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UTILIZATION OF SEAWEED EXTRACTS AS BIOSTIMULANTS FOR SUSTAINABLE IMPROVEMENT OF WINTER RICE YIELD AND QUALITY IN THE NEW ALLUVIAL ZONE OF WEST BENGAL INDIA

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ABSTRACT

To address the declining factor productivity, ensure yield sustainability and promote environmental safety, a field experiment was conducted during two consecutive *kharif* seasons (2023 and 2024) at the Instructional Farm of Agriculture, BCKV, Jaguli. The objective was to evaluate the influence of different seaweed saps on growth, yield and quality enhancement of rice (*cv.* Satabdi) in the New Alluvial Soil of West Bengal. Treatments included foliar applications of Gracilaria, Kappaphycus, Soleria and Sargassum extracts (@ 5 ml/l), BIO-ZYME (@ 2 ml/l) and a control with only the recommended dose of fertilizers (RDF). Sprays were applied twice, at 30 and 50 days after transplanting. Among the treatments, Sargassum sap + 100% RDF showed the most promising results, significantly improving growth, yield and grain quality. This treatment recorded the highest grain yield (3.98 t/ha), straw yield (5.80 t/ha) and harvest index (40.71%), along with notable enhancement in head rice recovery (%) and amylose content (%) and an economic return reflected by a B:C ratio of 1.83. These findings highlight the potential of Sargassum extract for sustainable and profitable rice cultivation in this region.

***Key words*:** Biostimulant, Rice, Seaweed, Grain quality, Yield

Introduction

Since independence, Indian agriculture has undergone a remarkable transformation not only from a food-deficit nation to a self-sufficient one but also globally a competitive food producer. Despite the glorious part of the green revolution, there remains some grey zones; the country obviously has a substantial share of challenges. The sustainability of agricultural growth is now at risk due to declining input use efficiency, soil degradation and stagnant productivity. According to a report by Hindustan Times in 2015, the population of India has been escalating at an annual rate of 1.28%, while the average growth rate of total food grain production is about 0.6%. This disparity underscores the urgent need for measures to boost agricultural productivity for keeping pace with the population growth. In this context, the integration of nature-based solutions like bio stimulants, particularly seaweed extracts, offer a promising alternative. Seaweed-derived bio stimulants are rich in plant growth regulators, micronutrients and bioactive compounds that enhance crop growth, stress resilience and yield in an eco-friendly manner (Pramanick *et al*., 2014). Given the significance of rice in Indian agriculture, the present study was undertaken to evaluate the effect of different seaweed saps on the growth, yield and quality of *kharif* (rainy season) rice as well as its economic impact when used in rice grown in New Alluvial Soil of West Bengal, aiming to promote both productivity and sustainability.

Materials and Methods

The present investigation was conducted during two consecutive *Kharif* seasons of 2023 and 2024 at the Instructional Farm of BCKV (22°93' N latitude, 88°53' E longitude and 9.75 m above mean sea level), Jaguli, Nadia, West Bengal to evaluate the impact of different seaweed saps on the growth, yield, quality and economics of *kharif* rice (*Oryza sativa* L.) *cv*. Satabdi (IET 4786) grown in New Alluvial Soil. The soil was sandy loam in texture with a pH of 6.8, moderate organic carbon (0.65%), and available N P_2O_5, and K_2O levels of 213.4, 22.5, and 184.3 kg/ha, respectively. The experiment was laid out in a Randomized Block Design (RBD) with six treatments and four replications. The six treatments were: T_1 – 100% RDF + *Gracilaria* sap @ 5 ml/l; T_2 – 100% RDF + *Kappaphycus* sap @ 5 ml/l; T_3 – 100% RDF + *Soleria* sap @ 5 ml/l; T_4 – 100% RDF + *Sargassum* sap @ 5 ml/l; T_5 – 100% RDF + BIO-ZYME @ 2 ml/l; T_6 – 100% RDF only (control). The recommended dose of fertilizers (60:30:30 kg/ha N:P_2O_5: K_2O) was uniformly applied using urea, SSP and MOP. Nitrogen was split-applied—half as basal, and one-fourth each at 25 and 45 days after transplanting (DAT). Twenty-three days old seedlings were transplanted in plots of 4 m × 3 m with spacing of 20 cm × 15 cm. Foliar sprays of seaweed saps were applied at 30 and 50 DAT by knapsack sprayer.

Compositions of marine algal saps

Gracilaria sap contains high moisture (88.88%), carbohydrates (45.92%), crude protein (9.58 g/100 g), fiber (10.40 g/100 g), lipid (2.00 g/100 g) and ash (38.91 g/100 g). It is also rich in potassium (8633 mg/100 g), magnesium (549.50 mg/100 g), phosphorus (278.50 mg/100 g), calcium (295.50 mg/100 g), iron (67.35 mg/100 g) and vitamin C (28.50 mg/100 g), along with amino acids (889.78 mg/g protein) and saturated fatty acids (48.92%). Trace elements include zinc, copper, manganese, cobalt and lead in small amounts (Benjama and Masniyom, 2012).

Kappaphycus sap is rich in moisture (94.38 g/100 ml), with notable levels of potassium (358.35 mg/100 ml), calcium (32.49 mg/100 ml), magnesium (116.79 mg/100 ml) and iodine (160 mg/100 ml). It contains plant growth regulators like indole acetic acid (23.36 mg/L), gibberellin GA_3 (27.87 mg/L) and kinetin + zeatin (31.91 mg/L), along with trace elements such as iron, zinc, copper and chromium (*National Institute of Nutrition, Hyderabad, India*).

Soleria sap is primarily composed of ash (44.30%) and carbohydrates (32.96%), followed by moisture (16.91%), crude protein (5.61%) and a minimal amount of total fat (0.22%), indicating its potential as a mineral-rich and energy-supplying bio stimulant (Aijik and Tahiuddin, 2023).

Sargassum sap is nutrient-rich, containing key macronutrients like potassium (9.72%), phosphorus (0.95%) and calcium (10,557 mg/kg), along with vital micronutrients such as manganese (127.67 mg/kg), iron (83.01 mg/kg) and molybdenum (200.49 mg/kg). It also includes plant growth regulators like IAA (381.07 ppb) and zeatin (3868.40 ppb), with anthocyanin pigment at 0.35 mg/g (Vaghela *et al.*, 2023).

BIO-ZYME sap derived from *Ascophyllum nodosum* (brown seaweed) is composed primarily of water (70–85%) and ash (15–25%), with significant levels of alginic acid (15–30%), carbohydrates (10%), protein (5–10%) and mannitol (5–10%). It also contains minor constituents like fucoidan, laminarin, potassium, sodium, magnesium, and iodine, highlighting its value in agricultural and biostimulant applications (Nayak *et al.*, 2020).

Field operations were followed as per standard agronomic practices. Mechanical analysis was performed using the international pipette method (Piper, 1966) to classify soil texture. Chemical analysis included soil pH measurement in 1:2.5 soil-water suspension (Jackson, 1973), organic carbon by the Walkley and Black wet digestion method (Jackson, 1973), soil available nitrogen through alkaline KMnO„ oxidation (Nelson and Sommers, 1980), phosphorus by Olsen's extraction method using 0.05M $NaHCO_3$ and UV-VIS spectrophotometry (Olsen *et al.*, 1954; Jackson, 1973) and potassium using ammonium acetate extraction followed by flame photometry (Jackson, 1973). To evaluate nutrient uptake by rice, plant samples were collected at harvest and dry matter along with nitrogen (N), phosphorus (P) and potassium (K) contents were analyzed using the Modified Kjeldahl method for N and the Molybdophosphoric Blue method for P (Pratt, 1961), while K was estimated via wet digestion using a tri-acid mixture (Jackson, 1973). Total nutrient uptake was calculated by multiplying nutrient percentages in grain and straw with their respective dry weights. For soil analysis, samples were collected before and after harvest, air-dried, sieved (2 mm) and stored for further study.

Post-harvest quality traits such as hulling percentage, milling percentage and head rice recovery were evaluated in the laboratory using a SATAKE rice huller and calculated using specific equations (i, ii and iii).

$$\text{Hulling (\%)} = \frac{\text{Weight of brown rice (g)}}{\text{Weight of rough rice (g)}} \times 100 \quad \text{...i}$$

$$\text{Milling (\%)} = \frac{\text{Weight of milled rice (g)}}{\text{Weight of rough rice (g)}} \times 100 \quad \text{...ii}$$

$$\text{Head rice recovery (\%)} = \frac{\text{Weight of head rice (g)}}{\text{Weight of rough rice (g)}} \times 100 \quad \text{...iii}$$

In addition, kernel length (L), breadth (B) and the length to breadth ratio (L:B) were measured. The amylose content in rice kernels was determined using the procedure proposed by Juliano (1971).

Economic analysis was performed by calculating the cost of cultivation, gross return, net return, and benefit-

Table 1: Impact of different treatments on plant height (cm) of rice at different growth stages (pooled data of two years).

Treatments	Plant height(cm)			Dry matter accumulation(g/m²)			No. of tillers/m²			LAI		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T_1	43.55	82.75	102.90	202.05	590.85	887.88	303.60	390.95	380.55	2.13	3.99	2.32
T_2	44.98	84.85	103.88	198.08	592.53	891.55	300.08	395.70	391.53	2.04	4.15	2.48
T_3	43.58	81.15	99.80	196.58	565.75	861.28	300.43	370.13	346.55	2.02	3.81	2.20
T_4	43.23	83.35	106.73	202.58	600.93	900.43	305.05	400.03	399.80	2.12	4.09	2.39
T_5	42.28	81.60	99.00	198.75	545.53	827.15	299.95	359.10	333.35	2.04	3.71	2.17
T_6	39.43	78.85	96.25	198.55	459.65	718.03	299.00	334.73	291.63	1.99	3.60	1.99
SEm(±)	1.17	0.89	0.72	1.61	6.37	11.59	1.55	1.91	2.22	0.03	0.04	0.03
CD at 5%	NS	2.68	2.18	NS	19.22	34.94	NS	5.78	6.69	NS	0.14	0.10

cost ratio. The recorded data were statistically analyzed using ANOVA under a Randomized Block Design (RBD) following the method outlined by Gomez and Gomez (1984).

Results and Discussion

Growth attributes

The addition of seaweed extracts with 100% RDF significantly triggered the growth attributes of rice. Though the highest leaf area index (LAI) was noticed under the treatment T_2 (*Kappaphycus* @ 5ml/l), but T_4 (*Sargassum* @ 5 ml/l) was recorded the tallest plants (106.73 cm at 90 DAT), highest dry matter accumulation (900.43 g/m²) and the maximum number of tillers (399.80/m²) as depicted in the Table 1. On the other hand, the lowest growth performance was recorded in T_6 (100% RDF alone), which produced the shortest plants (96.25 cm at 90 DAT), minimum dry matter accumulation (718.03 g/m²) and the least number of tillers (291.63/m²). The improvement may be attributed to bioactive compounds like cytokinins and auxins present in seaweeds that stimulate cell division and chlorophyll synthesis. Similar findings were reported by Rathore *et al*., (2009), indicating the beneficial role of seaweed extracts in enhancing early growth vigour and physiological efficiency.

Yield attributes and yield

Yield-contributing traits such as effective tillers and filled grains per panicle were significantly improved by seaweed foliar sprays (Table 2). Among the treatments, T_4 (*Sargassum* @ 5 ml/l) was the most effective,

Table 2: Impact of different treatments on yield parameters and yield of rice (pooled data of two years).

Treatments	Effective tillers/ m²	Filled grains/ panicle	Test weight (g)	Grain yield (t/ha)	Yield increase over control (%)	Straw yield (t/ha)	Yield increase over control (%)	Harvest index (%)
T_1	320.50	67.83	21.95	3.60	22.03	5.51	12.90	39.56
T_2	327.60	70.03	22.08	3.83	29.83	5.70	16.80	40.20
T_3	287.13	66.3	21.83	3.48	17.96	5.41	10.86	39.16
T_4	332.50	72.93	22.18	3.98	34.91	5.80	18.85	40.71
T_5	274.30	65.05	21.55	3.25	10.16	5.20	6.55	38.47
T_6	239.65	62.75	21.53	2.95	-	4.88	-	37.71
SEm(±)	1.75	0.66	0.37	0.03	-	0.06	-	0.41
CD at 5%	5.27	2.01	NS	0.10	-	0.20	-	1.25

Table 3: Impact of different treatments on quality parameters of rice (pooled data of two years).

Treatments	Hulling (%)	Milling (%)	Head rice recovery (%)	Kernel length (mm)	Kernel breadth (mm)	L:B	Amylose content (%)
T_1	76.95	66.22	57.55	6.30	1.70	3.65	23.84
T_2	76.98	67.21	58.35	6.35	1.73	3.66	24.06
T_3	76.23	66.50	57.50	6.25	1.67	3.67	22.70
T_4	77.33	67.07	59.18	6.55	1.75	3.75	24.43
T_5	76.17	66.48	56.35	6.15	1.65	3.65	23.20
T_6	76.09	66.43	52.95	6.08	1.63	3.66	21.59
SEm(±)	0.31	0.24	0.13	0.09	0.05	0.12	0.45
CD at 5%	NS	NS	0.39	NS	NS	NS	1.38

Table 4: Impact of different treatments on nutrient uptake by rice (pooled data of two years).

Treatments	GU			SU		
	N	P	K	N	P	K
T_1	47.09	6.77	21.76	22.52	5.57	113.77
T_2	50.95	7.29	23.35	23.11	6.14	119.17
T_3	46.24	6.96	19.66	20.70	4.61	108.24
T_4	52.52	8.23	22.87	25.24	5.78	122.55
T_5	44.69	5.95	18.91	22.19	4.17	102.00
T_6	40.13	5.18	13.81	18.06	3.64	96.08
SEm(±)	0.69	0.34	0.52	0.68	0.26	1.18
CD at 5%	2.09	1.04	1.58	2.06	0.80	3.57

GU: Grain Uptake (Kg/ha); **SU:** Straw Uptake (Kg/ha)

producing the highest number of effective tillers (332.50/m²) and filled grains per panicle (72.93), which resulted in the maximum grain yield of 3.98 t/ha**,** a 34.91% increase over the control (T_6). Straw yield also increased considerably, from 4.88 t/ha in the control (T_6) to 5.80 t/ha under T_4, with an improvement of 18.85%**.** Notably, the harvest index was highest in T_4 (40.71%), indicating potential efficiency in converting biomass into grain. Treatment T_2 (*Kappaphycus* @ 5 ml/l) also performed well, with 327.60 effective tillers/m², 70.03 filled grains/panicle and grain yield of 3.83 t/ha (29.83% increase over control). These results are consistent with the findings of Battacharyya *et al.*, (2015), who reported that seaweed-based biostimulants improve nutrient assimilation, hormonal regulation and overall reproductive efficiency, thereby enhancing yield and harvest index in crops.

The correlogram (Fig. 1) depicts the interrelationship among yield-contributing traits of rice, showing that all studied traits are positively and strongly correlated with each other. Plant height at 90 DAT exhibited a high positive correlation with dry matter accumulation (r = 0.88), effective tillers/m² (r = 0.96), filled grains/panicle (r = 0.93), test weight (r = 0.95) and grain yield (r = 0.98). Likewise, grain yield/ha showed the highest positive association with effective tillers/m² (r = 0.97), filled grains/panicle (r = 0.98) and test weight (r = 0.97), emphasizing these traits as the most influential contributors to yield. Overall, the analysis suggests that enhancing tillering efficiency, grain filling and test weight plays a crucial role in boosting rice productivity.

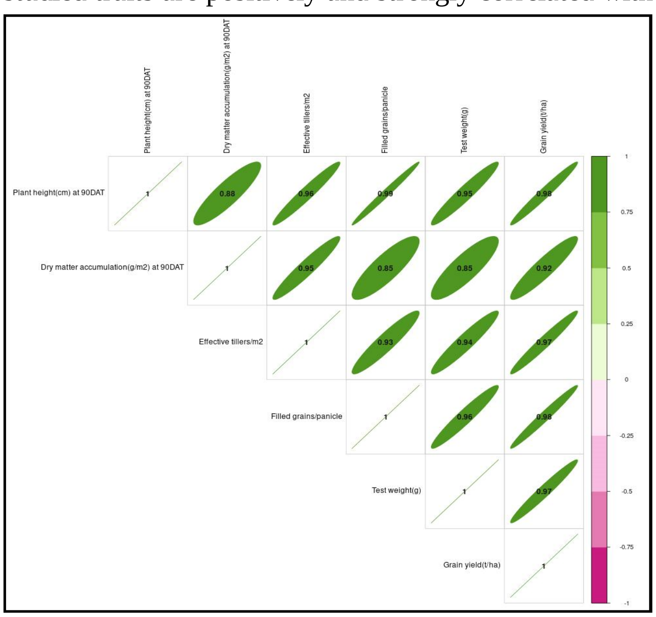

Fig. 1: Correlogram analysis among the yield contributing traits of rice (pooled data of two years).

Quality attributes

The foliar application of seaweed saps did not significantly influence the hulling and milling percentages of rice, as these parameters are largely governed by intrinsic grain characteristics. However, head rice recovery (%) showed substantial variation among treatments (Table 3), with T_4 (100% RDF + *Sargassum* @ 5 ml/l) achieving the highest value (59.18%) - 11.76% increase over the control (T_6). Amylose content varied significantly, ranging from 21.59% (T_6) to 24.43% (T_4), suggesting treatment effects on starch composition. This enhancement can be attributed to the presence of natural growth regulators and micronutrients in seaweed extracts, which promote uniform grain filling and structural integrity, thereby reducing grain breakage during milling. Similar trends were also observed by Layek *et al.*, (2018), emphasizing the role of seaweed bio stimulants in enhancing rice grain quality.

Nutrient Analysis

The application of seaweed saps significantly influenced nutrient uptake in rice. Among the treatments, T_4 (100% RDF + *Sargassum* @ 5 ml/l foliar spray) recorded the highest nitrogen (77.77 kg/ha), phosphorus (14 kg/ha) and potassium (145.42 kg/ha) uptake, which was statistically analogous with T_2 (100% RDF + *Kappaphycus* @ 5 ml/l). In contrast, the lowest uptake of N, P and K was observed in T_6 (100% RDF only). The improved nutrient absorption with seaweed saps may be attributed to their bioactive compounds, which enhance

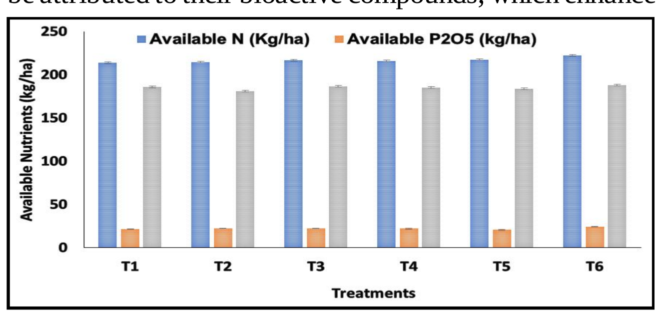

Fig. 2: Impact of different treatments on post-harvest soil status (pooled data of two years).

Table 5: Impact of different treatments on economic advantage of rice (pooled data of two years)

Treatments	Common cost (Rs./ha)	Treatment cost (Rs./ha)	Total cost (Rs./ha)	Gross Return (Rs./ha)	Net Return (Rs./ha)	B:C
T_1	40488	8577	49065	81157.50	32092.50	1.65
T_2	40488	8427	48915	86185.00	37270.00	1.76
T_3	40488	8527	49015	78540.00	29525.00	1.60
T_4	40488	8252	48740	89432.50	40692.50	1.83
T_5	40488	9127	49615	73452.50	23837.50	1.48
T_6	40488	6675	47163	66880.00	19717.00	1.42

nutrient solubility, microbial activity, root growth and enzyme biosynthesis, thereby increasing nutrient use efficiency. These results corroborate earlier findings by Banjare (2021). Post-harvest soil analysis (Fig. 2) revealed a decline in available N, P, and K compared to initial levels, with greater depletion under seaweed sap treatments due to enhanced nutrient uptake. Despite this reduction, no significant changes in overall soil properties were noted. Seaweed saps, however, are known to enrich macro- and micronutrients and can potentially improve soil's biological, chemical, and physical characteristics (Khan *et al*., 2009).

Economic analysis

Treatment T_5 (100% RDF + BIO-ZYME as foliar @ 5 ml/l) was found to be the most cost-effective, with a treatment cost of Rs. 9127/ha and a total cultivation cost of Rs. 49615/ha. In contrast, the maximum gross return (Rs. 89432.50/ha), net return (Rs. 40692.50/ha) and benefit cost ratio (1.83) were recorded under treatment T_4 (100% RDF + *Sargassum* as foliar @ 5 ml/l) (Table 5). These results confirm the dual benefit of seaweed foliar sprays in promoting crop performance and economic sustainability (Zodape *et al*., 2011).

Conclusion

Based on the findings of experiment, it can be concluded that entire recommended dose of fertilizer along with *sargassum* as foliar @ 5ml/l may be recommended for gaining higher profits from *winter* rice in New Alluvial soil of West Bengal.

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