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Research Paper

Effect of fertilizer level and seaweed sap on productivity and profitability of rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) season of 2012 and 2013 at Birsa Agricultural University, Ranchi, Jharkhand, to study the effect of 2 levels of fertilizer level, seaweed sap and its concentration on the productivity and profitability of rice (*Oryza sativa* L.). Treatments consisted of 2-fertilizer levels, viz. 100 and 50% recommended fertilizer in main plot, 2 sap source, viz. *Kappaphycus alvarezii* and *Gracilaria edulis* in subplot and 6 sap concentration spray, viz. 0 (water), 2.5, 5.0, 7.5, 10.0 and 15% in sub-subplot, laid out in a split-split-plot design and replicated thrice. Rice fertilized with 100% recommended fertilizer (120 kg N + 26.2 kg P + 33.2 kg K/ha) produced higher productive tillers (252.2/m^2), grains/panicle (65.2), panicle length (21.2 cm) resulting in higher grain (3.1 t/ha) and straw (4.2 t/ha) yield, net returns (22.5 × 10^3₹/ha), benefit: cost ratio (0.89) and nitrogen, phosphorus, potassium and sulphur uptake in grain and straw than 50% recommended fertilizer.

Key words : Fertilizer, Nutrient uptake, Productivity, Profitability, Rice, Seaweed sap

Crop sprayed with *Kappaphycus alvarezii* had produced more grains/panicle (65.9) and longer panicles (20.7 cm), resulting in higher grain yield (3.0 t/ha), net returns (22.8 × 10^3₹/ha), benefit: cost ratio (0.96) and NPKS uptake by grain and straw than *Gracilaria edulis*. Spraying of 10% sap concentration resulted in significantly more productive tillers (269.2/m^2), panicle length (21.9 cm), 1,000-grain weight (24.0 g) resulting in higher grain yield (3.5 t/ha), net returns (28.6 × 10^3₹/ha), benefit: cost ratio (1.17) and nutrient uptake of NPKS by grain and straw as compared to lower concentration. The interaction effect between fertilizer and seaweed sap also showed that rice receiving 100% recommended fertilizer and sprayed with 10% *Kappaphycus alvarezii* was more productive and remunerative as it gave more productive tillers (288.4), grain yield (4.2 t/ha), straw yield (5.4 t/ha), net returns (37.1 × 10^3₹/ha) and benefit: cost ratio (1.42) than the remaining combinations of fertilizer level, sap and its concentration. Further, crop fertilized with 50% recommended fertilizer and sprayed 2.5% concentration of either *Kappaphycus alvarezii* or *Gracilaria edulis* was as productive and remunerative as that of 100% recommended fertilizer alone. Hence application of 2.5% either *Kappaphycus alvarezii* or *Gracilaria edulis* sap can curtail the 50% fertilizer requirement of the crop.

Rice is the important staple food crops, providing 43% of calorie requirements for more than 70% of India's population. The productivity of rice in India is low (2.46 t/ha) as compared to the world average, 4 t/ha (DES, New Delhi 2013). Supply of nutrients at critical growth stages enhance the plant growth and yield. It is a common practice to use chemical fertilizers in large quantities to compensate the deficiency of nutrients in soil. The abundant use of chemical fertilizers adversely affects soil health. Seaweed, a natural source of nutrients, is of great importance to substitute the chemical fertilizers. Seaweeds are the macroscopic marine algae, found to the bottom of relatively shallow coastal waters. They grow in the intertidal, shallow and deep sea areas up to 180 m depth and also in estuaries and backwaters on the solid substrate such as 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

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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 improve ability 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 of soil. So, utilization of seaweeds and their extract will be useful for achieving higher agricultural production. Kavitha *et al.* (2008) and Pramanick *et al.* (2014) reported significant increase in yield of crops with foliar application of seaweed extracts. Hence this study was conducted to evaluate the application of different concentrations of seaweed extract in enhancing the productivity and profitability of rice.

MATERIALS AND METHODS

The field experiment was conducted during the rainy (*kharif)* season of 2012 and 2013 at the Birsa Agricultural University, Ranchi (23º17' N, 85º19' E and 625 m above altitude)**.** The soil was sandy loam, with *p*H 5.7 having organic carbon 0.45%, available nitrogen 255.9 kg/ha, phosphorus 14.0 kg/ha and potassium 169.4 kg/ha. The climate of the region is subtropical with hot and dry-summer, comparatively cool rainy season followed by moderate winter. Treatment consisted of 2 fertilizer levels, viz. 100 and 50% recommended fertilizer in main plot, 2 seaweed sap source, viz. *Kappaphycus alvarezii* (K-sap) and *Gracilaria edulis* (G-sap) in subplot and 6 sap concentrations, viz. 0 (water), 2.5, 5.0, 7.5, 10.0 and 15.0% in sub-subplot, 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. Half nitrogen and full dose of phosphorus and potash were applied basal at the time of transplanting and remaining nitrogen was top-dressed at panicle-initiation stage of the crop, The extract of *Kappaphycus alvarezii* (K-sap) and *Gracilaria edulis* (G-sap) were obtained from the Central Salt and Marine Chemicals Research Institute (CSMCRI), Bhavnagar, Gujarat, India along with their constituent composition (Table 1). 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 'Naveen' rice was transplanted at a spacing 20 cm × 10 cm during the first fortnight of July in both the years of experimentation. The rice crop received rainfall of 967.3 mm and 1,053.1 mm during 2012 and 2013, respectively, from June to October. However, irrigation was given as and when required, depending on intensity of rains to keep the soil in saturated condition throughout the crop-growth period. The rice crop was harvested at physiological maturity from the net plot area of 8 m × 1.4 m to record the grain and straw yield as well as yield-attributing characters. The plant samples collected at the time of harvesting were dried at 70ºC, powdered in Willey mill and digested to analyze the various nutrient compositions. Nitrogen, phosphorus, potassium and sulphur contents in plant parts were estimated by Kessler's reagent method (Nicholas and Nason, 1957), HNO_3 : $HClO_4$ (9:4) digestion, colour development by vandomolybdate solution fol-

Table 1. Constituents of *Kappaphycus alvarezii* and *Gracilaria edulis* sap (in ppm)

Kappaphycus alvarezii		*Gracilaria edulis*	
Nutrients	Amount present	Nutrients	Amount present
IAA	26.52	IAA	8.67
Zeatin	19.65	Zeatin	3.13
GA_3	23.65	GA_3	ND
Choline	7.30	Choline	35.75
Glycine Betaine	79.33	Glycine Betaine	62.96
Sodium	198.0	Sodium	1952
Potassium	33654	Potassium	682.1
Magnesium	1112	Magnesium	311.0
Iron	86.1	Iron	12.67
Manganese	2.1	Manganese	32.9
Nickel	3.45	Nickel	0.212
Copper	0.65	Copper	0.044
Zinc	4.7	Zinc	0.628
Lead	17.45	Lead	ND
Chromium	32.0	Chromium	0.004

lowed by spectrophotometer determination (Jackson, 1973), flame photometric determination after digestion in HNO_3 : $HClO_4$ (9:4) (Jackson, 1973) and turbidimetric method (Chesnin and Yien, 1951) respectively. The nutrient uptake was estimated by multiplying the nutrient concentration with the grain and straw yield. The data were subjected to statistical analysis as per Gomez and Gomez (1984) and significant effects were presented and discussed in this paper. Economics was computed on the basis of prevailing market rates of produce and agro-inputs. The benefit: cost ratio was calculated by dividing the net returns by the cost of cultivation.

RESULTS AND DISCUSSION

Yield attributes

Significantly higher productive tillers/m^2, grains/panicle and longer panicle length 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). Rice sprayed with K-sap produced higher grains/panicle and longer panicle than G-sap owing to comparatively better concentration of growth hormones. Increasing spray concentration gradually increased the productive tillers, panicle length and 1,000-grain weight 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).

The interactional effect showed that maximum productive tillers of rice was recorded when crop received 100% RDF and sprayed with 10% concentration of K-sap, which was significantly higher than (Table 3) rest of the combinations of fertilizer level, seaweed saps and spray concentration except 100% RDF with 10% G-sap and 50% RDF with 10% K-sap or G-sap, 100% RDF with 7.5% K-sap. Irrespective of fertilizer level, increasing concentration of K-sap and G-sap gradually increased the productive tillers of rice up to 10% concentration and thereafter it declined. However, crop fertilized with 50% RDF showed increasing trend in productive tillers up to 15% K-sap. Application of 10% K-sap along with 100% RDF produced 29.1% more productive tiller than 100% RDF alone in pooled data.

Yield

Rice receiving 100% RDF gave significantly higher grain and straw yield than 50% RDF (Table 2). 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 owing 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

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

Treatment	Productive tillers/m^2	Grains/ panicle	Panicle length (cm)	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Net returns (× 10^3 ₹/ha)	Benefit : cost ratio
Fertilizer level								
100% RDF	252.2	65.2	21.2	23.5	3.1	4.2	22.5	0.89
50% RDF	225.9	61.9	18.2	22.9	2.6	3.6	18.1	0.82
SEm±	2.5	0.4	0.1	0.1	0.1	0.1	0.5	0.02
CD (P=0.05)	15.1	2.5	0.8	N.S	0.3	0.3	3.1	N.S
Sap source								
K-sap	240.2	65.9	20.7	23.3	3.0	4.1	22.8	0.96
G-sap	238.0	61.2	18.7	23.1	2.7	3.7	17.8	0.75
SEm±	2.5	0.5	0.3	0.1	0.1	0.1	0.7	0.03
CD (P=0.05)	N.S	2.2	1.0	N.S	0.2	0.3	2.7	0.11
Spray concentration (%)								
Water	206.3	51.5	17.1	22.3	2.0	2.9	9.6	0.45
2.5	220.1	58.7	18.3	22.8	2.4	3.4	14.8	0.68
5.0	237.4	65.0	19.7	23.2	2.8	3.9	20.4	0.89
7.5	256.1	67.9	20.5	23.4	3.2	4.3	24.7	1.05
10.0	269.2	68.8	21.9	24.0	3.5	4.6	28.6	1.17
15.0	245.3	69.5	20.6	23.5	3.3	4.4	23.6	0.89
SEm±	4.3	1.0	0.4	0.2	0.1	0.1	0.9	0.04
CD (P=0.05)	12.4	2.8	1.2	0.6	0.2	0.3	2.5	0.11

RDF, Recommended dose of fertilizer

grain yield (Kumari *et al.,* 2013). Application of K-sap resulted in the maximum and significantly higher grain and straw yield of rice than G-sap. Application of K-sap showed 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 up to 10%. Further increase in sap concentration (15%) caused reduction in grain and straw yield by 6.4 and 4.1%. These findings are in conformity with the work of Kavitha *et al.* (2008) and Pramanick *et al.* (2014).

The interactional effect between fertilizer level and seaweed saps revealed that maximum grain and straw yield of rice was recorded from the crop raised with 100% RDF and sprayed with 10% concentrations of K-sap, which was significantly superior to rest of the combinations of fertilizer level, seaweed sap and its concentration except 100% RDF with 7.5% K-sap (Table 3). Irrespective of the fertilizer level, increasing concentration of K-sap gradually increased the grain and straw yield of rice up to 10% concentration and thereafter it declined, whereas, with G-sap it increased up to 15% concentration. It was observed that, crop receiving 50% RDF along with spraying of either 2.5% K-sap or G-sap gave as high rice grain and straw yield with that of crop receiving only 100% RDF indicating that spraying of only 2.5% concentration of either K-sap or G-sap is sufficient enough to compensate the yield loss caused due to 50% reduction in fertilizer level. Application of 10% K-sap with 100% RDF resulted in 83% and 59% more grain and straw yield than 100% RDF alone, whereas application of 15% G-sap with 100% RDF showed 63% and 42% more grain and straw yield of rice, respectively, than application of 100% RDF alone.

Table 3. Interaction effect on productive tiller, grain yield, straw yield, net returns and benefit: cost ratio of rice as influenced by fertilizer level and seaweed sap (pooled data of 2 years)

Fertilizer and sap	Productive tillers/m^2						
	Spray concentration (%)						Mean
	0 (Water)	2.5	5.0	7.5	10.0	15.0	
100% RDF + K-sap	222.6	216.1	270.5	277.6	288.4	256.2	255.2
100% RDF + G-sap	224.8	249.0	240.8	260.3	277.1	243.4	249.2
50% RDF + K-sap	185.1	220.0	215.4	235.7	245.3	249.0	225.1
50% RDF + G-sap	192.7	195.3	222.9	251.0	266.2	232.4	226.8
Mean	206.3	220.1	237.4	256.1	269.2	245.3	
SEm±				8.7			
CD (P=0.05)				24.9			

	Grain yield (t/ha)							Straw yield (t/ha)						
	Spray concentration (%)						Mean	Spray concentration (%)						Mean
	Water	2.5	5.0	7.5	10.0	15.0		Water	2.5	5.0	7.5	10.0	15.0	
100% RDF + K-sap	2.3	2.5	3.5	3.9	4.2	3.6	3.3	3.4	3.6	4.8	5.1	5.4	4.8	4.5
100% RDF + G-sap	2.2	2.6	2.8	2.9	3.2	3.6	2.9	3.3	3.7	3.8	3.9	4.3	4.7	3.9
50% RDF + K-sap	1.6	2.3	2.5	3.4	3.7	2.8	2.7	2.5	3.3	3.6	4.6	4.9	3.9	3.8
50% RDF + G-sap	1.7	2.1	2.5	2.6	3.0	3.3	2.5	2.5	2.9	3.4	3.5	4.0	4.4	3.4
Mean	2.0	2.4	2.8	3.2	3.5	3.3		2.9	3.4	3.9	4.3	4.6	4.5	
SEm±				0.1								0.178		
CD (P=0.05)				0.4								0.514		

	Net returns (× 10^3₹/ha)							Benefit: cost ratio						
	Spray concentration (%)						Mean	Spray concentration (%)						Mean
	Water	2.5	5.0	7.5	10.0	15.0		Water	2.5	5.0	7.5	10.0	15.0	
100% RDF + K-sap	13.3	15.1	29.1	33.8	37.1	26.1	25.8	0.60	0.65	1.21	1.35	1.42	0.93	1.02
100% RDF + G-sap	12.2	17.2	18.4	18.5	22.5	26.2	19.2	0.55	0.74	0.76	0.74	0.86	0.94	0.76
50% RDF + K-sap	6.0	15.4	17.7	29.5	32.6	17.7	19.8	0.31	0.77	0.84	1.33	1.42	0.70	0.89
50% RDF + G-sap	6.9	11.5	16.2	17.2	22.2	24.4	16.4	0.36	0.57	0.77	0.78	0.96	0.98	0.74
Mean	9.6	14.8	20.4	24.7	28.6	23.6		0.45	0.68	0.89	1.05	1.17	0.89	
SEm±				1.8								0.08		
CD (P=0.05)				5.1								0.21		

RDF, Recommended dose of fertilizer

Table 4. Nutrient uptake by rice as influenced by fertilizer level and seaweed sap (pooled data of 2 years)

Treatment	Nutrient uptake (kg/ha)											
	N			P			K			S		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Fertilizer level												
100 % RDF	40.67	40.19	80.86	8.64	9.89	18.53	9.27	56.45	65.71	4.38	6.64	11.02
50 % RDF	30.86	33.15	64.02	6.00	7.24	13.23	7.27	42.96	50.23	3.50	5.46	8.96
SEm±	0.81	0.58	0.50	0.13	0.14	0.16	0.16	1.07	0.97	0.10	0.08	0.18
CD (P=0.05)	4.93	3.51	3.03	0.81	0.84	0.98	0.97	6.52	5.88	0.62	0.51	1.08
Sap source												
K-sap	38.20	38.99	77.18	7.77	9.19	16.97	8.47	50.75	59.22	4.07	6.33	10.40
G-sap	33.33	34.36	67.69	6.87	7.93	14.80	8.06	48.66	56.73	3.81	5.77	9.58
SEm±	0.60	0.53	0.84	0.17	0.20	0.30	0.18	1.13	1.13	0.11	0.11	0.17
CD (P=0.05)	2.36	2.07	3.31	0.65	0.78	1.16	N.S	N.S	N.S	N.S	0.43	0.65
Sap concentration												
Water spray	23.59	26.53	50.12	4.87	6.14	11.02	5.36	32.12	37.48	2.60	4.20	6.80
2.5%	28.97	31.14	60.12	5.94	7.21	13.15	6.64	39.72	46.36	3.17	5.11	8.28
5%	34.85	36.23	71.08	7.22	8.48	15.70	8.09	48.07	56.16	3.84	5.97	9.81
7.5%	40.10	39.95	80.06	8.20	9.39	17.59	9.29	54.95	64.24	4.41	6.66	11.07
10%	44.45	43.63	88.08	9.08	10.25	19.33	10.36	61.64	72.00	4.93	7.26	12.19
15%	42.62	42.55	85.17	8.61	9.89	18.50	9.88	61.73	71.60	4.69	7.10	11.79
SEm±	1.05	1.05	1.52	0.23	0.26	0.35	0.23	1.53	1.54	0.12	0.19	0.22
CD (P=0.05)	3.01	3.01	4.35	0.65	0.73	1.00	0.66	4.36	4.40	0.35	0.53	0.62

Economics

Rice fertilized with 100% RDF gave significantly more net returns and benefit: cost ratio than 50% RDF (Table 2). Rice crop sprayed with K-sap gave significantly higher net returns and benefit: cost ratio than G-sap. Net returns and benefit: cost ratio of rice increased with increasing level of sap concentration up to 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 the maximum and significantly higher net returns and benefit: cost ratio than all other sap concentrations. This confirms the findings of Pramanick *et al.* (2014).

The interaction effect showed that rice receiving 100% RDF and sprayed with 10% K-sap recorded the maximum and significantly higher net returns than rest of the combinations of fertilizer level, seaweed sap (Table 3) and its concentration except 100% RDF with 7.5% K-sap. Rice receiving either 50 or 100% RDF and sprayed with 10% K-sap recorded similar benefit: cost ratio which was significantly higher than all other combinations of fertilizer level, sap and its concentration except crop with either 50% or 100% RDF and sprayed with 7.5% K-sap. Irrespective of the fertilizer level, increasing concentration of K-sap gradually increased the net returns and benefit: cost ratio of rice up to 10% concentration and, thereafter it declined, whereas with G-sap it increased up to 15% concentration. It was observed that, crop receiving 50% RDF along with spraying of either 2.5% K-sap or G-Sap recorded as high net returns and benefit: cost ratio as that of crop receiving only 100% RDF.

Nutrient uptake

Total nitrogen, phosphorus, potassium and sulphur uptake of rice were higher when the crop was raised with 100% recommended fertilizer (Table 4) compared to that raised with 50% recommended fertilizer. Increase in uptake of N, P and K with higher nutrients doses was owing to increased availability of nutrients facilitating better root growth and as such better nutrient uptake (Singh *et al.,* 2011). Crop sprayed with K-sap recorded higher total nitrogen, phosphorus and sulphur uptake than G-sap. Total nitrogen, phosphorus, potassium and sulphur uptake increased with increasing sap concentration upto 10%. Further increase in sap concentration led to reduction in total nitrogen, phosphorus, potassium and sulphur uptake. The increased nutrient uptake with seaweed sap application might be due to presence of biostimulants in seaweed extract that may contain chelating compounds (i.e. mannitol) which increase nutrient availability due to better absorption of the chelated compounds at leaf level (Salat, 2004). Zodape *et al*., (2010) reported that increase in mineral content of Na, P, K, Ca, Mg, Fe and N in green gram with foliar application of 10% sap of *Kappaphycus alvarezii* in comparison to control plots. As a consequence of increased nutrient content, the uptake of these nutrients were

also found higher by grain, straw as well as total biological produce since uptake of a nutrient is a function of concentration of nutrient and yield per hectare.

It was concluded that application of 100% recommended fertilizer along with 10% foliar spray of *Kappaphycus alvarezii* to rice crop is productive and remunerative, as it gave higher yield and economics. Foliar application of 2.5% either of *Kappaphycus alvarezii* or *Gracilaria edulis* sap can curtail the 50% fertilizer requirement of the crop.

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