

## RESEARCH ARTICLE

## EFFECT OF SEAWEED (CAULERPA RACEMOSE) AS BASAL AND SPRAY ON GROWTH, YIELD, AND YIELD ATTRIBUTES OF BORO RICE UNDER SALINE AND NON-SALINE CONDITIONS IN BANGLADESH

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## ABSTRACT

To determine the impact of seaweed on boro rice productivity, a field study was conducted to assess various application rates of both raw seaweed (*Caulerpa racemose*) and its liquid extract. The initial trials took place during the 2021 Boro season at two locations: the BINA headquarters farm in Mymensingh and a site in Shyamnagar, Satkhira. The potency of these extracts is influenced by the seaweed species (such as brown, red, or green varieties), the method of extraction, and the environmental conditions during its growth cycle. Seaweed is notably high in chlorophylls, proteins, and sulfated polysaccharides. Application methods for crops are versatile, including foliar sprays and soil amendments. It can fundamentally alter a plant's cellular respiration and introduce a range of growth-promoting hormones, including NAA, auxins, vitamins, and cytokinins. The study investigated two distinct factors: Basal Application: Processed seaweed was incorporated into the soil at six different rates: a control (no seaweed), 0.5, 0.625, 0.75, 0.875, and 1.0 tonne per hectare ( $t\ ha^{-1}$ ). Foliar Spray: A liquid seaweed extract was sprayed during the active tillering stage at seven concentrations: a control, 0.5, 0.625, 0.75, 0.875, 1.0, and 1.25 liters per hectare ( $L\ ha^{-1}$ ). The seaweed was harvested from the Bay of Bengal, then dried and processed for application. The liquid extract was diluted in water before being sprayed near the base of the rice plants at the tillering stage. The experiment was methodically arranged in a Randomized Complete Block Design (RCBD) with three replications, using  $5\ m \times 4\ m$  unit plots. Analysis of the results showed a significant positive response. The highest grain yield,  $5.73\ t\ ha^{-1}$ , was achieved with the basal application of  $1.0\ t\ ha^{-1}$  of seaweed, closely followed by the  $0.875\ t\ ha^{-1}$  treatment. For the foliar spray, the  $1.0\ L\ ha^{-1}$  application rate produced a statistically significant yield of  $5.38\ t\ ha^{-1}$ , with the  $0.75\ L\ ha^{-1}$  rate being the next most effective. Using seaweed extract on rice demonstrably enhances growth, grain production, and biological yield, while also improving the nutrient content of the grain. This boost in productivity is linked to an increased number of tillers, greater spikelet fertility, and fewer unfilled grains. These findings underscore that both the method of application and the specific dosage of seaweed are critical factors in maximizing the yield of boro rice.

## KEYWORDS

Seaweed, Yield, Rice.

## 1. INTRODUCTION

Seaweed product emerging as organic agrochemical inputs, exhibit benefits for plant growth and resilience in stress prone diverse ecosystem. Complex biochemical compound influences physiological responses in plants system. Seaweed extracts enhance crop vigor, (proline, glycine, glutamic acid helps to mitigate stress tolerance), and improves yield across various crop species. Integrating seaweed extracts reduces chemical dependency while improving yield and yield attributes of cereal, pulse and vegetables. To find out suitable eco-friendly management approaches within integrated nutrient management with chemical fertilizers as emerging issues related to blu economy. There are over 190 species of seaweed found in the coastal waters of Bangladesh, of which approximately 26 species are considered commercially important. Research on seaweed resources in Bangladesh reveals significant

biodiversity and commercial potential along the country's 480 km coastline. Studies report varying estimates of total seaweed species, with documenting 193 species. Consensus on commercially important species, with Sobuj et al. (2024) identifying 26 commercially significant species, comprising red seaweed (10 species, 38.46%), green seaweed (8 species, 30.77%), and brown seaweed (8 species, 30.77%) (Sarkar et al., 2016). Other studies report lower numbers, with (Sarkar et al., 2016). Commercially cultivated genera include *Caulerpa*, *Ulva*, *Padina*, *Sargassum*, *Hypnea*, and *Gracilaria* (Sobuj et al., 2024). These seaweeds are primarily found in St. Martin Island, Cox's Bazar, and the Sundarbans mangrove forest, with applications in pharmaceuticals, food, cosmetics, and biofuel raw materials (Sobuj et al., 2024; Sarkar et al., 2016). Seaweed species diversity and traits reveals significant knowledge gaps and regional variations. Mabey et al. (2023) conducted a systematic review for examining invasive seaweed traits, identifying 158 species, with

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research concentrated primarily in Europe and North America. The analysis documented approximately 865 seaweed taxa in Indian waters, though only a few are taxonomically well-characterized (Mantri et al., 2019). Exploring strategies to enhance rice productivity, particularly for the Boro rice season, is of paramount importance. One potential approach to improving Boro rice yield is the use of seaweed-based bio-stimulants. Seaweed extracts have been shown to have a positive effect on the growth and yield of various crops, including rice. Seaweed-based bio-stimulants have gained attention due to their potential to enhance crop growth parameters and productivity (Yakhin et al., 2017). The efforts to maximize the absorption of nutrients by spraying extracts of natural products that contain stimulants, is a strategic move to suppress the use of excessive doses of inorganic fertilizer. There is no enough knowledge on availability, distribution, seasonal variation, utilization status is causing impediment on utilization (e.g. seaweeds as human food, hydrocolloids, animal feed, fertilizer, cosmetic products, etc.) of available seaweeds naturally occurring in Bangladesh (Sarkar et al., 2016). Seaweeds have emerged as promising marine living resources globally. With a distribution of over 20,000 species worldwide, only a tiny fraction, approximately 1.1 %, are commercially utilized (Sobuj et al., 2024). About 12 of these genera, including Hypnea, Gracilaria, Gelidium, Enteromorpha, Halimeda, Padina, Dictyota, Caulerpa, Hydroclathrus, Sargassum, Kappaphycus, and Porphyra have substantial commercial importance. Seaweeds are available along the whole Bangladeshi coast, mostly in St. Martin Island, Cox's Bazar and Sundarbans Mangrove forest. Total 193 seaweed species including 19 commercially important species, belonging to 94 genera are found (Islam et al., 2022). Due to seasonal variation in water quality parameters, generally seaweeds are available from October to April, but highest abundance occurs from January to March. Seaweeds influences on global carbon fixation through atmospheric, biotic, pedologic, geologic and oceanic pool (Satpati, G.G. et al., 2022). Seaweed extract (15%) was sprayed into the rice plants during

vegetative and generative stages. Extracts of Sargassum sp.1, Sargassum

sp.2, Sargassum polycistum, Hydroclathrus sp., Turbinaria ornata, and Turbinaria murayana, were able to induce growth of rice plants. Hydroclathrus sp. extract could enhance both growth and production of rice plants (Sunarpi et al., 2010). Seaweed extracts remaining potentiality on significantly enhance rice grain yield through foliar application. The study reported substantial yield increases of 41.47% and 34.99% when applying 15% Kappaphycus and Gracilaria extracts respectively, compared to control treatments (Pramanick et al., 2014). Seaweed stimulate to enhance nutrient uptake of nitrogen, phosphorus, and potassium, increased photosynthesis and stomatal conductance, and the presence of growth-promoting hormones in seaweed extracts (Thaimei et al., 2024; Pramanick et al., 2014). The beneficial effects can be attributed to the presence of bioactive compounds (phyto-hormones, amino acids, vitamins, and trace elements) that enhance physiological and biochemical processes in rice. These findings are in line with global research emphasizing the role of seaweed extracts as eco-friendly bio-stimulants for sustainable crop production. In Bangladesh, where sustainable intensification of rice production is crucial, seaweed extract foliar application could serve as a promising low-cost technology to improve productivity and resource-use efficiency.

## 2. MATERIALS AND METHODS

The experiment was carried out at the Field Laboratory of Agronomy Division, Bangladesh Institute of Nuclear Agriculture, head quarter farm Mymensingh, boro season during January to May 2021, 2022 and 2023. The experimental field was located at 24.750 N latitude and 90.500 E longitudes having an elevation of 18 m above from sea level. Experiment of Shyamnagar Satkhira located at Latitude: 22.3300° N Longitude: 89.1000° E having an elevation of 4 m above from sea level. Initial soil sample was randomly taken and analysis of composite sample to determine the soil morphological, physical and chemical characteristics of the experimental field.

**Table 1:** Soil morphological, physical and chemical characteristics of the experimental field

Morphological characteristics	Mymensingh	Reference
Agro-ecological zone (AEZ)	Old Brahmaputra Floodplain (AEZ 9)	Ganges Tidal Flood Plain (AEZ-13)
General Soil Type	Non-calcareous Dark Grey Floodplain Soils Parent material, Brahmaputra river borne deposits	Fluvaquentic endoaquepts and typic endoaquepts wetland soils common in tidal floodplains and riverine landscapes. Soils are generally <b>saline</b> , especially during the dry season and post-cyclonic events.
Topography	Medium high land and moderate drainage capacity	Shyamnagar features a <b>very flat and low-lying topography</b> , with average elevation around <b>4 meters above sea level</b>
Order	Inceptisol	Entisols
<b>Physical Characteristics</b>		
Sand	22.7	20.6
Silt	60.2	40.9
Clay	17.1	38.5
Textural Class	Silt loam	Silty clay
<b>Chemical characteristics</b>		
Interpretation pH	(soil : water=1:2.5) 6.5	USDA Handbook No. 60
Organic matter (%)	1.71	Walkley and Black, 1934
Low Total N	(%) 0.171	Subbiah and Asija, 1956
Low Available K	( c mol kg <sup>-1</sup> 0.08)	Olsen et al., 1954
Low Available P	(mg kg <sup>-1</sup> 2.78 )	Olsen et al., 1954
Very low Available S	(mg kg <sup>-1</sup> 14.12 )	Williams and Steinbergs, 1959
Low Available Zn	(mg kg <sup>-1</sup> 0.67 )	Lindsay and Norvell, 1978
Low Available B	(mg kg <sup>-1</sup> 0.23 )	Lindsay and Norvell, 1978
Low Available Cu	(mg kg <sup>-1</sup> 4.14 )	Lindsay and Norvell, 1978
High Available Mn	(mg kg <sup>-1</sup> 68.1 )	Lindsay and Norvell, 1978
High Available Fe	(mg kg <sup>-1</sup> 39.1 )	Lindsay and Norvell, 1978

## 2.1 Weather parameters

**Table 2:** Weather parameters during experimental periods January to May 2021, 2022 and 2023 average in Mymensingh, Bangladesh

Month	Temperature°C			Rainfall (mm)	RH (%)	Sunshine hours
	Min.	Max.	Average			
January	19	29	24	2.4	49	371
February	19	29	25	16.8	49	333
March	21	32	28	52.5	48	372
April	25	35	31	252.3	61	352
May	26	36	32	413.4	73	332

**Table 3:** Chemical properties of the soil at the experimental field of Shyamnagor, Satkhira

Chemical properties	Values
pH (1:5)	7.8
EC (1:5) (dS m <sup>-1</sup> )	8.7
Na <sup>+</sup> (meq L <sup>-1</sup> )	62
K <sup>+</sup> (meq L <sup>-1</sup> )	0.35
Ca <sup>2+</sup> (meq L <sup>-1</sup> )	5.7
Mg <sup>2+</sup> (meq L <sup>-1</sup> )	9.7
HCO <sub>3</sub> <sup>-</sup> (meq L <sup>-1</sup> )	7.4
Cl <sup>-</sup> (meq L <sup>-1</sup> )	45.3
SO <sub>4</sub> <sup>2-</sup> (meq L <sup>-1</sup> )	25.2
SAR (%)	19.4
ESP	33.2

**Table 4:** Weather parameters during experimental periods January to May 2021, 2022 and 2023 average in Shyamnagor, Satkhira, Bangladesh.

Growing period (month)	Days after transplanting (DAT)	Maximum temperature (°C) Range	Minimum temperature (°C) Range	Average temperature (°C)	Maximum relative humidity (%) range	Minimum relative humidity (%) range	Average relative humidity (%)	Average sunshine (minute)
January	0-30	19.5-27.8	5.6-17.1	16.8	77	24	78	709
February	31-58	19.5-33.6	5.6-20.8	22.8	77	19	72	570
March	59-89	30-35.6	15-25.6	28.6	77	20	71	660
April	90-119	28.4-37.2	19.4-29.8	29.6	78	37	73	817
May	120-127	31.8-36.2	21.4-28.6	30.2	92	45	79	738

## 2.2 Collection Of Seaweed

Seaweeds were meticulously gathered from the pristine waters of the Bay of Bengal, known for its diverse marine life. This research endeavor unfolded over a period, during which the changing seasons offered unique insights into the effects of seaweeds on agricultural practices.

**Table 5:** Chemical composition of seaweed species (*Caulerpa racemose*)

Parameters	<i>Caulerpa racemose</i>
Carbohydrate (%)	57.31
Protein (%)	12.62
Fat (%)	1.38
Ash (%)	13.29
K	2.74%
Ca	1.53%
Mg	1.22%
S	1.35%

## 2.3 Preparation Of Seaweed Extract

Seaweed that has been collected on each was weighed as much as 100 grams, cut into pieces and placed in the blender. After that, 100 mL of distilled water was added (ratio of 1:1 (w/v)), the mixture then blended until smooth, and filtered using filter paper. The slurry was centrifuged for 5 minutes at 4°C at 5000 rpm speed. Growth parameters observed were plant height, number of leaves, number of tillers and weight of stems and roots. Plant height was observed by measuring the plant height from the base of the clump which was exactly above the ground until the end of the highest grove. Number of leaves was observed by counting the

number of leaves on each clump, while number of tillers was observed by counting the number of puppies/tillers that grow from each clump. The observation was carried out from 14 days after planting, with intervals of 3 days, eight of stems and roots were measured after the completion of all others observation. Observations were conducted by calculating the fresh weight of plants. The crop yield parameters observed were the number of panicles, number of grains (seeds), weight per 100 seeds, and weight of seed per clump. The number of panicles was calculated by counting the number of panicles in each clump of plants per pot. All the data obtained are expressed in the form of an average of replication. Data were analyzed only by calculating the average value of three replications in each test, and presented in graphical form.

## 2.4 Season

Boro rice in Bangladesh is mainly grown during the dry season, from November to May. Proper land preparation is essential for successful rice production.

## 2.5 Land Selection

Soil with lowland characteristics, high fertility, and proper drainage was selected for the experiment.

## 2.6 Land preparation

Land preparation for boro rice transplanting should commence three weeks prior to planting. Begin by plowing the field three times and leveling it evenly. Then, incorporate 5 tons of decomposed farmyard manure per hectare to enhance soil health. Throughout the land preparation process, maintain a shallow water level of approximately 2 cm to soften the soil. Additionally, ensure that any excess water is drained before transplanting, as this will promote easier seedling establishment.

## 2.7 Weed and Pest Management

Weeds and previous crop residues should be collected to minimize pest infestations. To effectively minimize pest infestations, it is essential to

remove weeds and any remaining crop residues. Taking this proactive

## 2.8 Fertilizer Application

Applied the same fertilization and irrigation practices to all the plots to isolate the effect of *Caulerpa racemosa*. Basal fertilizers, including Urea, TSP (Triple Superphosphate), MOP (Muriate of Potash), gypsum, and zinc sulfate, were applied prior to the final plowing. The recommended application rates per hectare are as follows: Urea at 100 kg, TSP at 120 kg, MOP at 80 kg, Gypsum at 60 kg, and Zinc sulfate at 5 kg.

## 2.9 Preparation for Transplanting

Prepare raised seedbeds for healthy seedlings selected high-yielding and disease-resistant boro rice.

## 2.10 Treatments and Experimental Design

Establish plots of 20 m<sup>2</sup> each, utilizing a randomized complete block design (RCBD) to ensure replicability. Employ either direct seeding or transplanting in the plots, ensuring appropriate spacing of approximately 20 cm apart. Apply fertilizers uniformly across all plots in accordance with local recommendations. Maintain consistent water management by ensuring water levels suitable for boro rice cultivation. Record the number of panicles per plant at maturity. Harvest the rice once the grains have reached full maturity. Weight the total yield from each plot and calculate the average grain weight per panicle.

## 2.11 Data Analysis

Used ANOVA to assess the effects of treatments on rice yield and yield components and conducted LSD tests to determine significant differences

step will significantly enhance the health and yield of future crops.

between treatment means (Gomez et al., 1984).

## 3.RESULTS AND DISCUSSION

### 3.1 Effect of sea weed on yield and yield contributing characters of boro rice in Mymensingh during 2021

Application of seaweed as a basal dose showed noticeable effects on yield and yield-contributing characters of boro rice compared to the control. Plant height was not significantly influenced by treatments, ranging from 93.9 cm (T<sub>2</sub>) to 98.1 cm (T<sub>0</sub>). Total and effective tillers hill<sup>-1</sup> varied slightly, with the highest tiller number recorded at T<sub>3</sub> (12.6 and 10.9, respectively), indicating a positive tillering response at moderate doses. Panicle length was improved under seaweed application, reaching a maximum of 23.9 cm in T<sub>5</sub>, compared to 21.6 cm in the control. The number of filled grains panicle<sup>-1</sup> was significantly enhanced by seaweed, with T<sub>5</sub> producing the highest (172.8), showing nearly a 39% increase over the control. However, unfilled grains also increased at higher doses (T<sub>3</sub>-T<sub>6</sub>), suggesting that excessive application may lead to partial sink limitation. The 1000-grain weight remained statistically stable across treatments (20.3-21.5 g), reflecting limited influence of seaweed on grain size. Grain yield showed significant improvement, with the highest yield of 7.3 t ha<sup>-1</sup> recorded in T<sub>5</sub>, compared to 6.8 t ha<sup>-1</sup> in the control. Straw yield also increased at moderate levels (T<sub>3</sub>: 9.4 t ha<sup>-1</sup>). The harvest index ranged between 42.8-48.4%, with T<sub>2</sub> showing the highest efficiency. The results indicate that seaweed application enhanced panicle development, grain filling, and yield, with 1.0 t ha<sup>-1</sup> (T<sub>5</sub>) being the most effective dose (Table 6)

**Table 6:** Effect of sea weed as a basal dose (*Caulerpa racemosa*) on yield and yield contributing characters of boro rice in Mymensingh during 2021

Treatments	Plant height (cm)	Total tiller hill <sup>-1</sup> (no.)	Effective tillers hill <sup>-1</sup> (no.)	Panicle length (cm)	Filled grain panicle <sup>-1</sup> (no)	Unfilled grain panicle <sup>-1</sup> (no)	1000 seed wt. (g)	Grain yield (t ha <sup>-1</sup> )	Straw yield (t ha <sup>-1</sup> )	Harvest index (%)
<b>Basal doses</b>										
Control (T <sub>0</sub> )	98.1	11.8	11.0	21.6	124.7	27.2	20.3	6.8	8.3	44.9
0.50 t ha <sup>-1</sup> (T <sub>1</sub> )	96.3	11.2	10.6	21.3	104.1	25.0	21.2	7.2	8.8	45.7
0.625 t ha <sup>-1</sup> (T <sub>2</sub> )	93.9	10.8	10.0	22.6	118.0	33.0	20.6	7.2	7.8	48.4
0.75 t ha <sup>-1</sup> (T <sub>3</sub> )	96.7	12.6	10.9	23.5	117.3	45.6	21.2	7.0	9.4	42.8
0.875 t ha <sup>-1</sup> (T <sub>4</sub> )	96.2	10.2	9.7	23.6	126.7	40.1	21.5	6.8	8.5	44.3
1.00 t ha <sup>-1</sup> (T <sub>5</sub> )	95.5	11.3	10.7	23.9	172.8	39.5	20.9	7.3	8.8	45.6
1.25 t ha <sup>-1</sup> (T <sub>6</sub> )	97.7	10.8	10.3	23.1	122.3	48.3	20.6	7.2	8.5	45.7
LSD <sub>0.05</sub>	2.7	2.8	2.7	0.8	19.3	7.0	1.2	0.5	1.4	3.8
CV (%)	1.6	14.0	14.4	2.0	8.5	10.7	3.1	3.6	9.4	4.7

**Note:** Control (T<sub>0</sub>), 0.50 t ha<sup>-1</sup> (T<sub>1</sub>), 0.625 t ha<sup>-1</sup> (T<sub>2</sub>), 0.75 t ha<sup>-1</sup> (T<sub>3</sub>), 0.875 t ha<sup>-1</sup> (T<sub>4</sub>), 1.00 t ha<sup>-1</sup> (T<sub>5</sub>), 1.25 t ha<sup>-1</sup> (T<sub>6</sub>). Binadhan-24

Grain yield and filled grain count peaked at 1.00 t ha<sup>-1</sup> (T<sub>5</sub>), suggesting this dose may be optimal. Panicle length and harvest index showed strong performance at 0.625 t ha<sup>-1</sup> (T<sub>2</sub>) and 1.25 t ha<sup>-1</sup> (T<sub>6</sub>). Unfilled grains were highest at 1.25 t ha<sup>-1</sup> (T<sub>6</sub>) and 0.75 t ha<sup>-1</sup> (T<sub>3</sub>), indicating potential

inefficiencies at those levels (Fig.1).

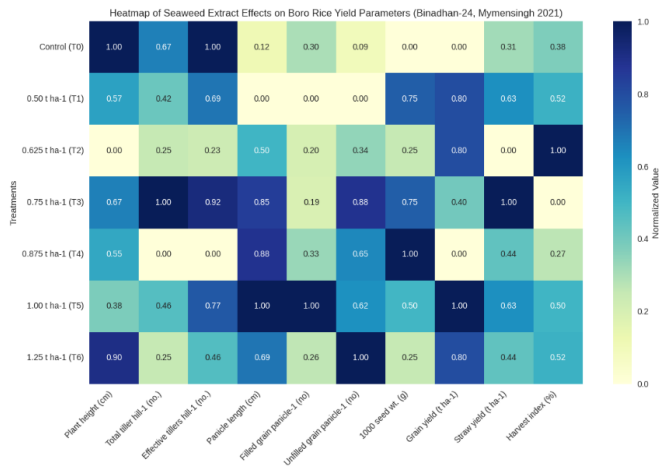


Figure 1: Effect of sea weed as a basal dose in Mymensingh during 2021

Seaweed application significantly influenced most growth and yield parameters compared with the control treatment. Plant height varied from 93.1 cm (control) to 95.9 cm (T4: 0.875 L ha<sup>-1</sup>). The tallest plants in T4 may be attributed to enhanced hormonal activity such as auxins and cytokinins present in seaweed extracts, which stimulate cell elongation and division. Total tillers hill<sup>-1</sup> ranged from 10.9 (T0) to 12.9 (T6), while effective tillers hill<sup>-1</sup> varied from 10.2 (T0) to 11.9 (T6). Treatments T2, T3, and T6 produced significantly more effective tillers than the control. The stimulation of tillering may be linked to increased cytokinin activity and better nutrient assimilation promoted by seaweed bioactives. This finding aligns with the observations of who reported that seaweed extracts enhance tiller initiation and survival by improving assimilate partitioning (Crouch and van Staden, 1993). Panicle length significantly improved under seaweed treatments, with the longest panicles recorded

in T5 (23.2 cm) followed by T4 (22.9 cm), compared to 21.0 cm in control.

Longer panicles are often associated with higher sink capacity and potential for greater grain filling, suggesting that seaweed extract improved panicle development. The number of filled grains panicle<sup>-1</sup> was highest in T2 (124.7) and T4 (124.2), while the lowest was recorded in T5 (109.3). Conversely, the number of unfilled grains panicle<sup>-1</sup> was highest in control (43.1) and lowest in T6 (30.4). These results indicate that seaweed extract enhanced grain setting and reduced sterility, possibly due to improved pollen viability and carbohydrate supply during anthesis and grain filling. The 1000-seed weight ranged narrowly between 20.1–21.1 g, with the highest values in T4 and T6. The relatively stable trend suggests that seed size was less responsive to seaweed extracts than grain number, which is consistent with earlier findings that seaweed mainly enhances tillering and grain filling rather than grain size (Kumar and Sahoo, 2011). Grain yield was markedly increased by seaweed spray. The control yielded 6.3 t ha<sup>-1</sup>, while the highest yield was obtained in T5 (7.4 t ha<sup>-1</sup>), followed closely by T3, T4, and T6 (7.1 t ha<sup>-1</sup>). The increase in yield can be attributed to more effective tillers, longer panicles, and higher filled grains per panicle. Straw yield ranged from 8.6–9.5 t ha<sup>-1</sup>, with the highest in T2 (9.5 t ha<sup>-1</sup>). Harvest index values ranged from 41.5% (T2) to 45.7% (T5). The highest HI in T5 indicates improved partitioning of assimilates towards grain rather than vegetative growth, reflecting the efficiency of seaweed extract in enhancing reproductive allocation. Among the treatments, T5 (1.0 L ha<sup>-1</sup>) produced the maximum grain yield and harvest index, while T2 and T4 showed superior panicle length and filled grains. It can be inferred that moderate to higher doses of seaweed extract (0.75–1.0 L ha<sup>-1</sup>) are beneficial for enhancing both yield attributes and final productivity of boro rice in Mymensingh conditions. Previous studies support these findings, indicating that seaweed extracts improve rice growth and yield through multiple mechanisms, including hormonal stimulation, enhanced photosynthetic efficiency, and better nutrient uptake (Khan et al., 2009; Kumar et al., 2011). The reduction in unfilled grains and improvement in harvest index also suggest physiological stress mitigation, as reported by in cereals (Table 7) (Zodape et al., 2011).

**Table 7: Effect of sea weed extracts as spraying in active tillering stage (*Caulerpa racemose*) on yield and yield contributing characters of boro rice in Mymensingh during 2021**

Treatments	Plant height (cm)	Total tiller hill <sup>-1</sup> (no.)	Effective tillers hill <sup>-1</sup> (no.)	Panicle length (cm)	Filled grain panicle <sup>-1</sup> (no)	Unfilled grain panicle <sup>-1</sup> (no)	1000 seed wt. (g)	Grain yield (t ha <sup>-1</sup> )	Straw yield (t ha <sup>-1</sup> )	Harvest index (%)
<b>Basal doses</b>										
Control (T <sub>0</sub> )	93.1	10.9	10.2	21.0	117.9	43.1	20.1	6.3	8.9	41.6
0.50 L ha <sup>-1</sup> (T <sub>1</sub> )	94.0	11.5	10.7	20.7	115.3	40.7	20.6	6.5	8.6	43.4
0.625 L ha <sup>-1</sup> (T <sub>2</sub> )	94.7	12.3	11.5	22.0	124.7	35.3	21.0	6.7	9.5	41.5
0.75 L ha <sup>-1</sup> (T <sub>3</sub> )	95.3	12.7	11.2	22.8	122.3	38.6	20.6	7.1	9.4	43.1
0.875 L ha <sup>-1</sup> (T <sub>4</sub> )	95.9	11.8	10.7	22.9	124.2	43.3	21.1	7.1	9.1	44.2
1.00 L ha <sup>-1</sup> (T <sub>5</sub> )	95.6	12.3	10.9	23.2	109.3	35.0	20.6	7.4	8.9	45.7
1.25 L ha <sup>-1</sup> (T <sub>6</sub> )	94.5	12.9	11.9	22.4	105.9	30.4	21.0	7.1	8.8	44.6
LSD <sub>0.05</sub>	3.1	2.0	1.9	0.8	15.1	9.7	1.0	0.4	1.4	4.9
CV (%)	1.8	9.3	9.7	2.0	7.3	14.3	2.6	3.5	8.8	6.3

Note: Control (T0), 0.50 L ha<sup>-1</sup> (T1), 0.625 L ha<sup>-1</sup> (T2), 0.75 L ha<sup>-1</sup> (T3), 0.875 L ha<sup>-1</sup> (T4), 1.00 L ha<sup>-1</sup> (T5), 1.25 L ha<sup>-1</sup> (T6). Test crop Binadhan-24

Grain yield peaked at 1.00 L ha<sup>-1</sup> (T5), suggesting this dose may be optimal for productivity. Effective tillers and harvest index were highest at 1.25 L ha<sup>-1</sup> (T6), indicating strong physiological response. Unfilled grains dropped notably at higher doses, especially T6, which may reflect improved grain filling (Fig.2).

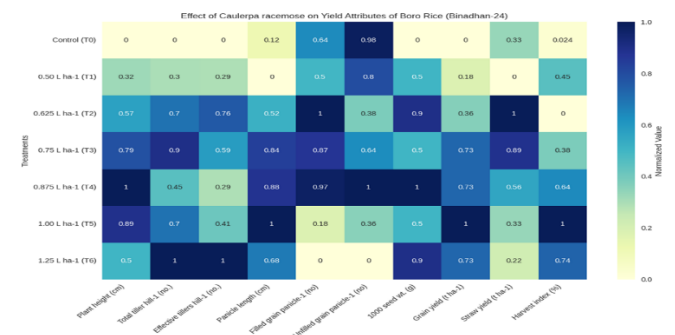


Figure 2: Effect of sea weed as spray in Mymensingh during 2021

### 3.2 Effect of sea weed on yield and yield contributing characters of boro rice in saline soil Satkhira during 2021

The application of seaweed as a basal dose showed notable effects on yield and yield-attributing characters of boro rice grown in saline soil at (Satkhira during, 2021). Plant height remained fairly uniform (100.8–103.5 cm) across treatments, indicating that basal seaweed application had limited influence on vegetative elongation. Tillering ability showed slight improvement with seaweed application. Total tillers hill<sup>-1</sup> ranged between 8.6–9.7, while effective tillers hill<sup>-1</sup> varied between 8.3–8.9, compared with 9.4 and 8.9 in control, suggesting marginal effects on tiller survival. Panicle length ranged from 24.9 cm (T2) to 26.9 cm (T6), with slight increases under higher doses (T3, T6). This reflects some positive influence of seaweed on panicle development. Filled grains panicle<sup>-1</sup> were highest in T3 (134.8) and T4 (114.1) compared to 86.4 in control, indicating enhanced reproductive success. Conversely, unfilled grains were lowest in T1 (45.0) and highest in T5 (77.0), showing that optimal

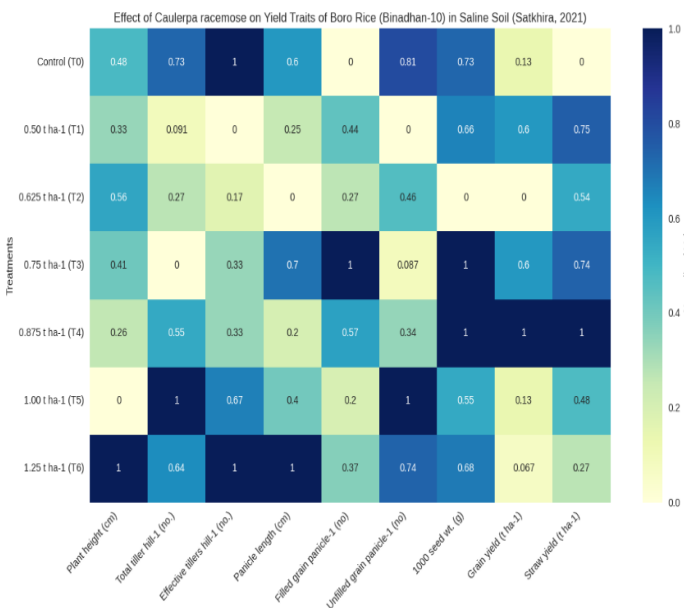
rather than excessive doses are more effective in reducing spikelet sterility under salinity stress. Seed weight remained stable across treatments (20.3–24.7 g), with the highest in T3 and T4 (24.7 g), suggesting seaweed may improve grain plumpness. Grain yield improved significantly with seaweed application, ranging from 4.1 t ha<sup>-1</sup> (T2) to 5.6 t ha<sup>-1</sup> (T4), compared with 4.3 t ha<sup>-1</sup> in control. The best performance was obtained in T4 (0.875 t ha<sup>-1</sup>), which produced about 30% higher grain yield over control. Straw yield increased notably, with the maximum in T5 (15.5 t ha<sup>-1</sup>) and T6 (14.8 t ha<sup>-1</sup>) compared to 8.1 t ha<sup>-1</sup> in control, suggesting that higher doses favored vegetative biomass accumulation more than grain productivity (Table 8). The results demonstrate that moderate doses (0.75–0.875 t ha<sup>-1</sup>) of seaweed extract were most effective in enhancing yield and yield attributes, particularly by improving filled grains and reducing spikelet sterility. Excessive application ( $\geq 1.0$  t ha<sup>-1</sup>) tended to favor straw production at the expense of grain yield, which indicates the importance of dose optimization.

**Table 8:** Effect of sea weed as a basal dose (*Caulerpa racemosa*) on yield and yield contributing characters of boro rice in saline soil Satkhira during 2021.

Treatments	Plant height (cm)	Total tiller hill <sup>-1</sup> (no.)	Effective tillers hill <sup>-1</sup> (no.)	Panicle length (cm)	Filled grain panicle <sup>-1</sup> (no)	Unfilled grain panicle <sup>-1</sup> (no)	1000 seed wt. (g)	Grain yield (t ha <sup>-1</sup> )	Straw yield (t ha <sup>-1</sup> )
<b>Basal doses</b>									
Control (T <sub>0</sub> )	102.1	9.4	8.9	26.1	86.4	70.8	23.5	4.3	5.05
0.50 t ha <sup>-1</sup> (T <sub>1</sub> )	101.7	8.7	8.3	25.4	107.5	45.0	23.2	5.0	6.15
0.625 t ha <sup>-1</sup> (T <sub>2</sub> )	102.3	8.9	8.4	24.9	99.3	59.8	20.3	4.1	5.85
0.75 t ha <sup>-1</sup> (T <sub>3</sub> )	101.9	8.6	8.5	26.3	134.8	47.8	24.7	5.0	6.14
0.875 t ha <sup>-1</sup> (T <sub>4</sub> )	101.5	9.2	8.5	25.3	114.1	55.8	24.7	5.6	6.52
1.00 t ha <sup>-1</sup> (T <sub>5</sub> )	100.8	9.7	8.7	25.7	95.9	77.0	22.7	4.3	5.75
1.25 t ha <sup>-1</sup> (T <sub>6</sub> )	103.5	9.3	8.9	26.9	104.1	68.6	23.3	4.2	5.45
LSD <sub>0.05</sub>	3.8	1.2	0.8	2.3	8.4	9.2	1.7	0.4	2.24
CV (%)	2.1	7.3	5.3	4.9	4.5	8.5	4.2	4.2	10.3

**Note:** Control (T<sub>0</sub>), 0.50 t ha<sup>-1</sup> (T<sub>1</sub>), 0.625 t ha<sup>-1</sup> (T<sub>2</sub>), 0.75 t ha<sup>-1</sup> (T<sub>3</sub>), 0.875 t ha<sup>-1</sup> (T<sub>4</sub>), 1.00 t ha<sup>-1</sup> (T<sub>5</sub>), 1.25 t ha<sup>-1</sup> (T<sub>6</sub>). Test crop Binadhan-10

Grain yield and filled grain count were highest at 0.875 t ha<sup>-1</sup> (T<sub>4</sub>) and 0.75 t ha<sup>-1</sup> (T<sub>3</sub>), suggesting these doses may be optimal. Unfilled grains peaked at 1.00 t ha<sup>-1</sup> (T<sub>5</sub>), possibly indicating stress or inefficiency at that level. Panicle length and seed weight showed strong performance at 1.25 t ha<sup>-1</sup> (T<sub>6</sub>) and 0.75 t ha<sup>-1</sup> (T<sub>3</sub>) (Fig.3).



**Figure 3:** Effect of sea weed as a basal dose in Satkhira during 2021

The application of seaweed extract (*Caulerpa racemosa*) as foliar spray during the active tillering stage influenced the yield and yield-attributing characters of boro rice under saline soil conditions in Satkhira. Plant height varied slightly across treatments (101.9–107.0 cm) with no consistent trend, indicating that seaweed spraying had limited impact on elongation under saline stress. Tillering ability improved with seaweed application, as total tillers hill<sup>-1</sup> ranged from 8.7 (T<sub>3</sub>, T<sub>5</sub>) to 10.5 (T<sub>6</sub>) compared with 8.8 in control. Similarly, effective tillers hill<sup>-1</sup> were higher in T<sub>2</sub> (9.5) and T<sub>6</sub> (9.9), showing the positive effect of bioactive compounds in seaweed that stimulate tiller survival. Panicle length increased modestly, reaching the maximum in T<sub>4</sub> (26.6 cm) compared to 25.0 cm in control, suggesting improved assimilate supply to reproductive organs. For grain filling, the highest number of filled grains panicle<sup>-1</sup> was observed in T<sub>5</sub> (132.2), followed by T<sub>1</sub> (119.4), while the control produced only 94.3. Conversely, unfilled grains were highest in T<sub>4</sub> (83.9) and lowest in T<sub>5</sub> (49.5), highlighting that moderate doses of seaweed helped reduce sterility under saline stress. Seed weight (1000-seed wt.) remained relatively stable (20.8–24.4 g), with a slight advantage in T<sub>3</sub> (24.4 g) and T<sub>5</sub> (23.5 g). Grain yield increased significantly with seaweed application, ranging from 3.9 t ha<sup>-1</sup> in control to 5.0 t ha<sup>-1</sup> in T<sub>5</sub>. Treatments T<sub>6</sub> (4.7 t ha<sup>-1</sup>) and T<sub>1</sub>–T<sub>3</sub> (4.3–4.4 t ha<sup>-1</sup>) also showed improvement, indicating a consistent positive response. Straw yield was highest in T<sub>1</sub> and T<sub>4</sub> (6.8 t ha<sup>-1</sup>) compared with 6.25 t ha<sup>-1</sup> in control, reflecting enhanced biomass accumulation under treated plots (Table 9). Overall, the results suggest that moderate doses (0.75–1.0 t ha<sup>-1</sup>) of seaweed extract are effective in enhancing yield and yield attributes of boro rice under saline conditions. The improvement is likely due to the combined effects of bioactive compounds, better nutrient uptake, and

hormonal stimulation, which helped reduce spikelet sterility and improve

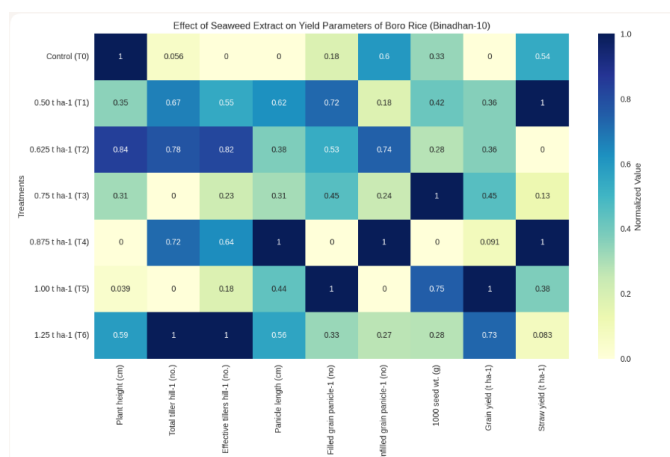
grain filling, consistent with earlier reports (Khan et al., 2009).

**Table 9:** Effect of sea weed extracts as spraying in active tillering stage (*Caulerpa racemosa*) on yield and yield contributing characters of boro rice in saline soil Satkhira during 2021.

Treatments	Plant height (cm)	Total tiller hill <sup>-1</sup> (no.)	Effective tillers hill <sup>-1</sup> (no.)	Panicle length (cm)	Filled grain panicle <sup>-1</sup> (no)	Unfilled grain panicle <sup>-1</sup> (no)	1000 seed wt. (g)	Grain yield (t ha <sup>-1</sup> )	Straw yield (t ha <sup>-1</sup> )
<b>Basal doses</b>									
Control (T <sub>0</sub> )	107.0	8.8	7.7	25.0	94.3	70.1	22.0	3.9	6.25
0.50 t ha <sup>-1</sup> (T <sub>1</sub> )	103.7	9.9	8.9	26.0	119.4	55.6	22.3	4.3	6.8
0.625 t ha <sup>-1</sup> (T <sub>2</sub> )	106.2	10.1	9.5	25.6	110.5	75.1	21.8	4.3	5.6
0.75 t ha <sup>-1</sup> (T <sub>3</sub> )	103.5	8.7	8.2	25.5	106.8	57.8	24.4	4.4	5.75
0.875 t ha <sup>-1</sup> (T <sub>4</sub> )	101.9	10.0	9.1	26.6	85.7	83.9	20.8	4.0	6.8
1.00 t ha <sup>-1</sup> (T <sub>5</sub> )	102.1	8.7	8.1	25.7	132.2	49.5	23.5	5.0	6.05
1.25 t ha <sup>-1</sup> (T <sub>6</sub> )	104.9	10.5	9.9	25.9	101.1	58.9	21.8	4.7	5.7
LSD <sub>0.05</sub>	5.3	1.3	1.0	2.2	8.6	6.4	1.7	0.9	2.0
CV (%)	2.9	7.5	6.0	4.6	4.5	5.6	4.3	11.5	9.5

**Note:** Control (T<sub>0</sub>), 0.50 L ha<sup>-1</sup> (T<sub>1</sub>), 0.625 L ha<sup>-1</sup> (T<sub>2</sub>), 0.75 L ha<sup>-1</sup> (T<sub>3</sub>), 0.875 L ha<sup>-1</sup> (T<sub>4</sub>), 1.00 L ha<sup>-1</sup> (T<sub>5</sub>), 1.25 L ha<sup>-1</sup> (T<sub>6</sub>). Test crop Binadhan-10

Grain yield and filled grain count peaked at 1.00 t ha<sup>-1</sup> (T<sub>5</sub>), suggesting this dose may be optimal. Unfilled grains were highest at 0.875 t ha<sup>-1</sup> (T<sub>4</sub>), indicating potential stress or inefficiency at that level. Total and effective tillers improved with moderate doses like 0.625–1.25 t ha<sup>-1</sup>, showing positive growth response (Fig. 4).



**Figure 4:** Effect of sea weed as spray in Satkhira during 2021

#### 4. CONCLUSION

The application of *Caulerpa racemosa* has significant potential to enhance the yield and yield components of boro rice. Its role is not merely as a nutrient provider but also as a powerful biostimulant that improves the overall physiological efficiency of the rice plant. The most promising approach appears to be an integrated nutrient management strategy, combining a reduced dose of chemical fertilizer with *C. racemosa* compost. This strategy could maintain or even boost yields while substantially reducing reliance on synthetic inputs, thereby promoting a more sustainable and environmentally sound rice production system.

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