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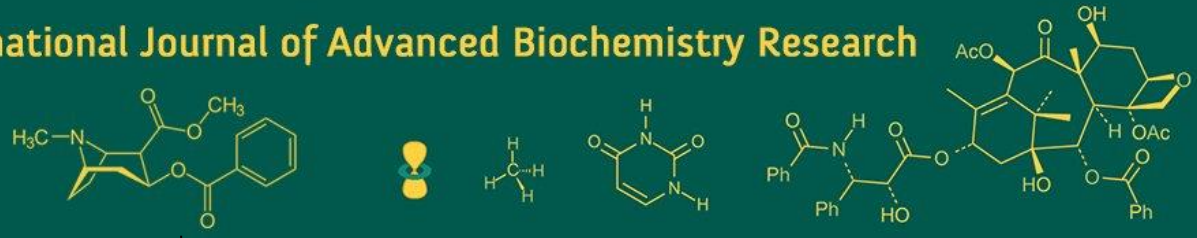

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Research Paper

The effect of seaweed extracts on growth, nutrient uptake, and yield improvement of transplanted rice in a *Vertisol* in Chhattisgarh, India

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Abstract
The field experiment titled "The Effect of Seaweed Extracts on Growth, Nutrient Uptake, and Yield Improvement of Transplanted Rice (var. Rajeshwari) in a *Vertisol* in Chhattisgarh, India" was conducted at the Indira Gandhi Agricultural University in Raipur, Chhattisgarh, during the Kharif season of 2023. The soil in the experimental field was black (*Vertisol*, locally known as "kanhar") and had a clayey texture, with a neutral pH of 7.47. The experiment was designed as a randomized block design with three replications. It included twelve treatments, which comprised a control group, two separate applications of 75% and 100% of the recommended fertilizer dose (RDF at 120:60:40 kg per hectare for N, P_2O_5, and K_2O), and nine different combinations of soil applications of seaweed extracts. The seaweed extracts used were *Kappaphycus* sp. and *Gracilaria* sp., applied as granules at a rate of 25 kg per hectare, along with a foliar spray of seaweed liquid at a concentration of 0.25% with 75% and 100% of the RDF. Based on the experimental findings, it can be concluded that both fertilizer levels and seaweed extracts significantly impact the growth parameters—such as plant height and the number of effective tillers per hill—and yield attributes like panicle length. Additionally, they influence the grain yields (55.0–60.0 q/ha) and straw yields of the rice variety *Rajeshwari* when granules are applied to the soil at a rate of 25 kg/ha and a foliar spray of seaweed liquid is used at a concentration of 0.25%.

Keywords: Seaweed extracts, transplanted rice, variety *Rajeshwari*

Introduction
In the context of climate change, inadequate rice crop performance is a significant challenge that requires effective agro-technological interventions. Total food grain production of India is 3322 million tons in 2023-24. The indiscriminate use of fertilizers has led to an imbalance, which has gradually decreased soil productivity over the years. Balanced fertilizer use is essential for sustaining rice production. Seaweed extract is a promising alternative to chemical fertilizers that is gaining popularity. Seaweeds are naturally organic and biodegradable, making them an environmentally friendly option. These macroscopic, multicellular marine algae have evolved in coastal ecosystems and serve as bio-stimulants for plants. Among the three major types of seaweed—red, brown, and green—brown seaweeds (Phaeophyta) are the most commonly used in agriculture (Blunden and Gordon, 1986). Seaweeds are among the most important marine resources in the world. Their derived products are widely utilized as amendments in crop production systems due to the presence of various plant growth-stimulating compounds. These include cytokinins, auxins, gibberellins, and betaines, as well as essential macronutrients such as calcium (Ca), potassium (K), and phosphorus (P), and micronutrients like iron (Fe), copper (Cu), zinc (Zn), boron (B), manganese (Mn), cobalt (Co), and molybdenum (Mo). These nutrients are necessary for plant growth and development (Mahima Begum, 2018). Seaweed extracts play a significant role in sustainable agriculture due to their organic and biodegradable properties (Cassan *et al*., 1992) [7]. The commercially important seaweed, *Kappaphycus alvarezii*, was introduced to India by the Central Salt and Marine Chemical Research Institute (CSMCRI) in Bhavnagar, Gujarat.

The liquid seaweed sap obtained by liquefying fresh *Kappaphycus alvarezii* is rich in both micro and macro plant nutrients, as well as plant growth regulators. This sap has been shown to effectively enhance crop productivity across a variety of crops (Zodape, 2011) [6]. Foliar spraying of seaweed sap on crops, vegetables, and trees has resulted in increased plant growth, grain yield, and overall productivity (Pramanik *et al*., 2014).

Methods and Materials

The current study, titled "The Effect of Seaweed Extracts on the Growth, Nutrient Uptake, and Yield Improvement of Transplanted Rice (var. Rajeshwari) in a *Vertisol* in Chhattisgarh, India," was conducted during the Kharif season of 2023 at Indira Gandhi Krishi Vishwavidyalaya in Raipur, Chhattisgarh. Raipur is located between 22° 33' N and 21° 14' N latitude and 82° 6' E and 81° 38' E longitude, with an altitude of 293 meters above Mean Sea Level. During the crop growth period of 2022-2023, the weekly mean maximum temperature ranged from 28.7 °C to 34.3 °C, with an average of 32.3 °C. The weekly mean minimum temperature varied from 10.2 °C to 28 °C, averaging 22 °C. The recorded rainfall during the crop growth period was 236.8 mm, and relative humidity throughout the crop season in 2023 ranged from 82% to 95%.

The soil in the experimental field was classified as *Vertisol*. A representative initial soil sample was collected from the field before the application of treatments, while final soil samples were collected from each plot after the harvest of the rice crop. These samples were air-dried and prepared for analysis by grinding and sieving through a 2 mm sieve. The prepared soil samples were then analysed for various physicochemical properties. A total of 12 treatments were used in the study. Each treatment received soil fertilizer applications at both 100% and 75% of the recommended dose (RDF). The recommended dosage consists of 120 kg N, 60 kg P_2O_5, and 40 kg K_2O per hectare for the 100% RDF, and 90 kg N, 45 kg P_2O_5, and 30 kg K_2O per hectare for the 75% RDF. These fertilizer doses were mixed with 0.25% seaweed liquid extract and 25 kg/ha of seaweed granules. To prepare the 0.25% solution, combine 2.5 ml of seaweed liquid extract with one liter of water.

This text outlines different treatment conditions:

- **T_1: ** Control (0:0:0)
- **T_2: ** 75% RDF (90:45:30)
- **T_3: ** 100% RDF (120:60:40)
- **T4:** 75% RDF with a spray of seaweed liquid (0.25%) at 21 DAS
- **T_5:** 100% RDF with a spray of seaweed liquid (0.25%) at 21 DAS
- **T_6:** 75% RDF with a spray of seaweed liquid (0.25%) at 42 DAS
- **T_7:** 100% RDF with a spray of seaweed liquid (0.25%) at 42 DAS
- **T_8:** 75% RDF with soil application of seaweed granules (25 kg/ha)
- **T_9:** 100% RDF with soil application of seaweed granules (25 kg/ha)
- **T_{10}:** 75% RDF with soil application of seaweed granules (25 kg/ha) at 21 DAS and a spray of seaweed liquid (0.25%) at 42 DAS
- **T_{11}:** 11100% RDF with soil application of seaweed granules (25 kg/ha) at 21 DAS and a spray of seaweed liquid (0.25%) at 42 DAS
- **T_{12}:** 100% RDF with seed soaking in seaweed liquid (0.1%) and a spray of seaweed liquid (0.25%) at 21 DAS

Soil sampling and analysis

A representative soil sample (0-15 cm depth) was collected from the experimental field to assess the initial nutrient status of the soil. The soil sample was prepared by sieving it through a 2 mm sieve for analysis. After the crop was harvested, surface soil samples (0-15 cm depth) were separately collected from each plot. These samples were air-dried in a shaded area, and then they were prepared using a wooden rod and sieved through a 2 mm sieve. Soil pH was determined using a 2.5:1 water-to-soil suspension, after stirring for 30 minutes, with a glass electrode pH meter, following the methodology suggested by Piper (1966). Organic carbon (OC) was estimated using Walkley and Black's rapid titration method (1934), as described by Jackson (1973) [15]. Available nitrogen in the soil was measured using the alkaline potassium permanganate method, according to Subbiah and Asija (1956). Available phosphorus was extracted from the soil with 0.5 M NaHCO3, and its quantitative determination was conducted using the procedure outlined by Olsen *et al*. (1954), with results expressed in kg ha^{-1}. Available potassium was assessed by extracting the soil with neutral normal ammonium acetate solution, with potassium estimation performed using a flame photometer, as described by Jackson (1973) [15]. The available micronutrients, including zinc, iron, manganese, and copper, were evaluated using the DTPA extraction method followed by Atomic Absorption Spectroscopy (AAS), as Lindsay and Norvel (1978) outlined.

Results and Discussion

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

Overall, the results regarding the effects of seaweed extracts (both liquid and granules) on the growth parameters, yield attributes, and overall yields of rice indicate that plant height, the number of effective tillers per hill, and panicle length were significantly influenced by the levels of fertilizer and the application of seaweed extracts. Combinations of seaweed extracts with 100% Recommended Dose of Fertilizer (RDF) showed similar effects to those of 100% RDF applied alone, regarding growth and yield attributes. Furthermore, applying seaweed extracts with 75% RDF (specifically treatments T4, T_6, T_8, and T_{10}) yielded results comparable to those of 100% RDF. This suggests a positive effect of seaweed extracts, allowing for a 25% reduction in RDF usage. The observed increases in growth parameters and yield attributes can likely be attributed to the nutrient levels and the presence of plant growth regulators, trace elements, vitamins, and other beneficial components found in seaweed extract.

The effect of seaweed extract on crop yield was found to be significant when applied alongside a lower dose of chemical fertilizer (75% Recommended Dose of Fertilizer or RDF).

Specifically, the addition of seaweed extracts to the 75% RDF increased grain yield of 4.6%, 7.9%, 11.0%, and up to 12.1%, the highest increase, compared to the application of 75% RDF alone (52.58 quintals per hectare). The treatments

using seaweed extracts with 100% RDF (specifically T_5, T_7, T_9, T_{11}, and T_{12}) increased the grain yield by 1.84%, 3.5%, 6.44%, 7.59% (the highest), and 2.3%, respectively, when compared to a single application of 100% RDF (58.5 quintals per hectare).

The application of seaweed extracts (either as a liquid spray on crops or as granules in the soil) along with the 75% RDF (Treatments T4, T_6, T_8, and T_{10}) produced comparable grain yields (ranging from 55.0 to 60.0 quintals per hectare) to the sole application of 100% RDF (58.5 quintals per hectare). Consequently, a single spray of seaweed liquid (0.25%) on rice at 21 DAT (T4), two sprays at days 21 and 42 DAT (T_6), or the application of seaweed granules (25 kg/ha) at 21 DAT in the soil (T_8), or combining seaweed granules at 21 DAT with a spray of seaweed liquid at 42 DAT (T_{10}), can yield results similar to using the full recommended dose of fertilizer, thus saving 25% of the RDF.

The overall highest yield of 62.9 quintals per hectare was achieved with the application of 100% RDF combined with seaweed granules at 25 kg/ha at 21 DAT, along with seaweed liquid at 0.25% at 42 DAT (T_{11}). Conversely, the lowest yield statistically recorded was 27.67 quintals per hectare with the control treatment (T_1).

Effect of seaweed extracts on the physico-chemical properties of the soil

The application of 100% RDF (Recommended Dose of Fertilizer) combined with seaweed granules at 21 DAT and seaweed liquid at 42 DAT resulted in the highest soil organic carbon level at 0.61%. In contrast, the lowest organic carbon level, at 0.59%, was observed in the control and lower fertilized treatments.

The residual available nitrogen in the soil after rice harvest was not significantly affected by the levels of fertilizer and the seaweed extracts applied. However, the application of seaweed extracts with 100% RDF (60 kg/ha of phosphorus) led to a higher residual available phosphorus, ranging from 27.31 to 27.90 kg/ha, compared to treatments where seaweed extracts were combined with 75% RDF, which yielded available phosphorus levels between 24.1 and 25.3 kg/ha.

Among the treatments using seaweed extracts with 75% RDF, the following combinations were most effective in managing residual available phosphorus in the soil and reducing phosphorus fertilizer usage by 25%, 75% RDF + spray of seaweed liquid (0.25%) at 21 DAT and 42 DAT (T_6), 75% RDF + soil application of seaweed granules (25 kg/ha) at 21 DAT (T_8),75% RDF + soil application of seaweed granules (25 kg/ha) at 21 DAT + spray of seaweed liquid (0.25%) at 42 DAT (T_{10}).

Table 1: Effect of seaweed extracts on growth parameters, Yield (q/ha) of rice.

S. No.	Treatments	Growth parameters		Yield (q/ha)		Soil properties		
		Plant height (cm)	Effective tillers/hill (No.)	Grain	Straw	pH	EC (dSm^{-1})	OC (%)
T_1	Control (0:0:0)	108.00c	5.3c	27.6e	32.2e	7.30a	0.27a	0.59a
T_2	75% RDF (90:45:30)	114.80b	6.2b	52.5d	60.8d	7.26a	0.27a	0.6a
T_3	100% RDF (120:60:40)	120a	7.1a	58.4abc	67.4abc	7.25a	0.27a	0.6a
T_4	75% RDF with a spray of seaweed liquid (0.25%) at 21 DAS	117.5ab	6.9ab	55.cd	61.3d	7.2a	0.26a	0.6a
T_5	100% RDF with a spray of seaweed liquid (0.25%) at 21 DAS	119.3ab	7.1a	59.5abc	68.6ab	7.2a	0.26a	0.7a
T_6	75% RDF with a spray of seaweed liquid (0.25%) at 42 DAS	118.7ab	7.0a	56.7bcd	62.cd	7.2a	0.27a	0.7a
T_7	100% RDF with a spray of seaweed liquid (0.25%) at 42 DAS	120.2a	7.2a	60.5ab	70.2ab	7.2a	0.27a	0.6a
T_8	75% RDF with soil application of seaweed granules (25 kg/ha)	117.8ab	7.1a	58.3abc	67.0abc	7.2a	0.26a	0.6a
T_9	100% RDF with soil application of seaweed granules (25 kg/ha)	120.4a	7.2a	62.2ab	72.0a	7.2a	0.27a	0.7a
T_{10}	75% RDF with soil application of seaweed granules (25 kg/ha) at 21 DAT and a spray of seaweed liquid (0.25%) at 42 DAT	118.4ab	7.1a	60ab	71.7ab	7.2a	0.26a	0.6a
T_{11}	100% RDF with soil application of seaweed granules (25 kg/ha) at 21 DAS and a spray of seaweed liquid (0.25%) at 42 DAS	120.1a	7.2a	62.9a	72.4a	7.2a	0.25a	0.62a
T_{12}	100% RDF with seed soaking in seaweed liquid (0.1%) and a spray of seaweed liquid (0.25%) at 21 DAS	119.5ab	7.2a	59.8ab	70.4ab	7.2a	0.25a	0.63a
SEm±		1.7	0.25	1.59	1.87	0.05	0.02	0.02
CD (P=0.05)		5.1	0.7	4.66	5.48	NS	NS	NS

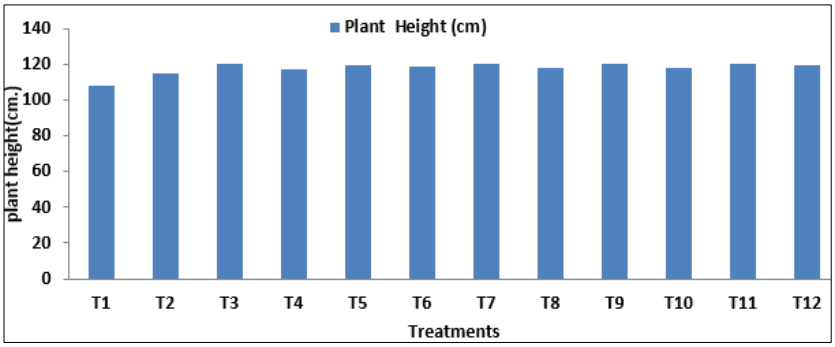

Fig 1: Effect of seaweed extract on plant height (cm)of rice

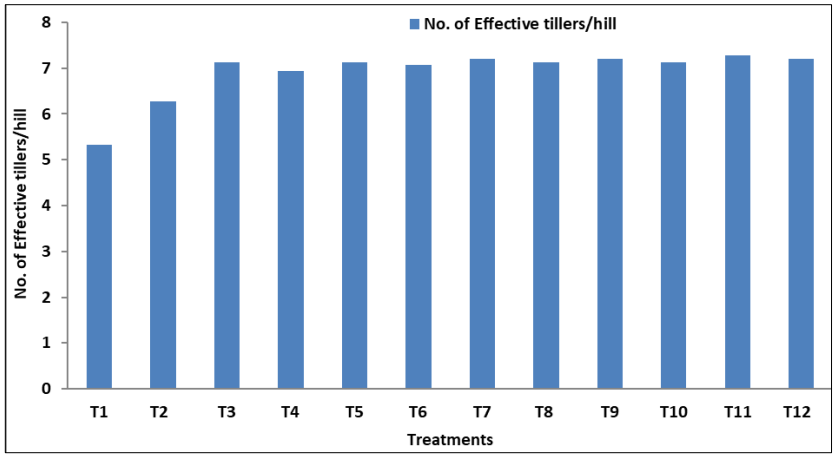

Fig 2: Effect of seaweed extract on No. of Effective tillers/hill of rice

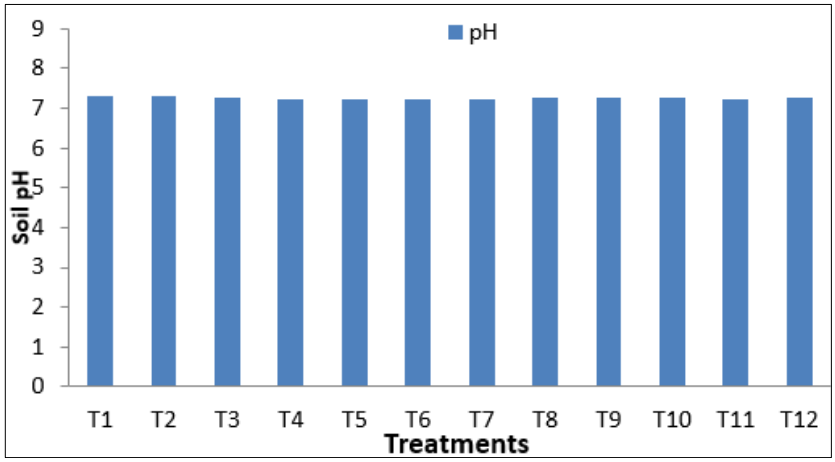

Fig 3: Effect of seaweed extract on soil pH at harvest of rice

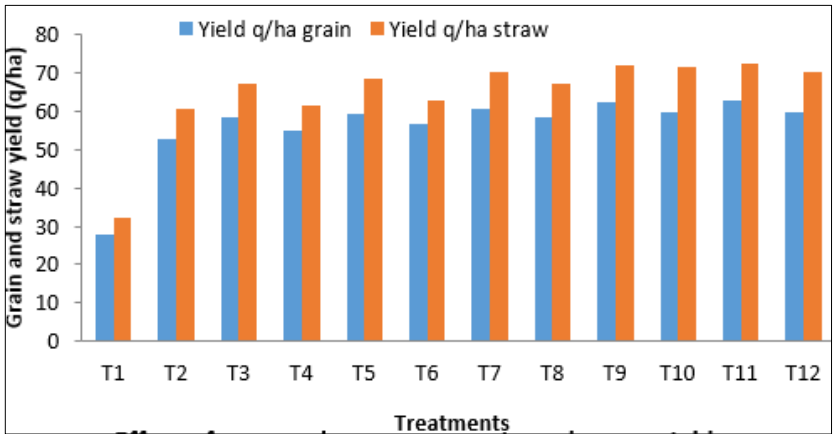

Fig 4: Effect of seaweed extract on grain and straw yield (q/ha) of rice

Conclusion

The application of seaweed extracts in combination with 75% Recommended Dose of Fertilizer (RDF) is recommended to enhance rice yield compared to the sole application of 75% RDF. These combined treatments increased grain yield by 4.6% to 12.1%. Specifically, the treatment of 75% RDF with seaweed granules at a rate of 25 kg/ha applied in the soil at 21 DAT, along with a foliar spray of seaweed liquid at a concentration of 0.25% at 42 DAT (T_{10}), resulted in a 12.1% increase in grain yield. Additionally, applying 75% RDF with seaweed granules (25 kg/ha) in the soil at 21 DAT (T_8) produced an 11% increase in grain yield, both exceeding the yield obtained with the sole application of 75% RDF (52.58 q/ha). These treatments are recommended for improving rice grain yields.

Similarly, the application of seaweed extracts with 100% RDF resulted in a 1.8% to 7.6% increase in rice yields compared to the sole application of 100% RDF (58.5 q/ha). The combination of soil application of seaweed granules (25 kg/ha) at 21 DAT and a foliar spray of seaweed liquid (0.25%) at 42 DAT with 100% RDF (T_{11}) achieved the highest overall yield of 62.9 q/ha, reflecting a 7.6% increase compared to the application of 100% RDF alone. Furthermore, applying seaweed granules (25 kg/ha) at 21 DAT along with 100% RDF (T_9) resulted in a 6.4% increase in grain yield. These practices are also recommended for enhancing rice.

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