, the use of seaweed extracts as plant nutrient bearing fertilizer is an important one. Marine bioactive substances extracted from marine algae are used in agricultural and horticultural crops, and many beneficial effects may be achieved in terms of enhancement of yield and quality. Seaweed extracts contain major and minor nutrients, amino acids, vitamins, cytokinins, auxin and abscisic acid like growth promoting substances and have been reported to stimulate the growth and yield of plants, develop tolerance to environmental stress, enhance antioxidant properties and increase nutrient uptake from soil (Turan and Kose, 2004). It supplies nitrogen, phosphorous, potash as well as the trace minerals like Zn, Mn, Mg, Fe etc. It also contains natural plant growth substances like auxins, gibberlins and cytokinins (Jameson, 1998). Liquid extracts obtained from seaweeds have recently gained importance as foliar sprays for many crops including various grasses, cereals, flowers and vegetable species. In recent years, use of seaweed extracts have gained in popularity due to their potential use in organic and sustainable agriculture especially in rainfed crops, as a means to avoid excessive fertilizer applications and to improve mineral absorption. Unlike, chemical fertilizers, extracts derived from seaweeds are biodegradable, non-toxic, non-polluting and non-hazardous to humans, animals and birds (Dhargalkar and Pereira, 2005). Keeping all these in milieu, a field experiment was carried out with the main objectives of studying the efficacy of seaweed saps derived from two marine algae viz. *Kappaphycus* and *Gracilaria* on growth and yield improvement of sesame; nutrient uptake of the crop and monetary advantage of using these saps.

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MATERIALS AND METHODS

The field experiment was conducted during the *pre-kharif* season of 2012 and 2013 in inceptisol at Uttar Chandamari village of Nadia district of West Bengal in India. The soil of the site was sandy clay loam with pH 6.53, organic carbon 0.49%, total nitrogen 0.059%, available P_2O_5 26.67 kg ha^{-1} and available K_2O 151.03 kg ha^{-1}. The climate of the region is humid subtropical. The experimental site is located at 22°57′N latitude, 88°20′E longitude and altitude is 7.8 m above mean sea level.

The experiment comprised of ten treatments, viz, T_1- 2.5% *Kappaphycus* sap + 75% RDF, T_2- 5% *Kappaphycus* sap + 75%RDF, T_3- 10% *Kappaphycus* sap + 75%RDF, T_4- 15% *Kappaphycus* sap + 75%RDF, T_5- 2.5% *Gracilaria* sap + 75%RDF, T_6- 5% *Gracilaria* sap + 75%RDF, T_7- 10% *Gracilaria* sap + 75%RDF, T_8- 15% *Gracilaria* sap + 75%RDF, T_9- 75%RDF + Water spray and T_{10}- 100% RDF in randomized block design (RBD) replicated thrice. Three sprays of *Kappaphycus* and *Gracilaria* extract

were applied at 20, 40 and 60 days after sowing (DAS). For proper adherence, extracts were mixed with proper surfactant (Active 80 @ 0.5 ml l^{-1} of water) at the time of spraying. The total spray volume was 550 l ha^{-1} in each application. The plot size was 5 m × 6 m. The recommended dose of fertilizer (RDF) for sesame was 80, 40, 40 kg ha^{-1} N, P_2O_5 and K_2O respectively and all fertilizers were applied as basal. Irrigations are given as and when required. The variety of the crop used in this experiment was *Tilottama*.

The seaweed extract used in this study was obtained from *Kappaphycus* sp. and *Gracilaria* sp. The saps were prepared following the method as described by Eswaran *et al*., 2005. The liquid filtrate was taken as 100% concentration of the seaweed extract and further diluted as per the treatments. The nitrogen (N) content of seaweed extract (100% concentrate) was determined by semi-micro Kjeldahl method (AOAC 1995), and other nutrient elements were analysed by ICP-OES *i.e.* inductively coupled plasma-optical emission spectroscopy (Richards, 1954).

Data were taken through random sampling at 25, 50, 75 DAS and at harvest to measure plant height, dry matter accumulation, crop growth rate (CGR) and leaf area index (LAI). CGR was computed with the help of the formula: $[(W_2 - W_1)/ (t_2 - t_1)]$ where, W_1= dry weight per unit area at t_1, W_2= dry weight per unit area at t_2, t_1= first sampling and t_2= second sampling. LAI was computed by the ratio of leaf area to the area of ground cover. Data on yield attributes were taken randomly before harvesting. Phosphorus (P) content was determined by the Vanado-Molybdate yellow method (Jackson, 1973) and Potassium (K) content by flame photometry (Jackson, 1973).

Table 1: Chemical composition of *Kappaphycus* sap and *Gracilaria* sap

***Kappaphycus* sap**		***Gracilaria* sap**	
Nutrient	**Amount present**	**Nutrient**	**Amount present($100g^{-1}$)**
Protein	0.085 g.100 ml^{-1}	Crude protein	9.58 g
Crude fibre	0.01 g.100 ml^{-1}	Crude fibre	10.40 g
Carbohydrate	1.800 g.100 ml^{-1}	Carbohydrate	45.92g
Potassium	358.35 mg.100 ml^{-1}	Potassium	8633.00 mg
Magnesium	116.79 mg.100 ml^{-1}	Magnesium	549.50 mg
Phosphorous	2.96 mg.100 ml^{-1}	Phosphorus	278.50 mg
Calcium	32.49 mg.100 ml^{-1}	Calcium	295.50 mg
Copper	0.077 mg.100 ml^{-1}	Copper	0.20 mg
Zinc	0.474 mg.100 ml^{-1}	Zinc	1.00 mg
Iron	8.58 mg.100 ml^{-1}	Iron	67.35 mg
Manganese	0.22 mg.100 ml^{-1}	Manganese	4.16 mg
Nickel	0.35 mg/100 ml	Nickel	0.92 mg
Sodium	18.10 mg.100 ml^{-1}	Sodium	158.50 mg
Iodine	160nmg/100ml	Cobalt	0.24 mg
Indole acetic acid	23.36 $mg.l^{-1}$	Sulphate	106.20 mg
Gibberelin GA_3	27.87 $mg.l^{-1}$	Chlorine	1170.00 mg
Kinetin + Zeatin	31.91 $mg.l^{-1}$	Pb	1.11 mg

[Source: Pramanick *et al.,* 2013]

The prevailing market price of sesame seed and stover was ₹55,000 and ₹2,000 $tonne^{-1}$ repectively. Common cost of cultivation was ₹23,860 ha^{-1}. Rate of *Kappaphycus* and *Gracilaria* sap was ₹20 L^{-1}.

Data were analysed using analysis of variance (ANOVA) following randomized block design (Gomez and Gomez, 1984). Differences were considered significant at 5% level of probability.

RESULTS AND DISCUSSION

Growth of sesame

Foliar application of different seaweed saps along with 75% RDF increased growth attributes of sesame significantly over sole application of chemical fertilizer (Table 2). In general, a gradual increase in

plant height, dry matter accumulation and LAI was observed with increasing seaweed extract application. The maximum plant height, dry matter accumulation, CGR and LAI was recorded with the dual application of 15% *Kappaphycus* sap and 75% RDF (T_4) and this treatment was statistically at par with the treatment T_8. This result is in agreement with the view of Jeannin *et al*. (1991) who opined that the foliar application of seaweed extract increased total fresh matter production of cereal maize seedlings by 15 – 25% over the control.

Yield attributes and yield

The highest number of branches plant^{-1}, capsules plant^{-1} and seeds capsule^{-1} were observed under the treatment T_4 (15% *Kappaphycus* sap along with 75% RDF) which was closely followed the treatment T_8 (15% *Gracilaria* sap along with 75% RDF). Total yield might be considered as the mirror of all yield attributes. As the treatment T_4 showed the best yield attributes thus the maximum seed (0.96 t ha^{-1}) and stover yield (2.33 t ha^{-1}) of sesame were also documented in this treatment and it represented no statistical divergence with the treatment T_8 (15% *Gracilaria* sap along with 75% RDF) and T_3 (10% *Kappaphycus* sap along with 75% RDF) (Table 3). Similar kind of results reported for *Phaseolus aureus* (Bai *et al*., 2008). The favourable effect of organic and inorganic sources of nutrients on production of rapeseed also reported by De *et al.* (2009).

Nutrient uptake

The use of the seaweed extracts significantly increased N, P and K uptake by seeds and stover at higher concentrations (10% and above) and reached maximum at 15% seaweed extract compared with sole application of chemical fertilizer (Table 4). The highest N, P and K uptake by seed as well as stover were recorded with the treatment T_4 (15% *Kappaphycus* sap along with 75% RDF). These results confirm those findings previously reported by Crouch *et al*. (1990) who noted an increased uptake of Mg, K and Ca in lettuce with seaweed concentrate application. Turan and Köse (2004) and Mancuso *et al*. (2006) also observed increased uptake of N, P, K and Mg in grapevines and cucumber with the application of seaweed extract. The presence of marine bioactive substances in seaweed extract improves stomata uptake efficiency in treated plants compared to non-treated ones (Mancuso *et al*., 2006).

Economic analysis

The maximum gross income (₹57460), net monetary return (₹28650) and benefit: cost ratio (1.99) were recorded in the treatment T_4 (15% *Kappaphycus* sap along with 75% RDF) which was closely followed by the treatment T_8 (15% *Gracilaria* sap along with 75% RDF) (Table 5). Though the application of foliar extracts over 75% RDF increases the cost of cultivation to some extent but the significant yield

Table 2 : Effect of treatments on plant height, dry matter accumulation, CGR and LAI of sesame (pooled over two years)

Treatments	Plant height (cm)				Dry matter accumulation (g m^{-2})				Crop growth rate (g m^{-2} day^{-1})			Leaf area index		
	DAS			At	DAS			At	DAS		At	DAS		
	25	50	75	harvest	25	50	75	harvest	50	75	harvest	25	50	75
T_1	6.97	48.67	63.93	67.53	5.02	88.42	158.17	285.00	3.34	2.78	5.07	0.151	1.903	3.396
T_2	7.73	50.72	65.26	69.55	5.89	90.78	171.80	292.17	3.39	3.24	4.81	0.159	2.192	3.478
T_3	8.57	53.60	66.31	70.52	6.11	92.85	182.29	320.11	3.46	3.57	5.51	0.163	2.248	3.582
T_4	9.40	55.63	73.53	78.36	6.92	119.51	190.06	357.09	4.50	2.82	6.68	0.174	2.863	3.748
T_5	6.13	47.53	59.55	63.03	4.85	85.49	147.23	260.17	3.22	2.47	4.51	0.149	1.839	3.185
T_6	6.87	48.96	60.43	64.85	5.11	89.20	148.44	289.58	3.36	2.36	5.64	0.153	2.013	3.309
T_7	7.57	50.24	62.19	65.60	5.73	109.48	152.95	310.58	4.15	1.74	6.31	0.160	2.347	3.415
T_8	8.50	53.57	64.85	68.36	6.33	112.37	154.17	330.78	4.24	1.67	7.06	0.162	2.589	3.489
T_9	5.33	46.37	58.66	60.76	4.60	84.32	145.14	250.33	3.18	2.43	4.21	0.147	1.735	3.093
T_{10}	7.63	51.48	66.07	68.39	5.82	91.23	162.49	295.34	3.41	2.85	5.31	0.158	2.195	3.416
SEm(±)	**0.38**	**0.368**	**0.27**	**0.25**	**0.35**	**1.39**	**0.492**	**0.98**	**0.06**	**0.14**	**1.45**	**0.07**	**0.13**	**0.15**
LSD(0.05)	**1.14**	**1.27**	**0.93**	**0.85**	**1.03**	**2.45**	**1.47**	**1.78**	**0.78**	**1.65**	**3.87**	**0.23**	**0.56**	**0.79**

Table 3: Effect of treatments on yield components and seed and stover yield of sesame (pooled over two years)

Treatment	No. of branches plant^{-1}	No. of capsules plant^{-1}	No. of seeds capsule^{-1}	Test weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
T_1	2.82	50.13	53.92	3.05	0.75	1.90
T_2	2.99	51.39	54.74	3.25	0.80	1.99
T_3	3.11	55.42	57.23	3.31	0.88	2.11
T_4	3.42	58.66	59.19	3.89	0.96	2.33
T_5	2.77	49.49	51.27	2.99	0.73	1.88
T_6	2.90	51.82	52.63	3.11	0.79	1.97
T_7	3.07	54.21	56.05	3.27	0.86	2.05
T_8	3.37	57.67	57.92	3.51	0.93	2.25
T_9	2.55	45.27	50.33	2.89	0.70	1.79
T_{10}	3.05	51.78	54.01	3.41	0.79	2.01
SEm(±)	**0.17**	**0.62**	**0.39**	**0.40**	**0.033**	**0.108**
LSD(0.05)	**0.51**	**1.8**	**1.15**	**NS**	**0.091**	**0.308**

Table 4 : Effect of treatments on nutrient uptake by seed and stover (pooled over two years)

Treatments	Seed uptake (kg ha^{-1})			Stover uptake (kg ha^{-1})		
	N	P	K	N	P	K
T_1	28.13	9.05	7.13	40.08	6.57	42.33
T_2	28.67	9.33	7.25	41.75	6.90	43.09
T_3	29.97	9.67	7.97	44.33	7.50	45.67
T_4	31.55	9.99	8.33	46.98	8.95	47.93
T_5	27.96	9.01	7.05	40.05	6.45	41.95
T_6	28.29	9.27	7.18	40.99	6.93	42.23
T_7	30.11	9.55	7.60	45.13	7.33	44.99
T_8	30.62	9.72	7.89	46.72	8.86	47.57
T_9	27.00	8.96	7.02	39.20	5.58	39.99
T_{10}	26.85	8.67	7.00	38.99	5.55	39.81
SEm(±)	**0.89**	**0.22**	**0.17**	**1.51**	**0.35**	**1.33**
LSD(0.05)	**2.68**	**0.65**	**0.50**	**4.50**	**1.18**	**4.05**

[*T_1: 2.5% Kappaphycus- sap + 75% RDF; T_2: 5% Kappaphycus- sap + 75% RDF; T_3: 10% Kappaphycus- sap + 75% RDF; T_4: 15% Kappaphycus- sap + 75% RDF; T_5: 2.5% Gracilaria - sap + 75% RDF; T_6: 5% Gracilaria - sap + 75% RDF; T_7: 10% Gracilaria - sap + 75% RDF; T_8: 15% Gracilaria - sap + 75% RDF; T_9: 75% RDF + Water spray; T_{10}: 100% RDF*]

augmentation due to the application of these extracts escalates the net monetary return and ultimately the benefit: cost ratio over conventional method of cultivation.

Being a wealthy source of versatile plant nutrients especially potassium (K), Phosphorous (P), Calcium (Ca), Iron (Fe), Manganese (Mg) etc; phytohormones especially cytokinin, auxin and gibberellins; amino acids; vitamins; stimulatory and antibiotic substances (Table 1) the liquid seaweed extract enhances root volume and proliferation, bio-mass accumulation, plant growth, flowering, distribution of photosynthates from vegetative parts to the developing fruits and promotes fruit development, reduces chlorophyll degradation, disease occurrence etc resulting in improved nutrient uptake, water and nutrient use efficiency causing sound general plant growth and vigor ultimately reflecting higher yield and superior quality of agricultural products. These findings are in agreement with Jeannin *et al*., 1991, Mancuso *et al*., 2006 and Pramanick *et al*., 2013.

Thus it can be concluded that the seaweed extracts are effective in increasing the growth parameters, yield attributes, yield of sesame. The saps also enhance nutrient uptake by this oilseed crop. Presence of microelements and plant growth regulators,

Table 5: Effect of the treatments on gross return, net return and B: C ratio

Treatment	Cost of cultivation (₹)	Gross return (₹)	Net return (₹)	B: C ratio
T_1	24685	45050	20365	1.82
T_2	25510	47980	22470	1.88
T_3	27160	52620	25460	1.94
T_4	28810	57460	28650	1.99
T_5	24685	43910	19225	1.78
T_6	25510	47390	21880	1.86
T_7	27160	51400	24240	1.89
T_8	28810	55650	26840	1.93
T_9	23860	42080	18220	1.76
T_{10}	24950	47470	22520	1.90

[*T_1: 2.5% Kappaphycus- sap + 75% RDF; T_2: 5% Kappaphycus- sap + 75% RDF; T_3: 10% Kappaphycus- sap + 75% RDF; T_4: 15% Kappaphycus- sap + 75% RDF; T_5: 2.5% Gracilaria - sap + 75% RDF; T_6: 5% Gracilaria - sap + 75% RDF; T_7: 10% Gracilaria - sap + 75% RDF; T_8: 15% Gracilaria - sap + 75% RDF; T_9: 75% RDF + Water spray; T_{10}: 100% RDF*]

especially cytokinins in *Kappaphycus* and *Gracilaria* extracts is responsible for the increased yield and improved nutrition of sesame receiving foliar application of the aforesaid two saps.

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