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Original Research Article

Studies on Efficacy of Seaweed Extract and Fertility Levels on Growth, Yield and Economics of Rice

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Keywords

Fertilizer, *Gracilaria edulis*, Growth, *Kappaphycus alvarezii*, Rice, Seaweed sap

A B S T R A C T

A field experiment was conducted during rainy (*kharif*) season of 2012 and 2013 at Research Farm of Birsa Agricultural University, Ranchi, Jharkhand, India to study the efficacy of seaweed extract and fertility levels on growth, yield and economics of rice. Treatment comprized of two fertilizer levels *viz.*, 100 and 50% recommended fertilizer in main plot, two seaweed sap source *viz.*, *Kappaphycus alvarezii* (K-sap) and *Gracilaria edulis* (G-sap) in sub plot and 6 sap concentration *viz.*, 0 (water), 2.5, 5.0, 7.5, 10.0 and 15.0% in sub-sub plot laid out in a split-split plot design and replicated thrice. The morpho-physiological analysis of growth and yield of rice revealed that rice fertilized with 100% recommended dose of fertilizer manifested significantly higher plant height, total tillers m^{-2}, leaf area index, dry matter accumulation, crop growth rate, relative growth rate, net assimilation rate, productive tillers m^{-2}, grains/panicle resulting in significantly higher grain and straw yield, net return and benefit: cost ratio as compared to 50% recommended dose of fertilizer. Among seaweed sap, *Kappaphycus alvarezii* (K-sap) exhibited significantly higher growth and yield attributes viz. plant height, total tillers m^{-2}, leaf area index, dry matter accumulation, crop growth rate, relative growth rate, net assimilation rate which ultimately led to higher grain and straw yield, net return and benefit: cost ratio than *Gracilaria edulis* (G-Sap). Irrespective of sap, spraying of 10% sap concentration produced significantly taller plant, higher total tillers m^{-2}, leaf area index, dry matter accumulation, crop growth rate, relative growth rate, net assimilation rate resulting in higher grain and straw yield, net return and benefit: cost ratio as compared to lower sap concentration.

Introduction

In the last decades, environmental pollution, chemical treatment and upgrading food using additive substances create a new dimension to the problem of rational nutrition, with direct implication of human health. It has become vital and necessary to promote organic farming techniques. Use of seaweed extract in organic farming techniques is one of the safest ways to conserve environmental resources and avoid pollution to obtain quality food and agricultural crops (Devi and Mani, 2015). Seaweed, a natural source of nutrients is of great importance to substitute the chemical fertilizers. Seaweeds are the macroscopic marine algae found at the bottom of relatively shallow coastal waters. They grow in the intertidal, shallow and deep sea areas up to 180 meter depth and also in estuaries and backwaters on the rocks, dead corals and pebbles. Seaweeds have been used as green manure, cattle feed, food for human consumption and as a source of phycocolloids such as sugar, alginic acid and carrageenan. The liquid extracts obtained from seaweeds popularly known as SLF/LSF have gained importance in recent years as foliar sprays for several crops because the extract contains not only nitrogen, phosphorus and potash but also contain ample amount of trace elements like Zn, Mn, Mg, Fe etc., metabolites, growth promoting hormones i.e. auxins (IAA, IBA), cytokinins, vitamins and amino acids. These seaweed extract application have been found beneficial to crop plants as it increased the crop yield, delay of fruit senescence, improved overall plant vigour, quality and to withstand adverse environmental conditions (Featonby and Van Staden, 1983). In addition, the carbohydrates and other organic matter present in seaweeds alter the nature of soil and improve its moisture retaining capacity. So, utilization of seaweeds extract will be useful for achieving higher agricultural production. Keeping all these points in view, the present investigation was planned to study the effect of fertility levels and seaweed sap source applied at varied concentration level on rice in order to identify suitable nutrient management practices for sustainable rice production in chotanagpur plateau region of Jharkhand.

Materials and Methods

The field experiment was conducted during *kharif* season of 2012 and 2013 at Birsa Agricultural University, Ranchi, Jharkhand. The soil was sandy loam in texture, with pH 5.7 having organic carbon 0.45%, available nitrogen 255.9 kg ha^{-1}, phosphorus 14.0 kg ha^{-1} and potassium 169.4 kg ha^{-1}. The climate of the region is subtropical with hot and dry summer, comparatively cool rainy season followed by moderate winter. Treatment consisted of two fertilizer levels *viz.*, 100 and 50% recommended fertilizer in main plot, two seaweed sap source *viz.*, *Kappaphycus alvarezii* (K-sap) and *Gracilaria edulis* (G-sap) in sub plot and 6 sap concentration *viz.*, 0 (water), 2.5, 5.0, 7.5, 10.0 and 15.0% in sub-sub plot laid out in a split-split plot design and replicated thrice. The recommended dose of fertilizer was 120 kg N + 26.2 kg P + 33.2 kg K ha^{-1}. Half nitrogen and full dose of phosphorus, potash was applied as basal at the time of transplanting and remaining half nitrogen top dressed at panicle initiation stage of the crop, The extract of *Kappaphycus alvarezii* (K-sap) and *Gracilaria edulis* (G-sap) were obtained from Central Salt and Marine Chemicals Research Institute (CSMCRI), Bhavnagar, Gujarat, India. Three sprays of K-sap and G-sap were applied each at the tillering stage, panicle initiation and boot stage. For proper adherence, extracts were mixed with surfactant (Mazik drop) at the time of spraying. Twenty two days old seedling of rice variety 'Naveen' was transplanted at a spacing 20 cm x 10 cm during first fortnight of July in both the years of experimentation. Plants sampling was done at 30, 60, 90 days after transplanting and at harvest to record the growth parameters such as plant height, total tiller m^{-2}, leaf area index, dry matter accumulation m^{-2}, crop growth rate, relative growth rate and net assimilation rate while the yield attributes, grain yield and straw yield were recorded at harvest. The crop growth rate, relative growth rate and net assimilation rate were calculated by using the formula given by Radford (1967).

$$\text{Crop growth rate (g day}^{-1}\text{)} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{G}$$

$$\text{Relative growth rate (g g}^{-1}\text{day}^{-1}\text{)} = \frac{\log_e W_2 - \log_e W_1}{(t_2 - t_1)}$$

Net assimilation rate (mg $cm^{-2}day^{-1}$)

$$= \frac{(W_1 - W_2)(\log A_2 - \log A_1)}{(t_2 - t_1)(A_2 - A_1)}$$

Where, W_1 and W_2 represent the dry weights of the plant at the beginning and end of the time interval t_1 and t_2 respectively and A_1 and A_2 represent the leaf area at the beginning and end of the time interval t_1 and t_2 respectively. The G represents the ground area. The data were subjected to statistical analysis as prescribed by Gomez and Gomez (1984) and significant effects were presented. The economics were computed on the basis of prevailing market rates of produce and agro-inputs. The net return was calculated by subtracting total cost of cultivation from gross return. The benefit: cost ratio was calculated by dividing the net return by the cost of cultivation.

Results and Discussion

Plant height

Rice plant height gradually increased as the growth progressed. This was mainly due to increase in the length of leaves and size of panicle till harvest. The nutrient level, sap source and its concentration failed to cause significant effect on plant height at 30 days after transplanting (Table 2). Higher fertility level significantly augmented plant height at 60, 90 days after transplanting and at harvest and maximum plant height was observed with 100% recommended dose of fertilizer due to improved N, P, K supplying capacity of soil at higher fertility level (Singh *et al.*, 2011). Rice crop sprayed with K-sap recorded significantly higher plant height than G-sap throughout the crop period except at 30 days after transplanting owing to comparatively better concentration of growth hormones. Increasing spray concentration gradually increased the plant height and maximum plant height was recorded with 10% sap concentration at all the growth stages. The 10% sap concentration recorded significantly taller plant than 5% and 2.5% sap concentration as well as control but failed to cause significant variation with 7.5% and 15% sap concentration at 60 days after transplanting. However, at 90 days after transplanting and at harvest, application of 10% sap concentration manifested significantly higher plant height over 2.5% sap concentration and control but statistically at par with other sap concentration.

Total tillers

Total tillers m^{-2} of transplanted rice increased with crop age reaching its peak at 60 days after transplanting and then declined afterwards till harvest (Table 2). Total tillers m^{-2} was significantly affected by fertilizer levels. The reduction in tillers after 60 DAT was due to intra species competition for higher space and nutrients which are responsible for degeneration of late formed tillers. Irrespective of growth stages, fertility levels manifested marked variation in the number of tillers m^{-2} and were significantly higher under high fertility level (120 kg N + 26.2 kg P + 33.2 kg K ha^{-1}). Tillering ability is genetically controlled which is closely associated with the nutritional condition of the mother culm and improved nutrient supply at higher fertility level might have enhanced the tiller production. Significant enhancement in total tillers m^{-2} of rice was recorded with application of with K-sap over G-sap at 60, 90 DAT and at harvest which might be due to higher concentration of Zeatin and betaine in K-sap in comparasion of G-sap. The total tiller production m^{-2} increased with each increment in sap concentration upto 10 % sap concentration which was significantly superior over other concentration at all the growth stages except at 30 days after transplanting. Beneficial effect on tiller production might be due presence of microelements and growth regulator present in the sap (Zodape *et al.*, 2010).

Leaf area index

The leaf area index increased successively as the growth progressed up to 90 days after transplanting and thereafter it declined till harvest due to drying of leaves (Table 2). The leaf area index was significantly higher in 100% recommended dose of fertilizer as compared to 50% recommended fertilizer at all the crop growth stages. As such, higher fertility level increased the supplying capacity of the soil which in turn resulted in a better leaf growth rate eventually leading to higher leaf area index. The increase in leaf area index with higher fertility level is in agreement with the findings of Singh *et al.*, (2011). Crop sprayed with K-sap had significantly higher leaf area index than G-sap at all the growth stages except at 30 days after transplanting. The higher tiller number obtained with K-sap might be responsible for higher leaf area index. Leaf area index of rice progressively increased with increasing sap concentration upto 10% which was significantly higher than 2.5% sap concentration and control at 60 and 90 days after transplanting. Increase in sap concentration beyond 10 % led to reduction in leaf area index.

Dry matter accumulation

The dry matter accumulation/m2 increased as the growth progressed and the maximum value was observed at harvest (Table 2). The dry matter production is the sum total effect of overall growth. Application of 100% RDF increased plant height, tillers m^{-2} and leaf area index indicating higher photosynthetic efficiency which in turn resulted in higher dry matter accumulation m^{-2} than 50% RDF application at all the growth stages. This was in conformity with the finding of Singh *et al.*, (2015a). Rice crop sprayed with K-sap produced higher dry matter than G-sap at all the growth stages except at 30 days after transplanting due to better vegetative growth of rice with K-sap. Dry matter accumulation increased with increasing sap concentration upto 10% which was significantly higher over its lower levels at all the growth stages except at 30 days after transplanting and decline with further increase in sap concentration. Further increase in sap concentration led to reduction in dry matter at all the growth stages. Increase in dry matter accumulation may be due to the presence of plant growth regulator (indole$_3$ acetic acid, gibberellins GA_3, Kinetin and zeatin) present in the sap (Zodape *et al.*, 2010).

Crop growth rate

Crop growth rate increased with crop age and reached to its peak during 60-90 days after transplanting (DAT) and thereafter declined till harvest (Table 3). Rice crop fertilized with 100% recommended dose of fertilizer produced significantly higher crop growth rate than 50% recommended fertilizer at all growth stages. The adequate supply of resources at high fertility level contributed towards higher dry matter accumulation and better partitioning of photosynthate resulting in higher crop growth rate. Among the sap, application of K-sap produced significantly higher crop growth rate than G-sap as a result of better vegetative growth at all the growth stages. Crop growth rate of rice increased progressively with increasing sap concentration upto 10%. Further increase in sap concentration led to reduction in crop growth rate throughout the crop growth period.

Table.2 Growth attributes of rice as influenced by fertilizer level, sap and its concentration at different growth stages (Pooled data of 2 years)

Treatment	Plant height (cm)				Leaf Area Index			Total tiller m^{-2}				Dry matter production (g m^{-2})			
	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest
Fertilizer level															
100 % RDF	35.5	77.8	92.0	97.5	1.26	3.63	3.85	160.5	324.3	289.5	265.9	173.99	422.79	810.01	982.08
50 % RDF	32.4	71.9	87.2	92.4	1.16	3.46	3.57	143.3	307.6	274.5	245.3	163.29	387.42	738.43	886.94
SEm±	0.5	0.9	0.5	0.4	0.01	0.02	0.04	2.0	2.6	1.3	1.7	1.42	3.49	8.32	9.04
CD (P=0.05)	N.S	5.5	2.9	2.2	0.06	0.12	0.25	12.2	15.7	8.2	10.0	8.66	21.21	50.61	55.03
Sap source															
K-sap	34.3	76.2	90.9	96.4	1.23	3.62	3.78	151.9	322.3	284.2	257.8	169.97	420.72	808.66	978.49
G-sap	33.7	73.5	88.3	93.6	1.20	3.47	3.64	151.9	309.5	279.9	253.4	167.31	389.49	739.78	890.54
SEm±	0.4	0.5	0.6	0.5	0.01	0.03	0.03	1.4	4.7	3.6	2.7	0.86	4.24	7.93	8.03
CD (P=0.05)	N.S	1.9	2.2	1.8	N.S	0.13	0.11	N.S	N.S	N.S	N.S	N.S	16.66	31.13	31.53
Sap concentration (%)															
Water spray	32.0	65.1	81.2	88.4	1.16	3.40	3.53	147.0	287.0	257.7	231.0	163.15	371.69	702.38	840.22
2.5	33.3	72.5	86.4	92.3	1.18	3.47	3.62	148.6	295.5	265.4	239.8	165.88	390.78	741.89	891.46
5.0	34.0	75.0	89.8	95.5	1.21	3.53	3.68	151.6	312.2	278.7	251.9	168.36	403.97	775.67	935.14
7.5	34.5	77.7	92.8	96.8	1.23	3.59	3.78	154.0	324.3	291.4	268.7	170.22	412.74	790.55	956.75
10.0	35.5	80.6	94.6	99.5	1.26	3.65	3.85	156.6	347.2	307.5	282.7	174.55	433.17	835.42	1016.95
15.0	34.6	78.0	93.0	97.4	1.23	3.62	3.82	153.5	329.5	291.4	259.4	169.68	418.28	799.42	966.55
SEm±	0.9	1.8	1.8	2.0	0.02	0.06	0.06	3.2	5.9	5.6	5.7	3.20	7.15	14.91	17.23
CD (P=0.05)	N.S	5.1	5.1	5.7	N.S	0.16	0.18	N.S	16.8	16.0	16.2	N.S	20.43	42.62	49.25

Table.3 Growth analysis parameters of rice as influenced by fertilizer level, sap and its concentration at different growth stages (Pooled data of 2 years)

Treatment	Crop growth rate ($g\ m^{-1} day^{-1}$)			Relative growth rate ($g\ g^{-1} day^{-1}$)			Nat assimilation rate ($g\ m^{-2} day^{-1}$)	
	30-60 DAT	60 -90 DAT	90 DAT-at harvest	30-60 DAT	60 -90 DAT	90 DAT-at harvest	30-60 DAT	60 -90 DAT
Fertilizer level								
100 % RDF	8.29	12.91	5.74	12.85	9.39	2.79	3.70	3.45
50 % RDF	7.47	11.70	4.95	12.44	9.36	2.65	3.55	3.34
SEm±	0.06	0.19	0.04	0.08	0.08	0.02	0.05	0.07
CD (P=0.05)	0.36	1.18	0.23	N.S	N.S	0.14	N.S	N.S
Sap source								
K-sap	8.36	12.93	5.66	13.12	9.44	2.76	3.79	3.50
G-sap	7.41	11.68	5.03	12.17	9.31	2.68	3.46	3.29
SEm±	0.13	0.17	0.05	0.15	0.09	0.04	0.06	0.05
CD (P=0.05)	0.53	0.68	0.22	0.59	N.S	N.S	0.25	0.19
Sap concentration (%)								
Water spray	6.95	11.02	4.59	11.90	9.21	2.60	3.33	3.19
2.5	7.50	11.70	4.99	12.35	9.29	2.67	3.53	3.30
5.0	7.85	12.39	5.32	12.67	9.42	2.71	3.63	3.44
7.5	8.08	12.59	5.54	12.76	9.44	2.76	3.66	3.43
10.0	8.62	13.41	6.05	13.15	9.50	2.83	3.84	3.58
15.0	8.29	12.70	5.57	13.04	9.38	2.75	3.75	3.42
SEm±	0.22	0.42	0.11	0.29	0.26	0.05	0.10	0.13
CD (P=0.05)	0.62	1.19	0.32	0.83	N.S	0.13	0.30	N.S

Table.4 Yield attributes, yield and economics of rice influenced by fertilizer level, sap and its concentration (pooled data of 2 years)

Treatment	Yield attributes			Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Economics	
	Productive tillers m^{-2}	Grains $panicle^{-1}$	1000 grain weight				Net return ($\times 10^3$ `ha^{-1})	Benefit : cost ratio
Fertilizer level								
100% RDF	252.2	65.2	23.5	3.1	4.2	42.21	22.5	0.89
50% RDF	225.9	61.9	22.9	2.6	3.6	41.80	18.1	0.82
SEm±	2.5	0.4	0.1	0.1	0.1	0.73	0.5	0.02
CD (P=0.05)	15.1	2.5	NS	0.3	0.3	N.S	3.1	N.S
Sap source								
K-sap	240.2	65.9	23.3	3.0	4.1	41.92	22.8	0.96
G-sap	238.0	61.2	23.1	2.7	3.7	42.09	17.8	0.75
SEm±	2.5	0.5	0.1	0.1	0.1	0.56	0.7	0.03
CD (P=0.05)	NS	2.2	NS	0.2	0.3	N.S	2.7	0.11
Spray concentration (%)								
Water	206.3	51.5	22.3	2.0	2.9	40.21	9.6	0.45
2.5	220.1	58.7	22.8	2.4	3.4	41.33	14.8	0.68
5.0	237.4	65.0	23.2	2.8	3.9	42.10	20.4	0.89
7.5	256.1	67.9	23.4	3.2	4.3	42.68	24.7	1.05
10.0	269.2	68.8	24.0	3.5	4.6	43.15	28.6	1.17
15.0	245.3	69.5	23.5	3.3	4.4	42.56	23.6	0.89
SEm±	4.3	1.0	0.2	0.1	0.1	0.88	0.9	0.04
CD (P=0.05)	12.4	2.8	0.6	0.2	0.3	N.S	2.5	0.11

Table.1 Chemical properties of Seaweed sap

Nutrients	Amount present (in ppm)	
	Kappaphycus alvarezii	*Gracilaria edulis*
IAA	26.52	8.67
Zeatin	19.65	3.13
GA_3	23.65	ND
Choline	7.30	35.75
Glycine Betaine	79.33	62.96
Sodium	198.0	195.2
Potassium	336.54	682.1
Magnesium	111.2	311.0
Iron	86.1	12.67
Manganese	2.1	32.9
Nickel	3.45	0.212
Copper	0.65	0.044
Zinc	4.7	0.628
Lead	17.45	ND
Chromium	32.0	0.004
Calcium	321.0	352.0

ND: Not Determined
Data as given by CSMCRI, Bhavnagar, Gujarat, India

This might be due to better vegetative growth at higher sap concentration reflecting an improvement in crop growth rate.

Relative growth rate

Relative growth rate (RGR) showed the declining trend from the start till maturity of the crop (Table 3). The maximum relative growth rate was associated with 100% recommended fertilizer which was significantly superior than 50% recommended dose of fertilizer at 90 DAT to at harvest. However, at other stages the variation in relative growth rate due to fertility level was found to be non-significant. Among seaweed sap, K-sap manifested significantly higher crop relative growth rate than G sap between 30 to 60 DAT due to better crop growth condition with K-sap source. At later stages, the sap source failed to cause significant differences in relative growth rate. The relative growth rate increased with increase in sap concentration upto 10% which was significantly higher than 2.5% sap concentration and control between 30-60 DAT and 90 DAT-at harvest. However, sap concentration failed to cause significant effect on relative growth rate at 60-90 DAT.

Net assimilation rate

The fertility level failed to cause significant variation in net assimilation rate of rice (Table 3). However, crop receiving 100% recommended dose of fertilizer recorded maximum net assimilation rate than 50% recommended dose of fertilizer. Application of K-sap resulted in the significantly higher net assimilation rate than G-sap at 30-60 DAT and 60-90 DAT. Net assimilation rate of rice increased with increasing sap concentration upto 10% which was significantly superior over 2.5% sap concentration and control at 30-60 DAT. Further increase in sap concentration led to reduction in net assimilation rate at all growth stages. Although, the increase/decrease was not marked at 60-90 days after transplanting.

Yield attributes

Significantly higher productive tillers m^{-2} and number of grains $panicle^{-1}$ of rice was recorded when crop was fertilized with 100% recommended dose of fertilizer (RDF) than 50% RDF (Table 2). Increase in yield attributes might be owing to availability of more nutrients to the crop under 100 % than 50 % RDF. These results confirm the findings of Gunri *et al.*, (2004). The fertilizer levels were unable to cause significant variation in 1000 grain weight. Rice sprayed with K-sap produced higher grains $panicle^{-1}$ than G-sap owing to comparatively better concentration of growth hormones. The sap source fails to exert significant influence on productive tillers and 1000 grain weight. Significant improvement in number of grains $panicle^{-1}$ was recorded upto 7.5% sap concentration while, the productive tillers and 1000-grain weight significantly improved up to 10% and there after it decreased (Table 2) might be owing to salt index of the seaweed sap at higher concentration, as reported by Beckett and Van Staden (1990).

Grain and straw yield

Rice receiving 100% RDF produced significantly higher grain and straw yield than 50% RDF (Table 4). Reduction of 50% fertilizer to rice crop reduced the grain and straw yield by 15.9 and 14.6%, respectively in comparison to 100% RDF. The higher value of grain yield of rice at higher fertility level may be due to greater availability of nutrient in soil, improvement of soil environment resulting in higher root proliferation leading to better absorption of moisture and nutrient and ultimately resulting in higher grain yield (Kumari *et. al*, 2013). Application of K-sap produced maximum and significantly higher grain and straw yield of rice than G-sap. The better yield and growth attributes with K-sap will led to higher grain and straw yield of rice with K-sap. This was in conformity with the finding of Singh *et al.*, (2015b). Application of K-sap produced 12.0 and 12.2% higher grain and straw yield, respectively as compared to G-sap. Grain and straw yield of rice significantly increased with each increment in sap concentration upto 10%. Further increase in sap concentration (15%) caused reduction in grain and straw yield by 6.4 and 4.1 percent. These findings are in conformity with the work of Kavitha *et al.*, (2008).

Economics

Rice fertilized with 100% RDF gave significantly higher net return and benefit: cost ratio than 50% RDF (Table 4). Rice crop sprayed with K-sap gave significantly higher net return and benefit: cost ratio than G-sap. Net return and benefit: cost ratio of rice increased with increasing level of sap concentration upto 10%. Further increase in sap concentration i.e. 15% led to significant reduction in net return and benefit: cost ratio. Rice sprayed with 10% sap concentration gave maximum and significantly higher net return and benefit: cost ratio than all other sap concentrations. This confirms the findings of Pramanick *et al.*, (2014).

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