**Unlocking the Potentiality of Seaweed Extract Based Bio stimulant (Crop Plus) for Rice Yield Enhancement**

**ABSTRACT**

Seaweed extract, a bio stimulant, promotes various metabolic processes that enhance plant growth and development. Seaweed extract is increasingly gaining popularity as a sustainable tool for crop growth and yield enhancement. It is well documented in world literature that alginic acid present in seaweed extracts influences photosynthesis rate, protein synthesis, nutrient uptake and enzymatic activities resulting in increased crop growth and yield. Despite the high potentiality many farmers are not getting the expected harvest from the application of seaweed extract to their crop mostly due to not following the proper application schedule. To address this issue, an experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, in the monsson season 2023. The study aimed to investigate into the effect of different foliar application schedules of the seaweed extract-based bio stimulant ‘Crop Plus’ (a commercial formulation marketed by Haychem Bangladesh Ltd.) on Monsoon rice, using a randomized complete block design with three replications. Two rice varieties namely BRRI dhan75 and BRRI dhan87 and six application schedules such as no Crop Plus (control), Crop Plus applied at 40 and 60 days after transplanting (DAT), at 30 and 60 DAT, at 20 and 60 DAT, at 20, 40, and 60 DAT, and at 30, 45, and 60 DAT were considered as treatments. A positive impact of seaweed extract application on rice growth and yield was evident and the variety BRRI dhan75 demonstrated a better response to Crop Plus than BRRI dhan87. Application schedule of Crop Plus also influenced rice growth and yield. Application of Crop Plus at early stage was found more effective than application at later stages. Foliar spraying with seaweed extract-based bio stimulant Crop Plus @ 500 ml ha-1 at 20 and 60 DAT appeared as the best application schedule for rice yield enhancement. Therefore, it is suggested to explore the potentiality of seaweed extract as a sustainable tool for rice yield improvement.

*Keywords: Seaweed extract, bio stimulant, alginic acid, application schedule, grain yield, paddy.*

# 1. INTRODUCTION

Rice (*Oryza sativa*) is the most important cereal crop globally and a staple food for more than half of the world’s population. Beyond its role in food security, rice also holds cultural, traditional, and economic significance, particularly in Asia. Bangladesh is one of the largest producers and consumers of rice, where it is the primary food source for approximately 169.8 million people (BBS, 2021).

The country cultivates rice in three seasons: *Aus* (March–July), *Aman* (July–December) and *Boro* (December–May), with *Aman* rice accounting for nearly 48% of the total area (BBS, 2021). Despite achieving self-sufficiency and entering the rice export market (BER, 2015), Bangladesh still lags in average yield approximately 3 tons ha-1 which is below the global average. To meet the projected population of 238 million by 2050, increasing rice productivity is imperative.

One major constraint in rice production is declining soil fertility, exacerbated by intensive cultivation and imbalanced fertilizer use. While synthetic fertilizers help mitigate macronutrient deficiencies, micronutrient deficiencies remain widespread due to their low application rates and farmers' limited capacity to assess soil health accurately (Singh *et al.,* 2017). Mismanagement of micronutrients not only leads to reduced productivity but may also degrade soil quality. Hence, a shift towards sustainable inputs like bio stimulant, bio-fertilizers and bio-agents is increasingly necessary.

PGRs are organic compounds that influence physiological processes such as cell division, elongation and enzyme activation (Soomro *et al.,* 2020). Despite their proven benefits such as increasing the number of panicles and improving crop resilience (Banful & Attivor, 2017), their use in Bangladesh’s rice cultivation remains limited. Seaweed-based biostimulants offer a promising alternative. Seaweed extracts are acquiring acknowledgment for their prospective use in organic and sustainable agriculture (Layek *et al*., 2018). Seaweeds are rich in growth regulators like cytokinins, auxins, gibberellins and essential nutrients and they have been shown to improve nutrient uptake, stress tolerance and yield (Khan *et al*., 2009; Sasi *et al*., 2021).

Liquid seaweed extracts, such as Crop Plus (marketed by Haychem Bangladesh Limited), are gaining attention as sustainable bio-stimulants. Crop Plus contains alginic acid (15–25%), which enhances nutrient absorption by reducing water surface tension and increasing foliar uptake (Nayak *et al.,* 2020). Application of such extracts has been associated with 15–25% yield improvements in rice. Moreover, while seaweed-based biostimulants Crop Plus, enhanced yields by 15–25% and improved nutrient uptake and stress tolerance, humic biostimulants raised rice yield by 7.4–15% across a multitude of development stages and environmental circumstances (Izquierdo *et al*., 2024)

Research indicates that the timing and method of PGR application are critical. For instance, applying indole-3-acetic acid (IAA) at 50 ppm during tillering and anthesis stages can significantly increase grain yield and dry matter production (Tang *et al*., 2024). Similarly, pre-transplant foliar spraying improves root growth and plant vigour.

Given the need to improve rice productivity and sustainably, the study was undertaken to (i) assess the efficacy of the bio stimulant Crop Plus on the growth and yield of Monsoon rice, (ii) evaluate varietal response of Monsoon rice (BRRI dhan75 and BRRI dhan87) to Crop Plus and (iii) identify the most suitable application schedule for maximizing yield and economic return.

# 2. MATERIALS AND METHODS

# 2.1 Experimental site and soil

The experiment was conducted at the Old Brahmaputra Floodplain (AEZ-9) in Bangladesh, on a non-calcareous dark grey silty clay loam soil with a pH of 6.5 and low organic matter content. The experimental field had neutral pH (6.8), low organic matter (1.37%), and generally poor fertility, with low levels of nitrogen, phosphorus, potassium, sulfur, and zinc. The site experienced a tropical climate with high temperatures, humidity, and rainfall from April to September, and cooler, drier conditions from October to March. During the 2023–2024 growing season (December–May), the monthly average maximum and minimum temperatures ranged from 24.2 to 320C and 13.6 to 25.80C, respectively with monthly average 72.8-83.5% relative humidity and 2.48-472.5 mm total monthly rainfall.

**2.2 Description of the Materials Used**

**2.2.1 Plant material**

Two short-duration, early maturing Monsoon rice varieties-BRRI dhan75 and BRRI dhan87-were used. BRRI dhan75 matures in 110–115 days with a yield potential above 5 t ha-1, while BRRI dhan87 matures in 120–130 days, yields about 6.5 t ha-1, and has strong nodes to prevent lodging.

**2.2.2 Crop Plus**

The foliar fertilizer Crop Plus (marketed by Haychem Bangladesh Ltd.), containing 15–25% alginic acid, was applied as a bio stimulant and nutrient supplement. Other chemical composition of Crop Plus is: total nitrogen: 8%; potash: 4%; phosphate: 2%; Fe: 1.56%; Mn:1.56%; Mg: 1% and other trace elements.

# 2.3 Experimental treatments and design

The experiment followed a randomized complete block design (RCBD) with three replications, comprising 12 treatment combinations. These treatments were based on two rice varieties (BRRI dhan75 and BRRI dhan87) and six Crop Plus application schedules: (1) control (no Crop Plus), (2) application at 20 days after transplanting (DAT), (3) at 30 DAT, (4) at 40 DAT, (5) at 45 DAT and (6) at 60 DAT. Each treatment was applied at a rate of 500 ml/ha. Each plot measured 10 m².

# 2.4 Land preparation and fertilizer application

Land preparation involved ploughing, levelling, and puddling, followed by the application of basal fertilizers-muriate of potash (MoP) at 105 kg ha-1, triple super phosphate (TSP) at 60 kg ha-1, gypsum at 67 kg ha-1 and zinc sulphate at 10 kg ha-1-with urea (260 kg ha-1) applied in three splits at 20, 30 and 45 DAT.

# 2.5 Seed sowing

Forty-day-old seedlings were transplanted at a spacing of 25×15 cm, with three seedlings per hill.

# 2.6 Intercultural operation

Standard crop management practices were followed, including gap filling, hand weeding (at 20, 40 and 60 DAT), irrigation at flowering, bird protection and regular monitoring.

# 2.7 Harvesting

Harvesting was done at full maturity when more than 80% of the grains turned golden yellow, with BRRI dhan75 harvested on October 25 and BRRI dhan87 on November 6.

# 2.8 Methods of data collection

Five hills plot-1 were sampled for data collection and the entire plot was harvested, threshed and dried to 14% moisture content. Growth and yield data were recorded, including plant height, tiller number, grains panicle-1, sterility percentage, 1000-grain weight, grain and straw yields and harvest index.

# 2.9 Statistical analysis

Statistical analysis was performed using ANOVA in MSTAT and mean differences were evaluated with Duncan’s Multiple Range Test (DMRT).

# 3. RESULTS AND DISCUSSION

# 3.1 Effect of variety on growth characters of Monsoon rice

The study found that the growth characters of Monsoon rice were influenced by variety, with BRRI dhan75 generally outperforming BRRI dhan87. Additionally, the total number of tillers hill-1 was significantly higher in BRRI dhan75 compared to BRRI dhan87 at all observed stages (30, 45, 60 DAT and harvest) (Table 2), which is likely due to the genetic potential of BRRI dhan75 for greater tiller production (Khatri, 2015).

# Table 1. Effect of variety on plant height of Monsoon rice at different days after transplanting

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variety | Plant height (cm) at different days after transplanting | | | |
| 30 DAT | 45 DAT | 60 DAT | At harvest |
| BRRI dhan75 | 47.50 | 82.78a | 103.06a | 109.27a |
| BRRI dhan87 | 45.18 | 75.33 b | 93.56 b | 102.38 b |
| Sx | 1.25 | 1.41 | 1.53 | 1.70 |
| Level of significance | NS | \*\* | \*\* | \*\* |
| CV (%) | 8.07 | 5.35 | 4.66 | 4.81 |

*\*\* =Significant at 1% level of probability, NS = Not-significant*

*In a column, figures with same letter or without letter do not differ significantly whereas figure with dissimilar letter differ significantly as per DMRT.*

# Table 2. Effect of variety on the tillering ability of Monsoon Rice at different days after transplanting

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variety | Total number of tillers hill-1 at different days after transplanting (DAT) | | | |
| 30 DAT | 45 DAT | 60 DAT | At harvest |
| BRRI dhan75 | 14.07a | 18.20a | 19.95a | 18.87a |
| BRRI dhan87 | 12.35 b | 16.29b | 17.84b | 16.47 b |
| Sx | 0.44 | 0.38 | 0.42 | 0.38 |
| Level of significance | \*\* | \*\* | \*\* | \*\* |
| CV (%) | 9.93 | 6.57 | 6.71 | 6.43 |

\*\* =Significant at 1% level of probability

V1= BRRI dhan75

V2= BRRI dhan87

In a column, figures with same letter or without letter do not differ significantly whereas figure with dissimilar letter differ significantly as per DMRT

# 3.2 Effect of application schedule of Crop Plus on growth characters of Monsoon rice

It was observed that, Crop Plus application increased plant height of rice compared to no use of Crop Plus. On an average plant height was increased by 10 cm due to Crop Plus application.

The number of total tillers hill-1 differed significantly at harvest, while no significant differences were observed at 30, 45 and 60 days after transplanting due to the application schedule of Crop Plus (Table 4). The results showed that application of Crop Plus at 20 and 60 DAT produced the highest number of total tillers hill-1 (18.66) and it produced the lowest number of total tillers hill-1 (16.61) at without use of Crop plus (Table 4). The number of total tillers hill-1 increased with the advancement of time up to 60 DAT due to the absorption of more nutrient, moisture and for availability of more sunlight and the reduction after 60 DAT might be due to the death and destruction of some unhealthy tillers (Soomro, 2020). Micronutrients feeding to leaves significantly increased rice yield components and yield has also been documented by (Lahijani *et al.*, 2020).

# Table 3. Effect of application schedule Crop Plus on plant height of Monsoon rice at different days after transplanting

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Application schedule | Plant height (cm) at different days after transplanting (DAT) | | | |
| 30 DAT | 45 DAT | 60 DAT | At harvest |
| No Crop plus | 44.76 | 74.03 b | 91.22 b | 100.88 b |
| Crop plus at 40 and 60 DAT | 44.83 | 73.88 b | 96.82ab | 104.08ab |
| Crop plus at 30 and 60 DAT | 44.71 | 80.65ab | 98.78ab | 103.97ab |
| Crop plus at 20 and 60 DAT | 49.75 | 82.48a | 98.02ab | 108.80ab |
| Crop plus at 20, 40 and 60 DAT | 49.65 | 83.20a | 102.53a | 110.28a |
| Crop plus at 30, 45 and 60 DAT | 44.33 | 80.13ab | 102.47a | 106.92ab |
| Sx | 2.16 | 2.44 | 2.64 | 2.94 |
| Level of significance | NS | \*\* | \*\* | \* |
| CV (%) | 8.07 | 5.35 | 4.66 | 4.81 |

\*\* =Significant at 1% level of probability, \* =Significant at 5% level of probability, NS = Not-significant

T1= No Crop plus, T2= Crop plus at 40 and 60 DAT, T3= Crop plus at 30 and 60 DAT, T4= Crop plus at 20 and 60 DAT, T5= Crop plus at 20, 40 and 60 DAT, T6= Crop plus at 30, 45 and 60 DAT; In a column, figures with same letter or without letter do not differ significantly whereas figure with dissimilar letter differ significantly as per DMRT.

# Table 4. Effect of application schedule of Crop Plus on the tillering ability of Monsoon rice at different days after transplanting

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Application schedule | Total number of tillers hill-1 at different days after transplanting (DAT) | | | |
| 30 DAT | 45 DAT | 60 DAT | At harvest |
| No Crop plus | 12.43 | 16.41 | 17.68 | 16.21 b |
| Crop plus at 40 and 60 DAT | 13.25 | 17.26 | 18.76 | 17.81ab |
| Crop plus at 30 and 60 DAT | 13.11 | 16.93 | 18.63 | 17.13ab |
| Crop plus at 20 and 60 DAT | 13.56 | 17.78 | 19.88 | 18.66a |
| Crop plus at 20, 40 and 60 DAT | 13.81 | 17.91 | 19.53 | 18.65a |
| Crop plus at 30, 45 and 60 DAT | 13.11 | 17.18 | 18.90 | 17.55ab |
| Sx | 0.75 | 0.65 | 0.73 | 0.66 |
| Level of significance | NS | NS | NS | \*\* |
| CV (%) | 9.93 | 6.57 | 6.71 | 6.43 |

\*\* =Significant at 1% level of probability, NS = Not-significant

# 3.3 Effect of interaction between variety and application schedule of Crop Plus on growth characters of Monsoon rice

The interaction between rice variety and Crop Plus application significantly affected plant height from 45 days after transplanting onward (Table 5). BRRI dhan75 consistently showed taller plants than BRRI dhan87 across all treatments. The highest plant height (115.13 cm at harvest) was recorded in BRRI dhan75 with Crop Plus applied at 20, 40 and 60 DAT. The shortest plants (97.60 cm) were observed in BRRI dhan87 with no Crop Plus application (Table 5). Frequent and early application of Crop Plus led to better growth, especially in BRRI dhan75.

The interaction between rice varieties and Crop Plus application schedules had a significant effect on the number of total tillers per hill at 45 and 60 days after transplanting (DAT) and at harvest, while the effect was not significant at 30 DAT (Table 6). The highest number of tillers hill-1 (21.13) was recorded at 60 DAT in BRRI dhan75 when Crop Plus was applied at 20 and 60 DAT. In contrast, the lowest number of total tillers hill-1 was observed in BRRI dhan87 with no Crop Plus application (Table 6).

The improvements in plant height and tiller number can be attributed to the growth-promoting effects of Crop Plus containing alginic acid. Alginic acid enhances plant growth by improving nutrient uptake, cell elongation, root development and photosynthetic activity. It also mimics plant hormones such as cytokinins and auxins, stimulating lateral shoot formation (tillers) and overall vegetative growth (Khan *et al*., 2009). The timing and frequency of Crop Plus application appear critical, with early and repeated applications aligning with the crop’s peak growth periods to maximize physiological benefits.

The stronger response of BRRI dhan75 suggests a higher physiological responsiveness and nutrient use efficiency compared to BRRI dhan87. The absence of significant differences at 30 DAT for both traits indicates that the effects of Crop Plus become more prominent as the rice plants enter more active vegetative and reproductive stages.

These findings align with previous research indicating that foliar application of seaweed-based biostimulants during early to mid-vegetative stages can significantly enhance tillering and overall vegetative growth in rice and other cereals (Zhang & Ervin, 2008; Khan *et al.,* 2009).

# Table 5. Interaction effect of variety and application schedule of Crop Plus on plant height of Monsoon rice at different days after transplanting

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variety x Application schedule | Plant height (cm) at different days after transplanting (DAT) | | | |
| 30 DAT | 45 DAT | 60 DAT | At harvest |
| V1T1 | 46.16 | 78.33ab | 96.80abcd | 104.17ab |
| V1T2 | 45.93 | 78.60ab | 100.87abc | 106.27ab |
| V1T3 | 46.26 | 84.23a | 103.30abc | 107.07ab |
| V1T4 | 50.80 | 85.53a | 102.23abc | 111.87ab |
| V1T5 | 50.00 | 86.13a | 107.93a | 115.13a |
| V1T6 | 45.86 | 83.90a | 107.20ab | 111.10ab |
| V2T1 | 43.36 | 69.73 b | 85.63d | 97.60 b |
| V2T2 | 43.73 | 69.16 b | 92.77cd | 101.90ab |
| V2T3 | 43.16 | 77.06ab | 94.27bcd | 100.87ab |
| V2T4 | 48.70 | 79.43ab | 93.80bcd | 105.73ab |
| V2T5 | 49.30 | 80.26ab | 97.13abcd | 105.43ab |
| V2T6 | 42.80 | 76.36ab | 97.73abcd | 102.73ab |
| Sx | 3.05 | 3.45 | 3.74 | 4.15 |
| Level of significance | NS | \*\* | \*\* | \*\* |
| CV (%) | 8.07 | 5.35 | 4.66 | 4.81 |

\*\* =Significant at 1% level of probability, NS = Not-significant

V1= BRRI dhan75, V2= BRRI dhan87; T1= No Crop plus, T2= Crop plus at 40 and 60 DAT, T3= Crop plus at 30 and 60 DAT, T4= Crop plus at 20 and 60 DAT, T5= Crop plus at 20, 40 and 60 DAT, T6= Crop plus at 30, 45 and 60 DAT

In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

# 3.4 Effect of variety on yield contributing characters and yield of Monsoon rice

The study revealed significant varietal differences in key yield components and final yield performance of Monsoon rice. BRRI dhan75 consistently outperformed BRRI dhan87 across most yield-contributing traits, indicating a superior agronomic profile.

Effective tillers hill-1 were significantly higher in BRRI dhan75 (17.03) than in BRRI dhan87 (14.01), likely due to the greater genetic potential for tiller production in BRRI dhan75, as supported by Khatri (2015). In contrast, BRRI dhan87 produced more non-effective tillers (2.45), compared to BRRI dhan75 (1.83), suggesting lower tiller efficiency in grain formation (Table 7).

The number of grains panicle-1 was also significantly higher in BRRI dhan75 (81.61) than in BRRI dhan87 (77.77), while BRRI dhan87 had more sterile spikelets panicle-1 (12.68) compared to BRRI dhan75 (10.85) (Table 7). The lower sterility in BRRI dhan75 could be a critical factor contributing to its superior grain yield.

Interestingly, although BRRI dhan87 had a higher 1000-grain weight (24.01 g) than BRRI dhan75 (21.35 g), the overall grain yield was significantly higher in BRRI dhan75 (3.82 t ha⁻¹) compared to BRRI dhan87 (3.51 t ha⁻¹) (Table 7). This suggests that grain number and spikelet fertility had a greater influence on yield than grain weight alone. These findings are consistent with previous studies that emphasize the importance of spikelet fertility and tiller effectiveness in determining rice yield (Singh *et al*., 2002; Fageria *et al*., 2003).

Similarly, straw yield (4.42 t ha⁻¹), biological yield (8.24 t ha⁻¹) and harvest index (46.36%) were all significantly higher in BRRI dhan75 than in BRRI dhan87 (Table 7), indicating more efficient partitioning of assimilates into grain production in BRRI dhan75.

# Table 6. Interaction effect of variety and application schedule of Crop Plus on the tillering ability of Monsoon rice at different days after transplanting

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variety ×  Application schedule | Total number of tillers hill-1 at different days after transplanting (DAT) | | | |
| 30 DAT | 45 DAT | 60 DAT | At harvest |
| V1T1 | 13.16 | 17.13ab | 18.43ab | 17.16abcd |
| V1T2 | 14.13 | 18.10ab | 20.00ab | 19.50abc |
| V1T3 | 14.00 | 17.90ab | 19.63ab | 18.06abcd |
| V1T4 | 14.46 | 19.10a | 21.13a | 20.26a |
| V1T5 | 14.80 | 18.93ab | 20.60ab | 19.66ab |
| V1T6 | 13.90 | 18.06ab | 19.93ab | 18.56abcd |
| V2T1 | 11.70 | 15.70 b | 16.93 b | 15.26 d |
| V2T2 | 12.36 | 16.43ab | 17.53ab | 16.13 cd |
| V2T3 | 12.23 | 15.96ab | 17.63ab | 16.20 cd |
| V2T4 | 12.66 | 16.46ab | 18.63ab | 17.06abcd |
| V2T5 | 12.83 | 16.90ab | 18.46ab | 17.63abcd |
| V2T6 | 12.33 | 16.30ab | 17.86ab | 16.53 bcd |
| Sx | 1.07 | 0.93 | 1.04 | 0.93 |
| Level of significance | NS | \*\* | \*\* | \*\* |
| CV (%) | 9.93 | 6.57 | 6.71 | 6.43 |

\*\* =Significant at 1% level of probability, NS = Not-Significant

V1= BRRI dhan75, V2= BRRI dhan87

T1= No Crop plus, T2= Crop plus at 40 and 60 DAT, T3= Crop plus at 30 and 60 DAT, T4= Crop plus at 20 and 60 DAT, T5= Crop plus at 20, 40 and 60 DAT, T6= Crop plus at 30, 45 and 60 DAT

In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

# 3.5 Effect of application schedule Crop Plus on yield contributing characters and yield of Monsoon rice

The application schedule of Crop Plus significantly affected all key yield-contributing traits and the final yield of Monsoon rice (Table 8). The best performance was observed when Crop Plus was applied at 20, 40 and 60 days after transplanting, followed closely by application at 20 and 60 days after transplanting, compared to the treatment with no Crop Plus application.

The number of effective tillers hill-1 was highest (16.96) when Crop Plus was applied at 20 and 60 days, while the lowest number (13.36) occurred without any application. Similarly, the highest number of non-effective tillers hill-1 (2.85) was observed in the no-application treatment, and the lowest (1.70) was found when Crop Plus was applied at 20 and 60 days (Table 8), indicating better tiller productivity under treated conditions.

The number of grains panicle-1 was also significantly improved with Crop Plus application. The highest number of grains (82.50) was recorded with application at 20, 40 and 60 days, whereas the lowest (75.90) was found in the no-application control. Correspondingly, the number of sterile spikelets panicle-1 was highest (15.51) without Crop Plus and lowest (9.88) when applied at 20, 40 and 60 days, highlighting a clear improvement in reproductive efficiency due to foliar feeding (Table 8).

In terms of 1000-grain weight, the highest value (23.18 grams) was observed with Crop Plus applied at 20, 40 and 60 days, followed by application at 20 and 60 days. The lowest grain weight (22.08 grams) occurred without Crop Plus (Table 8). This suggests that the biostimulant improved not only grain number but also grain filling.

These improvements resulted into a significantly higher grain yield, with the highest yield (3.88 t ha-1) observed under the three-time application schedule, and the lowest yield (3.39 t ha-1) recorded without Crop Plus. The straw yield, biological yield, and harvest index followed a similar trend. The highest biological yield (8.49 t ha-1) and harvest index (46.69%) were also achieved with three-time application.

These results can be attributed to the effects of alginic acid, which enhances plant metabolism by improving nutrient uptake, root development and hormone activity (Khan *et al.,* 2009; Rouphael & Colla, 2020). Proper scheduling, particularly early and repeated applications provide sustained physiological support during critical growth stages, thereby maximizing both vegetative and reproductive performance.

# 3.6 Effect of interaction between variety and application schedule of Crop Plus on Yield Contributing Characters and Yield of Monsoon rice

The interaction between rice variety and the application schedule of Crop Plus significantly influenced all major yield contributing traits and final yield performance in Monsoon rice (Table 9). Overall, BRRI dhan75 responded more positively to Crop Plus than BRRI dhan87, particularly when applied three times at 20, 40 and 60 days after transplanting.

The highest number of effective tillers hill-1 (18.80) was found in BRRI dhan75 with Crop Plus applied at 20 and 60 days, while the lowest number (12.13) occurred in BRRI dhan87 without any Crop Plus application. Similarly, the maximum number of non-effective tillers hill-1 (3.13) was recorded in BRRI dhan87 with no Crop Plus, and the lowest (1.46) in BRRI dhan75 with application at 20 and 60 days (Table 9), suggesting better tiller productivity in the latter.

For grains panicle-1, BRRI dhan75 with application at 20, 40 and 60 days produced the highest number (84.73), followed closely by BRRI dhan75 with application at 20 and 60 days (83.66). In contrast, the lowest grain count (74.53) was recorded in BRRI dhan87 without Crop Plus (Table 9), indicating a poor reproductive response in untreated plants.

The number of sterile spikelets panicle-1 followed a similar trend. The highest spikelet sterility (16.30) occurred in BRRI dhan87 without Crop Plus, while the lowest (9.06) was recorded in BRRI dhan75 with application at 20, 40 and 60 days.

Though BRRI dhan87 generally performed lower in most traits, it showed a higher 1000-grain weight, particularly when Crop Plus was applied three times (24.55 g), slightly higher than its two-time application (24.48 g). In contrast, the lowest 1000-grain weight (20.86 g) was observed in BRRI dhan75 without Crop Plus, suggesting the variety benefits significantly from growth regulator support.

The interaction also had a significant effect on grain yield, with the highest yield (4.07 t ha-1) recorded in BRRI dhan75 when Crop Plus was applied at 20, 40 and 60 days. This was followed by 3.99 t ha-1 when applied at 20 and 60 days. The lowest grain yield (3.28 t ha-1) was again seen in BRRI dhan87 without Crop Plus. Similar patterns were found for straw yield, biological yield and harvest index, all of which peaked in BRRI dhan75 under the three-time application schedule.

These interactions emphasize that both genetic potential and timely external input influence crop performance. BRRI dhan75’s superior response suggests it is more physiologically responsive to biostimulants than BRRI dhan87.

# Table 7. Effect of variety on yield and yield contributing characters of Monsoon rice

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variety | Effective tillers hill-1  (No.) | Non-effective tillers hill-1  (No.) | Grains panicle-1  (No.) | Sterile spikelets panicle-1  (No.) | 1000-grain weight (g) | Grain yield (t ha-1) | Straw yield (t ha-1) | Biological yield (t ha-1) | Harvest Index (%) |
| BRRI dhan75 | 17.03a | 1.83 b | 81.64a | 10.85 b | 21.35b | 3.82a | 4.42a | 8.24a | 46.35a |
| BRRI dhan87 | 14.01 b | 2.45a | 77.77 b | 12.68a | 24.01a | 3.51 b | 4.15 b | 7.67 b | 45.86 b |
| Sx | 0.45 | 0.18 | 0.38 | 0.35 | 0.19 | 0.02 | 0.03 | 0.05 | 0.13 |
| Level of significance | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* |
| CV (%) | 8.70 | 25.01 | 1.42 | 8.82 | 2.53 | 1.39 | 2.43 | 1.86 | 0.83 |

\*\* =Significant at 1% level of probability.

In a column, figures with same letter or without letter do not differ significantly whereas figure with dissimilar letter differ significantly as per DMRT.

# Table 8. Effect of application schedule of Crop Plus on yield and yield contributing characters of Monsoon Rice

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Application schedule | Effective tillers hill-1  (No.) | Non-effective tillers hill-1  (No.) | Grains panicle-1  (No.) | Sterile spikelets panicle-1  (No.) | 1000-grain weight (g) | Grain  yield  (t ha-1) | Straw yield  (t ha-1) | Biological yield  (t ha-1) | Harvest Index (%) |
| No Crop plus | 13.36 b | 2.85a | 75.90 d | 15.51a | 22.08 b | 3.39 c | 3.92c | 7.31 d | 46.40ab |
| Crop plus at 40 and 60 DAT | 15.78ab | 2.03ab | 78.76 c | 12.43b | 22.50ab | 3.59 b | 4.26b | 7.85 c | 45.71 c |
| Crop plus at 30 and 60 DAT | 14.98ab | 2.15ab | 79.05 c | 11.50bc | 22.71ab | 3.66 b | 4.29b | 7.96 bc | 46.05abc |
| Crop plus at 20 and 60 DAT | 16.96a | 1.70 b | 81.76ab | 9.750c | 23.07ab | 3.82a | 4.36b | 8.18 b | 46.69a |
| Crop plus at 20, 40 and 60 DAT | 16.45a | 2.20ab | 82.50a | 9.883c | 23.18a | 3.88a | 4.60a | 8.49a | 45.75 bc |
| Crop plus at 30, 45 and 60 DAT | 15.60ab | 1.95ab | 80.25 bc | 11.51bc | 22.56ab | 3.67 b | 4.30b | 7.97 bc | 46.05abc |
| Sx | 0.78 | 0.31 | 0.65 | 0.59 | 0.33 | 0.03 | 0.06 | 0.09 | 0.22 |
| Level of significance | \*\* | \* | \*\* | \*\* | \* | \*\* | \*\* | \*\* | \*\* |
| CV (%) | 8.70 | 25.01 | 1.42 | 8.82 | 2.53 | 1.39 | 2.43 | 1.86 | 0.83 |

\*\* =Significant at 1% level of probability, \* =Significant at 5% level of probability

T1= No Crop plus, T2= Crop plus at 40 and 60 DAT, T3= Crop plus at 30 and 60 DAT, T4= Crop plus at 20 and 60 DAT, T5= Crop plus at 20, 40 and 60 DAT, T6= Crop plus at 30, 45 and 60 DAT

In a column, figures with same letter or without letter do not differ significantly whereas figure with dissimilar letter differ significantly as per DMRT.

# Table 9. Interaction effect of variety and application schedule of Crop Plus on yield and yield contributing characters of Monsoon Rice

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variety x Application schedule | Effective tillers hill-1  (No.) | Non-effective tillers hill-1  (No.) | Grains panicle-1  (No.) | Sterile spikelets panicle-1  (No.) | 1000-grain weight (g) | Grain yield (t ha-1) | Straw yield (t ha-1) | Biological yield (t ha-1) | Harvest Index (%) |
| V1T1 | 14.60 bcde | 2.56ab | 77.27fgh | 14.73ab | 20.86 c | 3.49 fg | 4.09 e | 7.59f | 46.05abc |
| V1T2 | 17.80ab | 1.70ab | 81.30bcd | 11.50 cd | 21.27 c | 3.74 cd | 4.39 bcde | 8.13cde | 46.02abc |
| V1T3 | 16.23abcd | 1.83ab | 80.70bcde | 10.73 cd | 21.29 c | 3.78 cd | 4.31 bcde | 8.10cde | 46.70a |
| V1T4 | 18.80a | 1.46 b | 83.66ab | 8.500 d | 21.65 bc | 3.99ab | 4.60ab | 8.59ab | 46.47ab |
| V1T5 | 17.76abc | 1.90ab | 84.73a | 9.067 d | 21.81 bc | 4.07a | 4.74a | 8.81a | 46.22abc |
| V1T6 | 17.00abcd | 1.56ab | 82.16abc | 10.56 cd | 21.23 c | 3.85 bc | 4.40 bcd | 8.26bc | 46.65a |
| V2T1 | 12.13 e | 3.13a | 74.53h | 16.30a | 23.30ab | 3.28 h | 3.74 f | 7.03g | 46.75a |
| V2T2 | 13.76 cde | 2.36ab | 76.23gh | 13.36abc | 23.72a | 3.43 gh | 4.13 de | 7.57f | 45.40 bc |
| V2T3 | 13.73 de | 2.46ab | 77.40efgh | 12.26 bc | 24.13a | 3.55 efg | 4.27 cde | 7.82cdef | 45.39 bc |
| V2T4 | 15.13abcde | 1.93ab | 79.86cdef | 11.00 cd | 24.48a | 3.64 def | 4.12 de | 7.77def | 46.92a |
| V2T5 | 15.13abcde | 2.50ab | 80.26cdef | 10.70 cd | 24.55a | 3.70 de | 4.47abc | 8.17bcd | 45.29 c |
| V2T6 | 14.20 bcde | 2.33ab | 78.33defg | 12.46 bc | 23.89a | 3.49 fg | 4.19 cde | 7.69ef | 45.45 bc |
| Sx | 1.10 | 0.44 | 0.92 | 0.85 | 0.47 | 0.04 | 0.09 | 0.12 | 0.31 |
| Level of significance | \*\* | \*\* | \*\* | \*\* | \*\* | \* | \* | \*\* | \*\* |
| CV (%) | 8.70 | 25.01 | 1.42 | 8.82 | 2.53 | 1.39 | 2.43 | 1.86 | 0.83 |

\*\* =Significant at 1% level of probability, \* =Significant at 5% level of probability;

V1= BRRI dhan75, V2= BRRI dhan87

T1= No Crop plus, T2= Crop plus at 40 and 60 DAT, T3= Crop plus at 30 and 60 DAT, T4= Crop plus at 20 and 60 DAT, T5= Crop plus at 20, 40 and 60 DAT, T6= Crop plus at 30, 45 and 60 DAT

In a column, figures with same letter or without letter do not differ significantly whereas figure with dissimilar letter differ significantly as per DMRT.

# 4. CONCLUSION

Based on the findings, it is evident that applying Crop Plus twice at 20 and 60 days after transplanting produced a yield statistically similar to the three-time application at 20, 40 and 60 DAT. From an economic standpoint, the two-time application is more cost-effective, offering high yield and better profit margins.

The results clearly demonstrate the positive effect of Crop Plus on the growth and yield of Monsoon rice, with BRRI dhan75 consistently yielding better results than BRRI dhan87 in most yield-contributing traits. Early-stage applications of Crop Plus were more beneficial than later ones, indicating the importance of timing in growth regulator efficiency.

Therefore, for maximizing yield and profitability during the Monsoon season, it is suggested to foliar spray Crop Plus at 20 and 60 days after transplanting at a rate of 500 ml ha-1.

# DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

# REFERENCES

Banful, B.K., and Attivor, D. (2017). Growth and yield response of two hybrid rice cultivars to ATONIK plant growth regulator in a Tropical environment. Environ. Earth Ecol. 1(1): 33–45. http://dx.doi.org/10.24051/eee/69223

Bangladesh Bureau of Statistics. (2021). *Statistical yearbook of Bangladesh 2021*. Ministry of Planning, Government of the People’s Republic of Bangladesh.

BER (Bangladesh Economic Review) (2015): Ministry of Finance, Government of the People's Republic of Bangladesh, Bangladesh Secretariat, Dhaka, Bangladesh, 120.

Fageria, N. K., Baligar, V. C., & Jones, C. A. (2003). *Growth and mineral nutrition of field crops* (2nd ed.). CRC Press. <https://doi.org/10.1201/9780429131158>

Izquierdo, J., Arriagada, O., García-Pintos, G., Ortiz, R., García-Pintos, M., & García-Pintos, M. (2024). On-farm foliar application of a humic biostimulant increases the yield of rice. Agronomy Journal, 116, 2551–2563. https://doi.org/10.1002/agj2.21641

Khan, W., Rayirath, U. P., Subramanian, S., Jithesh, M. N., Rayorath, P., Hodges, D. M., & Prithiviraj, B. (2009). Seaweed extracts as biostimulants of plant growth and development. *Journal of Plant Growth Regulation, 28*, 386–399. https://doi.org/10.1007/s00344-009-9103-x

Lahijani, A. D., Mosavi, A. A., & Moballeghi, M. (2020). Effects of micronutrients foliar application on rice (Oryza Sativa L. cv. Shiroodi) morphological traits, yield and yield components. *International Journal of Agricultural and Biological Engineering*, *13*(1), 217-223. http://dx.doi.org/10.25165/j.ijabe.20201301.5272

Layek, J., Das, A., Idapuganti, R. G., Sarkar, D., Ghosh, A., Zodape, S. T., ... & Meena, R. S. (2018). Seaweed extract as organic bio-stimulant improves productivity and quality of rice in eastern Himalayas. Journal of Applied Phycology, 30, 547-558. DOI 10.1007/s10811-017-1225-0

Nayak, P., Biswas, S., & Dutta, D. (2020). Effect of seaweed extracts on growth, yield and economics of kharif rice (Oryza sativa L.). *Journal of Pharmacognosy and Phytochemistry*, *9*(3), 247-253. http://dx.doi.org/10.22271/phyto.2020.v9.i3d.11269

Khatri, N., Safi, D. K., & Mishra, K. N. (2015, March). Response of rice genotypes to different levels of nitrogen under rainfed condition, Dhanusha, Nepal. In *Proceedings of the 28th National Summer Crop Workshop* (Vol. 17, p. 18).

Soomro, A. S., Soomro, A. S., & Mazari, S. N. (2020). Impact of plant growth regulators on yield and yield components in rice (Oryza sativa L.) under field conditions. *International Journal of Applied Sciences and Biotechnology*, *8*(3), 318-322.

Rouphael, Y., & Colla, G. (2020). Biostimulants in agriculture. *Frontiers in Plant Science, 11*, 40. https://doi.org/10.3389/fpls.2020.00040

Sasi, M., Awana, M., Samota, M. K., Tyagi, A., Kumar, S., Sathee, L., ... & Singh, A. (2021). Plant growth regulator induced mitigation of oxidative burst helps in the management of drought stress in rice (Oryza sativa L.). *Environmental and Experimental Botany*, *185*, 104413. https://doi.org/10.1016/j.envexpbot.2021.104413

Singh, S., Tiwari, D., Gautam, S. S., Singh, M. K., & Pal, S. K. (2019). Seaweed: An alternative liquid fertilizer for plant growth. *International Journal of Current Microbiology and Applied Sciences*, *8*(12), 772-781. https://doi.org/10.20546/ijcmas.2019.812.101

Singh, V., & Singh, B. (2017). Fertilizer Management in Rice. Rice Production Worldwide. https://doi.org/10.1007/978-3-319-47516-5\_10.

Tang, J., Zhang, Z., Tung, S. A., Lu, B., & Yang, W. (2024). Plant growth regulators improve root growth of rice seedlings after mechanical transplanting and increase grain yield. *Experimental Agriculture*, *60*, e8. https://doi.org/10.1017/S0014479724000048

Zhang, X., & Ervin, E. H. (2008). Impact of seaweed extract‐based cytokinins and zeatin riboside on creeping bentgrass heat tolerance. *Crop Science*, *48*(1), 364-370. http://dx.doi.org/10.2135/cropsci2007.05.0262