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Leena Banjare
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Dr. Rakesh Banwasi
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

GK Jataw
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

LK Shrivastav
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Corresponding Author:
Leena Banjare
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Effect of seaweed extract on yield and nutrient uptake of rice in a *vertisol*

Leena Banjare, Dr. Rakesh Banwasi, GK Jataw and LK Shrivastav

Abstract
A study was conducted during kharif 2020 to "Effect of seaweed extract on yield and nutrient uptake of rice in a *Vertisol*" "at the Indira Gandhi Krishi Vishwavidyalaya's Research cum instructional farm in Raipur (C.G.). Experiment included twelve treatments with a control (no fertilizer, no seaweed), two independent applications of 75% and 100% RDF (@120, 60, 40 N, P2O5, and K2O kg ha-1), and nine various combinations of soil application of seaweed extracts as seaweed granules @ 25 kg/ha, foliar spray of seaweed liquid @ 0.25%, with 75% and 100% RDF. In the experiment, seaweed extract products, such as seaweed liquid (Sagarika liquid) and seaweed granules (Sagarika granules) fortified with seaweed extract derived from red and brown algae, were used. The results showed that combining seaweed extracts with 75% RDF (soil application of seaweed granules @ 25 kg/ha, foliar spray of seaweed liquid @ 0.25%) increased grain yields by 4.6–12.1% over the 75% RDF alone application (52.58 q/ha). Application of seaweed extracts with 100% RDF increased the grain yields 1.84-7.59% in comparison with alone application of 100% RDF (58.46 q/ha). The application of 100% RDF + Seaweed granules @ 25 kg ha-1 at 21 DAT + Seaweed liquid @ 0.25% at 42 DAT resulted in the highest 7.59% increase in grain yield, followed by a 6.4% increase with soil application of seaweed granule (25 kg ha-1) at 21 DAT. Application of seaweed extracts (spray of liquid or soil application of granules) with 75% RDF significantly increased the growth and yield attributes and was recorded at par with 100% RDF, which shows the positive effect of seaweed extracts and a saving of 25% RDF through the application of seaweed extracts.

Keywords: Fertilizer, nutrient uptake, productivity, profitability, rice, seaweed sap

Introduction
Rice (*Oryza sativa* L.) is valued for its high nutritive and caloric content. Concerns about increasing rice productivity are more prevalent in scenarios of rising food demand as a result of consistent population growth and agricultural land shrinkage. Yield stagnation, sharp increases in input prices, deterioration of soil health, and environmental footprints are some of the pertinent issues associated with the use of chemical fertilizers, and as a result, there is an urgent need for their partial replacement or complete paradigm shift towards modern biotechnological advances (Biswas *et al.,* 2019) [2]. Seaweed extract is one such promising alternative to chemical fertilizer's that is gaining traction at the moment. Seaweeds are naturally organic and biodegradable. Seaweeds are bio stimulants (macroscopic, multicellular marine algae) that have evolved naturally in coastal ecosystems. Brown (Phaeophyta) seaweeds are the most commonly used in agriculture out of the three major types of seaweed (red, brown, and green) (Blunden and Gordon, 1986) [3]. The use of liquid seaweed fertilizers on some plant species has been shown to reduce nitrogen, phosphorus, and potassium application doses on some crop plants while also stimulating growth and production in many plants. Seaweed extracts are important in sustainable agriculture because they are organic and biodegradable (Cassan *et al.,* 1992) [5]. Seaweed extracts contain phytohormones such as auxins, gibberrelins, cytokinins, and betaines (Crouch and van Staden, 1993) [7], as well as enzymes, vitamins, and hydrolyzed proteins, polysaccharides, nutrients, and trace elements (Fe, Cu, Zn, Co, Mo, Mn, and Ni) (Challen and Hemingway, 1965; Khan *et al.,* 2009) [6].
Seaweeds contain all the trace elements (Devi and Mani 2015; Pal *et al.* 2015) and some essential plant growth hormones (Zhang and Ervin 2008; Lotze and Hoffman 2016). Natural plant growth regulators (e.g., auxin, gibberellin, and cytokinin) present in seaweed extract give a major boost to crop yields by accelerating the plant's metabolic function (Zhang and Ervin 2008; Wang *et al.* 2016). However, such a study has yet to be attempted in Chhattisgarh.

Thus, the present investigation was conducted to study the effect of seaweed extract on the yield and nutrient uptake of rice in a *Vertisol.*

Materials and methods A description of the site

The present investigation, entitled

"Effect of seaweed extract on yield and nutrient uptake of rice in a *Vertisol",* was carried out during the Kharif-2020 in the Research and Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). Raipur is situated between 22o 33' N and 21o 14' N latitude and 82o 6' E and 81o 38' E longitude at an altitude of 293m above mean sea level. The exact location of the research site, i.e., IGKV Farm, is 21.2514o N latitude and 81.6296o E longitude. The weekly mean maximum temperature during the crop growth period ranged from 27.7oC to 33.3oC with an average of 31.30oC during 2020–21 and the weekly mean minimum temperature was 103oC to 26oC with an average of 21.26oC. The recorded rainfall in the crop growth period is 235.8 mm. Relative humidity throughout the crop season in 2020 varied from 81 to 93%. The soil of the experimental field was black (Vertisol-locally known as "kanhar") and clayey in texture, with a neutral pH (7.47). The physico-chemical properties of the experimental field are suitable for the rice crop. It was non-saline (EC 0.28 dSm-1) and low in organic carbon content (0.59%). The soil was low in available nitrogen (223 kg ha-1), high in available phosphorus (24.4 kg ha-1) and high in available potassium (384 kg ha-1).

Treatments

Treatment detail: (Named "Sagarika granule") were used in the experiment.

T1: Control (0:0:0)
T2: 75% RDF (90:45:30)
T3: 100% RDF (120:60:40)
T4: 75% RDF + Spray of seaweed liquid* (0.25%) at 21 DAT
T5: 100% RDF + Spray of seaweed liquid (0.25%) at 21 DAT
T6: 75% RDF + Spray of seaweed liquid (0.25%) at 21 DAT + at 42 DAT
T7: 100% RDF + Spray of seaweed liquid (0.25%) at 21 DAS + at 42 DAT
T8: 75% RDF + Soil application of seaweed granule* (25 kg/ha) at 21 DAT
T9: 100% RDF + Soil application of seaweed granule (25 kg/ha) at 21 DAT
T10: 75% RDF + Soil application of seaweed granule (25 kg/ha) at 21 DAT + Spray of seaweed liquid (0.25%) at 42 DAT
T11: 100% RDF + Soil application of seaweed granule (25 kg/ha) at 21 DAT + Spray of seaweed.

Field experiment

There are a total of 12 treatments used. All treatments were provided with soil applications of 100% and 75% of the recommended dose of fertilizer (RDF), i.e., 120:60:40 and 90:45:30 kg N, P2O5, and K2O kg ha-1, respectively. These recommended fertilizer dosages (RDF) of 100% and 75% are combined with 0.25% seaweed liquid extract and 25 kg/ha seaweed granules. Take 2.5 ml of seaweed liquid extract and one litter of water to make a 0.25% solution. These 12 treatment combinations were tested in a complete randomized block design and replicated three times. The total plot size was 5 x 4 metres2. Foliar sprays, soil applications, and seed soaking were all done with seaweed extract (liquid and granules).

Initial as well as post-harvest composite soil samples were collected (500 g composite sample, one sample from each plot) from 0 to 15 cm depth. Three soil samples were collected from each plot and composited. Samples were liquid (0.25%) at 42 DAT dried, processed using a 2-mm sieve and analyzed for soil pH by Thomas (1996), soil T12 100% RDF + Seed soaking with seaweed liquid(0.1%) organic carbon (SOC) by Walkley and Black's + Spray of seaweed liquid (0.25%) at 21 DAT.

Experimental material

Seaweed liquid and seaweed granules (seaweed extract products) In the experiment, IFCCO made seaweed extract products: seaweed liquid (named "Sagarika liquid") and seaweed granules rapid titration method (1934) as described by Jackson (1967), and available N by the alkaline permanganate method (Subbiah and Asija,), available P by Olsen *et al.,* (1954) [20] method and available K by neutral normal ammonium acetate solution. (Knudsen *et al.* 1982) [12].

Results and Discussion

Effect of seaweed extract on growth parameters, yield attributes and yields of rice

Significantly higher productive tillers/m2, plant height and longer panicle length of rice was recorded when crop was fertilized with 100% recommended dose of fertilizer (RDF) than 75% RDF. Increase in yield attributes might be owing to availability of more nutrients to the crop under 100% than 75% RDF. These results confirm the findings of Gunri *et al.* (2004).

After one year of experiment, overall results of effect of seaweed extracts (liquid end granules) on growth parameters, yield attributes and yields of rice showed that the plant height, effective tillers per hill and, panicle length were significantly influenced by the fertilizer levels and seaweed extracts applied. Combinations of seaweed extracts with 100% RDF were found at par with each other and gave similar effects as the application of 100% RDF alone on growth and yield attributes. Application of seaweed extracts with 75% RDF (T4, T6, T8, and T10) was observed at par with 100% RDF, which shows the positive effect of seaweed extracts and a saving of 25% RDF through the application of seaweed extracts. Similar results of increases in the growth parameters (plant height and effective tillers) and yield attributes (panicle length) due to the application of fertilizer levels and seaweed extract were also reported by many scientists, including Satapathy *et al.* (2014) [27], Raj *et al*. (2016), and Sunarpi *et al.* (2010) [31]

Yield

Rice receiving 100% RDF gave significantly higher grain and straw yields than 75% RDF. The results showed that adding 25%. fertilizer to the rice crop produced 11.18% and 10.83% more grain and straw yield as compared to the 75% recommended dose of fertilizer. Many scientists have also reported significant effects of higher doses of chemical fertilizer on the grain and straw yields of rice and an increase in yield with increasing doses of fertilizer. Singh *et al.* (2015). The addition of seaweed extracts with 75% RDF increased

grain yield by 4.6, 7.9, 11.0, and 12.1% (highest) over the application of 75% RDF alone (52.58 q/ha).Treatments T5, T7, T9, T11, and T12 (seaweed extracts with 100% RDF) increased the grain yield by 1.84, 3.5, 6.44, 7.59 (highest) and 2.3%, respectively, over the single application of 100% RDF (58.5 q/ha).

Application of seaweed extracts (spray of seaweed liquid on crop or seaweed granules in soil) with the 75% RDF (T4, T6, T8 and T10) was found at par grain yields (55.0–60.0 q/ha) in comparison with the application of 100% RDF (58.5 q/ha), which shows that the single spray of seaweed liquid (0.25%) on rice at 21 DAT (T4) or two sprays at 21 and 42 DAT (T6) or application of seaweed granules (25 kg/ha) at 21 DAT in soil (T8) or seaweed granules at 21 DAT + spray of seaweed liquid at 42 DAT (T10) may produce an equal yield of 100% of the recommended dose of fertilizer and can save 25% of RDF. The overall highest yield (62.9 q/ha) was obtained with the application of 100% RDF + seaweed granules @ 25 kg/ha at 21 DAT + seaweed liquid @ 0.25% at 42 DAT (T11), while the overall statistically lowest yield (27.67 q/ha) was found with T1 (Control).

Straw yield of treatment T4, T6, T8 and T10 where seaweed extract applied (spray of seaweed liquid on crop or seaweed granule in soil) with the 75% RDF were found at par with alone application of 100% RDF (67.43 q/ha), which shows that single spray of 0.25% seaweed liquid on rice at 21 DAT (T4) or two spray at 21 and 42 DAT (T6) or application of seaweed granules @ 25 kg/ha at 21 DAT in soil (T8) or seaweed granules @ 25 kg/ha at 21 DAT in soil with single spray of 0.25% seaweed liquid at 42 DAT (T10) may produce the straw equal to 100% RDF and can save 25% of RDF. Application of seaweed extracts in combination with the chemical fertilizers (RDF) increased grain and straw yield of rice was observed by Satapathy *et al.*, (2014) [27], Pramanick *et al*., 2014 and Sharma *et al.*, (2016).

Effect of seaweed extract on content doses of fertilizer improved the higher uptake of nutrients. Similar results were also reported by Kumar *et al.*, (2005), Maiti *et al*. (2006) and Senthivelu and Surya Prabha (2007). Among all the treatments (T1-T12), maximum uptake of N by grain and straw (61.3 kg ha-1) (32.05 kg ha-1) was found in treatment T11, where 100% RDF + seaweed granule at 21 DAT + spray of seaweed liquid at 42 DAT were applied, while the significantly lowest N uptake (29.9 kg ha-1) was recorded with control (T1). Among all treatments (T1-T12), treatment T11 had the and uptake of nitrogen, phosphorous and highest P uptake by grain (11.59 kg ha) and potassium straw (4.93 kg ha) and the lowest P uptake by grain (116.23 kg ha-1) was found in the treatment T8 where 100% RDF + seaweed granule at 21 DAT were applied while significantly lowest K uptake-1 variation in the doses of chemical fertilizer and (9.07 kg ha) was recorded with control (T1).

Seaweed extract (spray of liquid or soil The highest uptake of potassium by the straw,-1 application of granules) were also recorded by 116.2 kg ha, was recorded with treatment T11, Khemnar and Chaugule (2000), Yogendra *et al*., (2015), and Pramanick *et al*., (2020).

Nutrient uptake

Data of uptake of nitrogen, phosphorous and potassium by rice grain indicated that the treatments of alone applications of chemical fertilizer (T2 and T3), application of 100% RDF (120:60:40 N, P2O5 and K2O) was recorded significantly higher N uptake (57.71 kg ha-1), P uptake (10.83 kg ha-1) and K uptake (116.23 kg ha-1) over the 75% RDF. Application of higher while the significantly lowest uptake, 54.3 kg ha-1, was recorded with control. Overall results of the effect of seaweed extracts (liquid end granules) on nutrient uptake of rice (var.-Rajeshwari) showed that treatment-wise variations in the nutrient contents of grains and straws of rice were observed to be non- significant, whereas the uptake of nutrients by grains and straws of rice was significantly affected by the fertility levels and application of seaweed extracts. Similar results were also reported by Kumar *et al.* (2005), Maiti *et al.* (2006), and Senthivelu and Surya Prabha (2007)

Effect of seaweed extracts on the physico-chemical properties of the soil: Soil reaction, such as pH, and salt concentration in the soil, such as electrical conductivity, were not significantly influenced by the fertilizer levels and seaweed extracts applied. The residual available nitrogen in the soil after the harvesting of rice was not significantly influenced by the fertilizer levels and seaweed extracts applied. Residual available phosphorus in the soil after harvesting of rice was significantly influenced by fertilizer levels and seaweed extracts. The maximum residual available phosphorus (27.90 kg/ha) was obtained with the application of 100% RDF+ seaweed granule at 21 DAT + seaweed liquid at 42 DAT(T11),while the minimum available phosphorus (21.82 kg/ha P) was found in the control. Significant variation in the residual available phosphorus in the soil was also recorded by Beesley *et al.* (2011) and Pramanik *et al. (*2020). The residual status of available potassium in the soil after the harvesting of rice was not significantly influenced by the treatments applied. Among the different treatments, maximum available potassium (383.4 kg/ha) was recorded with T9 (100% RDF + Seaweed granule @ 25 kg/ha at 21 DAT), while minimum soil available potassium (370.3 kg/ha) was found with Control (T1). No variation in the soil K were also reported by Yogendra N. D. *et al*. (2015), Singh *et al*. (2015) [30], and Layek *et al.* (2018) [14].

Table 1: Effect of seaweed extracts on growth parameters and yield attributes of rice

S. No	Treatments	Growth parameters		Yield attributes		Yield (q/ha)	
	Plant height (cm)		Effective tillers/hill	Panicle length(cm)	Test weight(g)	Grain	Straw
T1	Control (0:0:0)	108.00	5.33	20.61	30.57	27.67	32.25
T2	75% RDF (90:45:30)	114.83	6.27	23.5	31.30	52.58	60.84
T3	100% RDF(120:60:40)	120.07	7.13	24.07	31.57	58.46	67.43
T4	75% RDF + Spray of seaweed liquid* (0.25%) at 21 DAT	117.53	6.93	23.69	31.30	55.00	61.33
T5	100% RDF + Spray of seaweed liquid (0.25%) at 21 DAT	119.37	7.13	24.23	31.33	59.54	68.69
T6	75% RDF + Spray of SL (0.25%) at 21 DAT + at 42 DAT	118.70	7.07	23.88	31.07	56.77	62.95
T7	100% RDF + Spray of SL (0.25%) at 21 DAS + at 42 DAT	120.23	7.20	24.43	31.60	60.51	70.24

T8	75% RDF + Soil application of SG* (25 kg/ha) at 21 DAT	117.80	7.13	24.34	30.87	58.33	67.07
T9	100% RDF + Soil application of SG (25 kg/ha) at 21 DAT	120.47	7.20	24.33	31.17	62.23	72.07
T10	75% RDF + Soil application of SG(25 kg/ha) at 21 DAT + Spray of SL (0.25%) at 42 DAT	118.40	7.13	24.48	31.10	60.00	71.77
T11	100% RDF + Soil application of SG (25 kg/ha) at 21 DAT + Spray of SL (0.25%) at 42 DAT	120.13	7.27	24.75	31.70	62.90	72.40
T12	100% RDF + Seed soaking with SL (0.1%) + Spray of SL (0.25%) at 21 DAT.	119.50	7.20	24.53	31.47	59.85	70.46
	S.Em±	1.76	0.26	0.73	0.43	1.59	1.87
	CD (P=0.05)	5.17	0.77	2.14	NS	4.66	5.48

Table 2: Effect of seaweed extract on N, P and K content (%) in rice grain and straw

S. No.	Treatments	N content		P conten Grai		K content Stra		Nitrogen uptake Grain Stra Total			Grai	Uptake of P Straw Total		Grai	Uptake of K Straw Total	
	Grain		Straw	n	Straw	Grain	w				n			n		
T1	Control (0:0:0)	1.09	0.51	0.202	0.072	0.329	1.69	29.95	16.27	46.21	5.59	2.33	7.92	9.07	54.32	63.39
T2	75% RDF (90:45:30)	1.04	0.48	0.185	0.067	0.305	1.64	54.40	28.94	83.34	9.68	4.09	13.77	16.03	99.81	115.83
T3	100% RDF(120:60:40)	0.99	0.46	0.185	0.068	0.292	1.63	57.71	30.84	88.55	10.83	4.56	15.39	17.07	109.61	126.68
T4	75% RDF + Spray of seaweed liquid* (0.25%) at 21 DAT	1.02	0.48	0.192	0.068	0.305	1.66	55.68	29.30	84.98	10.50	4.15	14.65	16.79	101.92	118.71
T5	100% RDF + Spray of seaweed liquid (0.25%) at 21 DAT	0.99	0.46	0.183	0.067	0.297	1.64	58.97	31.51	90.48	10.88	4.60	15.48	17.72	112.29	130.01
T6	75% RDF + Spray of SL (0.25%) at 21 DAT + at 42 DAT	1.01	0.47	0.188	0.067	0.307	1.64	57.17	29.80	86.97	10.64	4.25b	14.89	17.42	103.06	120.49
T7	100% RDF + Spray of SL (0.25 %) at 21 DAS + at 42 DAT	0.98	0.45	0.181	0.068	0.290	1.62	59.17	31.78	90.95	10.93	4.73	15.66	17.55	113.41	130.96
T8	75% RDF + Soil application of SG* (25 kg/ha) at 21 DAT	0.99	0.47	0.184	0.068	0.302	1.62	57.89	31.31	89.21	10.74	4.56	15.30	17.61	108.55	126.16
T9	100% RDF + Soil application of SG (25 kg/ha) at 21 DAT	0.97	0.44	0.181	0.068	0.289	1.61	60.30	31.89	92.19	11.24	4.88	16.13	17.98	115.80	133.78
T10	75% RDF + Soil application of SG(25 kg/ha) at 21 DAT + Spray of SL (0.25%) at 42 DAT	1.00	0.44	0.183	0.068	0.295	1.60	59.93	31.92	91.84	10.98	4.90	15.88	17.69	114.5	132.25
T11	100% RDF + Soil application of SG (25 kg/ha) at 21 DAT + Spray of SL (0.25%) at 42 DAT	0.97	0.44	0.184	0.068	0.289	1.61	61.29	32.05	93.33	11.59	4.93	16.52	18.12	116.23	134.35
T12	100% RDF + Seed soaking with SL (0.1%) + Spray of SL (0.25%) at 21 DAT.	0.99	0.45	0.181	0.067	0.292	1.60	59.40	31.85	91.25	10.85	4.71	15.56	17.40	112.1	129.52
	S.Em±	0.03	0.03	0.01	0.005	0.001	0.02	1.42	0.47	1.64	0.33	0.13	0.39	0.53	2.67	2.85
	CD (P=0.05)	NS	NS	NS	NS	NS	0.10	4.17	1.39	4.81	0.95	0.39	1.15	1.57	7.83	8.36

Table 3: Effect of seaweed extract on soil pH, EC and OC content after harvesting of rice

S. No.	Treatments	pH	EC(dSm- 1)	OC (%)	Avail. N	Avail. P	Avail. K
T1	Control (0:0:0)	7.30	0.27	0.59	219.89	21.82	370.3
T2	75% RDF (90:45:30)	7.29	0.26	0.59	225.79	24.69	376.3
T3	75% RDF + Spray of seaweed liquid*	7.27	0.26	0.60	228.73	27.11	319.5
T4	75% RDF + Spray of seaweed liquid*(0.25%) at 21 DAT	7.24	0.25	0.59	225.79	24.12	374.4
T5	100% RDF + Spray of seaweed liquid(0.25%) at 21 DAT	7.24	0.25	0.60	229.58	27.62	378.1
T6	75% RDF + Spray of SL (0.25%) at 21 DAT + at 42 DAT	7.24	0.26	0.60	229.97	24.57	373.5
T7	100% RDF + Spray of SL (0.25%) at 21 DAS + at 42 DAT	7.25	0.26	0.59	228.34	27.31	377.4
T8	75% RDF + Soil application of SG* (25	7.28	0.25	0.59	233.76	24.79	379.6
T9	100% RDF + Soil application of SG (25 kg/ha) at 21 DAT	7.27	0.26	0.60	235.46	27.49	383.4
T10	75% RDF + Soil application of SG(25 kg/ha) at 21 DAT + Spray of SL (0.25%) at 42 DAT	7.27	0.25	0.59	234.61	25.27	380.4
T11	100% RDF + Soil application of SG (25 kg/ha) at 21 DAT + Spray of SL (0.25%) at	7.26	0.26	0.61	230.88	27.90	382.0
T12	100% RDF + Seed soaking with SL (0.1%) + Spray of SL (0.25%) at 21 DAT.	7.25	0.26	0.60	231.67	27.34	377.0
	S.Em±	0.05	0.01	0.01	3.21	0.95	3.72
	CD (P=0.05)	NS	NS	NS	NS	2.78	NS

Conclusion

On the basis of the experimental findings, it may be concluded that the fertilizer levels and seaweed extracts (soil application of granules @ 25 kg/ha and foliar spray of seaweed liquid @ 0.25%) significantly affect the growth parameters (plant height and effective tillers per hill), yield attribute (panicle length), and grain and straw yields of rice (var.-Rajeshwari). Plant height and effective tillers, panicle length, and grain and straw yield were significantly increased with the increasing levels of fertilizer. A 100% RDF application (120:60:40 kg/ha N, P2O5, and K2O) was found to be significantly higher than a 75% RDF application (90:45:30 kg/ha N, P2O5, and K2O). Application of seaweed extracts (spray of liquid or soil application of granules) with 75% RDF significantly increased the growth and yield attributes and was recorded at par with 100% RDF, which

shows the positive effect of seaweed extracts and a saving of 25% RDF through the application of seaweed extracts.

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