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Effect of Foliar Application Timing of Vitamix as the Sources of NPKS and Harvesting time on Yield Performance of *Boro* Rice (Cv. Brri Dhan74)

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Abstract:

An experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh from December 2023 to May 2024 to evaluate the effect of foliar application time of Vitamix as the sources of NPKS and harvesting time on yield performance of boro rice. The experiment consisted of six foliar application time of Vitamix viz. soil application during transplanting (F_1), tillering stage (F_2), soil + tillering stage (F_3), panicle initiation (F_4), tillering + panicle initiation (F_5) and soil + tillering + panicle initiation (F_6) and three harvesting time viz. 25 days after flowering (H_1), 30 days after flowering (H_2) and 35 days after flowering (H_3). The experiment was laid out in a randomized complete block design (RCBD) with three replications. Yield and related traits were significantly affected by Vitamix application timing, harvesting time, and their interactions. Foliar application of Vitamix at tillering + panicle initiation stage produced maximum grain yield (8.40 t ha^{-1}) whereas, foliar application at soil + tillering stage produced minimum grain yield (7.74 t ha^{-1}). Harvesting at 35 days after flowering produced maximum grain yield (8.52 t ha^{-1}) whereas, harvesting at 25 days after flowering produced minimum grain yield (7.21 t ha^{-1}). From the interactions, foliar application of Vitamix at tillering + panicle initiation stage with harvesting at 35 days after flowering produced maximum grain yield (9.11 t ha^{-1}) whereas, foliar application at tillering

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stage with harvesting at 25 days after flowering produced minimum grain yield (6.17 t ha^{-1}). Therefore, this study suggests that foliar application of Vitamix at tillering stage + panicle initiation stage with harvesting at 35 days after flowering could be an effective way to improve the yield potential of boro rice.

Keywords: Boro rice, foliar fertilization, nutrient management, harvest timing, yield optimization.

1. INTRODUCTION

Rice (*Oryza sativa* L.) serves as the primary staple food for the majority of the population in Bangladesh (Monira et al., 2024). Bangladesh is an agriculture-based country where rice-centered intensive farming dominates the cropping system. Agriculture plays a major role in the economy, contributing about 13.47% to the national GDP (Islam et al., 2024). Rice production can be improved through proper agronomic and crop management practices, especially by maintaining suitable plant spacing and balanced fertilizer application. These practices help increase rice yield while ensuring sustainable crop production over time (Rahman et al., 2025). Rice productivity is heavily dependent on precise nutrient management and optimal physiological growth conditions (Monira et al., 2024). Despite these requirements, inadequate soil nutrient management and micronutrient deficiencies, particularly of zinc and boron, frequently impede the yield potential of high-yielding Boro varieties (Biswas et al., 2022). Consequently, integrating supplementary foliar nutrition during critical developmental phases has emerged as a strategic approach to mitigate such deficiencies and optimize biomass partitioning (Islam et al., 2024). Specifically, the targeted application of mineral elements at vegetative and reproductive stages has been shown to improve photosynthetic pigment concentration and translocation of assimilates to developing grains (Kamran et al., 2025; Rajput et al., 2023). Furthermore, empirical evidence suggests that coordinating nutrient delivery with key growth stages, such as tillering and panicle initiation, significantly optimizes both plant physiological traits and terminal grain yield (Mahmoodi et al., 2020). Beyond simple nutrient replenishment, foliar fertilization benefits from high absorption efficiency, allowing crops to bypass soil-related constraints and directly address metabolic requirements during peak demand (Alice & Collins, 2022). Similarly, the timing of grain harvest remains a critical determinant of total output, as premature collection often curtails the final translocation of photosynthates, while delayed reaping may compromise grain quality (Alice et al., 2023). Optimizing these variables through systematic field experimentation is essential to establishing agronomic protocols that maximize resource-use efficiency (Alim et al., 2023; Uddin & Rahman, 2024). The present study, therefore, aims to elucidate the synergistic effects of Vitamix as an NPKS source and precise harvest timing on the agronomic performance of Boro rice, establishing a framework for enhanced crop management. By evaluating the interplay between specialized foliar fertilization and physiological maturity, this research provides data-driven insights into mitigating the stagnant yield trends currently observed in staple grain production.

2. MATERIALS AND METHODS

2.1 Experimental Location

Geographically the experimental site is located at 24°75' N latitude and 90°50' E longitude at an elevation of 18 m above the sea level under Old Brahmaputra Floodplain area of Bangladesh.

2.2 Experimental Climate and Soil

The experiment was conducted on medium-high land of the Sonatola series under the Old Brahmaputra Alluvial Tract. The soil was silty loam, moderately drained, with a pH of 6.5 and moderate organic matter content. The experimental area falls under the sub-tropical climate that is characterized by high temperature, high humidity, and heavy rainfall with occasional gusty winds in the kharif season (April-September) and less rainfall associated with moderately low temperature during the rabi season (October-March). Soil properties and weather data are presented in Table 1.

Physical properties		**Chemical composition**	
Constituents	**Results**	**Constituents**	**Results**
Particle density(g/cc)	2.60	Soil pH	6.8
Bulk density (g/cc)	1.35	Organic matter (%)	1.19
Porosity (%)	46.67	N (%)	0.101
Sand (%) (0.0-0.02 mm)	20	P (ppm)	27
Silt (1%) (0.02-0.002 mm)	67	k (me%)	0.12
Soil textural class	Silt loam	S (ppm)	22.97

2.3 Experimental Treatments and Design

The experiment included two factors. Factor A consisted of six timings of Vitamix application as a source of NPKS: soil application during transplanting (F_1), application at the tillering stage (F_2), soil plus tillering stage application (F_3), application at panicle initiation stage (F_4), tillering plus panicle initiation stage application (F_5), and combined soil, tillering, and panicle initiation stage application (F_6). Factor B included three harvesting times: 25 days after flowering (H_1), 30 days after flowering (H_2), and 35 days after flowering (H_3). The experiment was laid out in a randomized complete block design (RCBD) with 3 replications. Each replication consists of 18 plots and the total number of plots were 54. Each plot size was 5 m^2 (2 m × 2.5 m).

2.4 Description of Planting Materials

BRRI dhan74 was selected for this study. This is one of the famous rice in Bangladesh during *boro* season. BRRI dhan74 was developed by the Bangladesh rice research institute (BRRI). It was released in 2014. It is a high-yielding *boro* rice with a medium-slender, white grain. The duration is 145-148 days. The Vitamix formulation contained NPKS in the following proportions: N = 12%, P = 16%, K = 22%, and S = 6.5%.

2.5 Details on Fertilization using Vitamix

The Vitamix formulation contained NPKS in the following proportions: N = 12%, P = 16%, K = 22%, and S = 6.5%. A solution was prepared by dissolving 3 g of Vitamix powder in 1 L of water. About 300 mL of the prepared solution was applied to each plot (5 m^2) using a knapsack sprayer.

2.6 Crop Husbandry

Seeds of the test variety were collected from Bangladesh Agricultural Development Corporation, Mymensingh. Healthy seeds were selected by the specific gravity method, soaked in water for 24 hours, and kept in gunny bags for sprouting. The seeds sprouted after 48 hours and were sown in the nursery bed on 31 December 2023 at the Agronomy Field Laboratory, Department of Agronomy, Bangladesh Agricultural University. The experimental land was prepared by tractor ploughing and laddering, and the final land preparation was completed on 6 February 2024. Forty-day-old seedlings were carefully uprooted and transplanted on 8 February 2024 at a spacing (20 cm × 15 cm) using 2-3 seedlings hill^{-1}. Recommended fertilizers including urea, TSP, MoP, and gypsum were applied at 260, 100, 120, and 110 kg ha^{-1}, respectively. Except urea, all fertilizers were applied as basal doses, while urea was top-dressed in three equal splits at 20, 35, and 55 DAT. Manual weeding was done three times, and 7-8 irrigations were applied maintaining about 6 cm standing water. No major insect or disease infestation was observed during the study.

2.7 Harvesting

The crops were harvested at 25, 30, and 35 days after flowering on 5, 10, and 15 May 2024, respectively. Five hills from each plot were selected for yield data collection. Grain and straw yields were recorded after threshing, grain moisture was adjusted to 14%, and final yields were converted into t ha^{-1}.

2.8 Data collection

Data on yield and yield-contributing characters were recorded from five randomly selected plants from each plot. The recorded parameters included plant height (cm), total tillers hill^{-1}, effective tillers hill^{-1}, non-effective tillers hill^{-1}, panicle length (cm), grains panicle^{-1}, sterile spikelets panicle^{-1}, 1000-grain weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}), and harvest index (%). Harvest index was measured by using following formula:

$$\text{Harvest Index (\%)} = (\text{Grain yield/ Biological yield}) \times 100.$$

2.9 Statistical Analysis

Data were collected at different growth stages and at harvest. The collected data were statistically analyzed using ANOVA with MSTAT-C and R software, and mean differences were compared using Duncan's Multiple Range Test (DMRT).

3. RESULTS

3.1 Effect of Foliar Application Time of Vitamix on Yield Performance of *Boro* Rice

The longest plant (94.74 cm) was observed from F_4 treatment followed by F_6, F_1, F_5 and F_3. The shortest plant (92.66 cm) was observed from F_2 treatment. The highest number of total tillers (14.92) was observed from F_4 treatment whereas the lowest number of tillers (12.81) was observed from F_6 treatment. Number of effective tillers was significantly influenced by foliar application time of Vitamix. The maximum number of effective tillers (13.51) was observed from F_4 treatment while the lowest number of effective tiller (11.55) was measured from F_6 treatment. Numerically the highest number of non-effective tiller (1.85) was found from and he lowest number of non-effective tiller

(1.25) was observed from F_6 treatment. The longest panicle (23.42 cm) was observed from F_4 treatment while he shortest panicle (22.94 cm) was observed from F_5 treatment. The highest number of grain panicle^{-1} (87.82) was observed from F_6 treatment whereas the lowest number of grain panicle^{-1} (83.40) was observed from F_5 treatment. The highest number of sterile spikelets (16.63) was observed from F_1 treatment while the lowest number of sterile spikelets (12.72) was observed from F_4 treatment. Thousand grain weight was not significantly influenced by foliar application time of Vitamix. Numerically the maximum weight of thousand grain (28.68 g) was observed from F_3 treatment and the minimum weight of thousand grain (28.39 g) was observed F_5 treatment. Grain yield was significantly influenced by foliar application time of Vitamix The highest grain yield (8.40 t ha^{-1}) was observed from F_5 treatment whereas the minimum weight of grain yield (7.74 t ha^{-1}) was observed from F_3 treatment. The maximum weight of straw yield (15.00 t ha^{-1}) was observed from F_4 treatment and the minimum weight straw yield (13.75 t ha^{-1}) was observed from F_2 treatment. The maximum biological yield (23.34 t ha^{-1}) was observed from F_5 treatment. The minimum biological yield (21.65 t ha^{-1}) was observed from F_3 treatment. The maximum harvest index (37.42) was observed from F_6 treatment while the minimum harvest index (35.12) was observed from F_4 treatment.

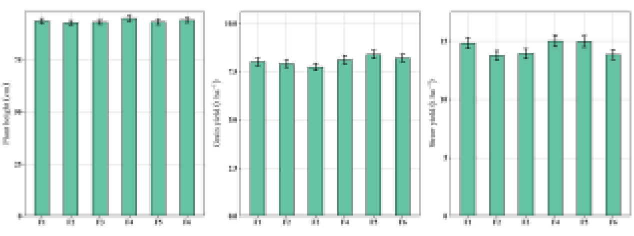

Figure 1. Effect of foliar application time of Vitamix on yield performance of boro rice. Where, F_1= Soil application (during transplanting), F_2 = Tillering stage, F_3 = Soil + tillering stage, F_4 = Panicle initiation, F_5 = Tillering + panicle initiation, F_6 = Soil + tillering + panicle initiation.

3.2 Effect of Harvesting Time on Yield Performance of *Boro* Rice

Plant height was not significantly influenced by harvesting time, the tallest plant (94.29 cm) was observed from H_1 treatment and the shortest plant (92.07 cm) was observed from H_3 treatment. Numerically the highest number of tiller (13.77) was observed from H_3 treatment while the lowest number of tiller (13.59) was observed from H_2 treatment. The maximum number of effective tillers (12.31) was found from H_1 treatment whereas the lower number of effective tiller (12.13) was observed from H_2 treatment. Numerically the highest number of non-effective tillers (1.59) was observed from H_3 treatment and the lowest number of non-effective tiller (1.40) was observed from H_1 treatment. The longest panicle (23.43 cm) was observed from H_1 treatment which was statistically identical with the H_2 treatment. The shortest panicle (23.04 cm) was observed from H_3 treatment. The highest number of grains panicle^{-1} (89.57) was observed from H_2 treatment. The lowest number of grain panicle^{-1} (82.37) was observed from H_1 treatment. The highest number of sterile spikelets panicle^{-1} (18.67) was observed from H_1 treatment while the lowest number of sterile spikelets panicle^{-1} (11.30) was observed from H_2 treatment. The highest weight of thousand grain (28.84 g) was observed from H_3 whereas the lowest weight of thousand grains (28.14 g) was observed from H_1 treatment. Grain yield was significantly influenced by harvesting time. The maximum weight of grain yield (8.52 t ha^{-1}) was observed from H_3 treatment while the minimum weight of grain yield (7.21 t ha^{-1}) was observed from H_1 treatment. The maximum weight of straw yield (15.26 t ha^{-1}) was observed from H_1 treatment whereas the minimum weight of straw yield (13.49 t ha^{-1}) was observed from H_3 treatment. The maximum biological yield (22.84 t ha^{-1}) was observed from H_2 treatment and the minimum biological yield (22.01 t ha^{-1}) was observed from H_3 treatment. Harvest index was significantly influenced by harvesting time. The maximum harvest index (38.81%) was observed from H_3 treatment while the minimum harvest index (32.08%) was observed from H_1 treatment.

Figure 2. Effect of harvesting time on yield performance traits of boro rice. Where, H_1 = 25 days after flowering, H_2 = 30 days after flowering, H_3 = 35 days after flowering

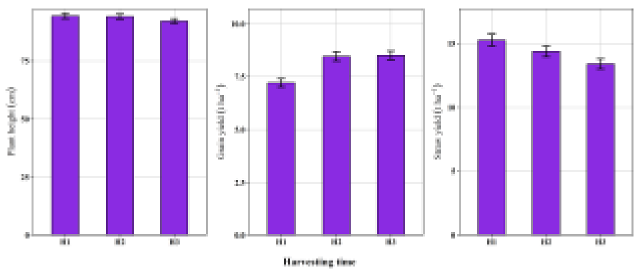

Table 2: Effect of foliar application time of Vitamix on yield contributing traits of *boro* rice.

Time of application	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no)	Number of sterile spikelets panicle^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
F_1	93.48	14.37ab	12.51ab	1.85	23.36	86.43	16.63a	28.55	8.01ab	14.81abc	22.82abc	35.19
F_2	92.66	13.26ab	11.88b	1.37	23.36	86.51	13.76ab	28.56	7.91ab	13.75d	21.66c	36.39
F_3	92.92	13.18ab	11.63b	1.55	23.30	86.16	13.38b	28.68	7.74b	13.91bcd	21.65c	35.76
F_4	94.74	14.92a	13.51a	1.40	23.42	84.92	12.72b	28.58	8.12ab	15.00ab	23.13ab	35.12
F_5	93.03	13.62ab	12.14ab	1.48	22.94	83.40	13.57ab	28.39	8.40a	14.94ab	23.34a	36.09
F_6	93.92	12.81b	11.55b	1.25	23.10	87.82	13.99ab	28.47	8.21ab	13.82cd	22.03bc	37.42
$LSD_{(0.05)}$	3.68	2.08	1.47	1.01	0.52	5.70	3.08	0.48	0.55	1.02	1.17	2.35
Level of significance	NS	**	**	NS	NS	NS	*	NS	**	**	**	NS
CV (%)	4.12	15.87	12.62	7.26	2.37	6.94	13.00	2.76	7.20	7.46	5.46	6.84

Means with the same letters within the same column do not differ significantly. ** = Significant at 1% level of probability, F1= Soil application (during transplanting), F2 = Tillering stage, F3 = Soil + tillering stage, F4 = Panicle initiation, F5 = Tillering + panicle initiation, F6 = Soil + tillering + panicle initiation.

Table 3: Effect of harvesting time on yield performance of boro rice

Harvesting Time	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Grain 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 (%)
H_1	94.29	13.72	12.31	1.4	23.43a	82.37b	18.67a	28.14b	7.21b	15.26a	22.47ab	32.08c
H_2	94.01	13.59	12.13	1.46	23.28ab	89.57a	11.30b	28.63a	8.47a	14.37b	22.84a	37.10b
H_3	92.07	13.77	12.18	1.59	23.04b	85.68ab	12.05b	28.84a	8.52a	13.39c	22.01b	38.81a
$LSD_{(0.05)}$	2.6	1.47	1.04	0.71	0.37	4.03	2.18	0.33	0.39	0.72	0.83	1.66
Level of significance	NS	NS	NS	NS	**	**	**	**	**	**	**	**
CV (%)	4.12	15.87	12.62	7.26	2.37	6.94	13	2.76	7.2	7.46	5.46	6.84

Where, Means with the same letters within the same column do not differ significantly. ** = Significant at 1% level of probability, NS = Non-significant, H1 = 25 days after flowering, H2 = 30 days after flowering, H3 = 35 days after flowering.

3.3 Interaction Effect of Foliar Application Time of Vitamix and Harvesting Time on Yield Performance of *Boro* Rice

Plant height was not significantly influenced by the interaction between foliar application time of Vitamix and harvesting time. The tallest plant (97.89 cm) was observed from the interaction between F_4H_2 and the shortest plant (90.89 cm) was observed from F_5H_3. Numerically the highest number of total tillers (14.66) was observed from the interaction between F_5H_3 while the lowest number of total tillers (11.88) was observed from F_3H_3. The highest number of effective tillers hill^{-1} (13.00) was observed from the interaction of F_5H_3 whereas the lowest number of effective tillers (11.00) was observed from F_3H_3. The maximum number of non-effective tillers hill^{-1} (2.66) was observed from the interaction between F_1H_1 and the minimum number of non-effective tillers hill^{-1} (0.55) was observed from F_4H_1. The tallest panicle (23.87 cm) was observed from the interaction between F_3H_1 and the shortest panicle **(**22.24 cm) was observed from F_5H_2 (tillering + panicle initiation and 30 days after flowering) (Table 3). The highest number grains panicle^{-1} (93.57) was observed from the interaction between F_2H_2 and the lowest number grains panicle^{-1} **(**78.54) was observed from F_5H_1. The greatest number of sterile spikelets panicle^{-1} (19.87) was observed from the interaction between F_3H_1 and the lowest number of sterile spikelets panicle^{-1} **(**9.41) was observed from F_5H_2. The maximum weight of thousand grains (29.06 g) was observed from the interaction between F_6H_3 and the minimum weight of thousand grains **(**27.76 g) was observed from F_5H_1. Grain yield was significantly influenced by the interaction between foliar application time of Vitamix and harvesting time. The maximum grain yield (9.11 t ha^{-1}) was observed from the interaction between F_5H_3 and the minimum grain yield (6.17 t ha^{-1}) was observed from F_2H_1. The maximum straw yield (16.07 t ha^{-1}) was observed from the interaction between F_5H_1 and the minimum straw yield (12.37 t ha^{-1}) was observed from F_3H_3. The maximum biological yield (23.91 t ha^{-1}) was observed from the interaction between F_4H_3 and the minimum biological yield (20.42 t ha^{-1}) was observed from F_3H_3. Harvest index was significantly influenced by the interaction between foliar application time of Vitamix and harvesting time. The maximum harvest index (40.55%) was observed from the interaction between F_2H_3 and the minimum harvest index (29.94%) was observed from F_2H_1.

Table 4: Interaction effect between foliar application time of Vitamix and harvesting time on yield performance of boro rice

Interaction	Plant height (cm)	Number of total tiller hill^{-1}	Number of effective tiller hill^{-1}	Number of non-effective tiller hill^{-1}	Panicle length (cm)	Grain panicle^{-1}	Number of sterile spikelets	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
F_1H_1	95.77	15.22	12.55ab	2.66a	23.69ab	85.25abc	19.82ab	28.62a-d	7.28fg	15.89ab	23.17abc	31.43efg
F_1H_2	92.11	13.66	12.22ab	1.44ab	23.43a-d	89.24ab	14.49b-f	28.29a-e	8.70ab	14.80a-d	23.50ab	37.03a-d
F_1H_3	92.55	14.22	12.77ab	1.44ab	22.98a-e	84.80abc	15.58a-e	28.73abc	8.05b-f	13.74d-g	21.80b-f	37.11a-d
F_2H_1	94.33	12.55	11.44b	1.11ab	23.61abc	81.16bc	18.09abc	28.17b-e	6.17h	14.43a-e	20.60ef	29.94g
F_2H_2	92.55	13.33	12.22ab	1.11ab	23.71ab	93.57a	11.85def	28.69abc	9.01ab	14.30a-f	23.31abc	38.67ab
F_2H_3	91.11	13.89	12.00ab	1.89ab	22.75cde	84.82abc	11.34ef	28.72abc	8.55a-d	12.53fg	21.08def	40.55a
F_3H_1	92.89	13.33	11.55b	1.77ab	23.87a	83.26bc	19.87a	28.46a-e	7.64d-g	14.98a-d	22.62a-e	33.79d-g
F_3H_2	93.11	14.33	12.33ab	2.00ab	22.95b-e	89.63ab	9.94f	28.64a-d	7.52efg	14.40a-e	21.92a-f	34.05c-f
F_3H_3	92.77	11.88	11.00b	0.89b	23.09a-e	85.60abc	10.32ef	28.95ab	8.05b-f	12.37g	20.42f	39.45a
F_4H_1	94.33	14.52	12.22ab	0.55b	23.23a-d	79.28c	16.77a-d	28.03cde	6.80gh	15.68abc	22.48a-e	30.34fg
F_4H_2	97.89	14.11	12.00ab	2.11ab	23.76ab	90.37ab	10.11f	28.92ab	8.47a-e	14.53a-e	23.00a-d	36.93a-d
F_4H_3	92.00	15.33	13.33ab	2.00ab	23.27a-d	85.12abc	11.28ef	28.80abc	8.83ab	14.80a-d	23.91a	38.11abc
F_5H_1	93.22	13.44	12.55ab	0.89b	23.11a-e	78.54c	17.96abc	27.76e	7.65d-g	16.07a	23.72ab	32.27efg
F_5H_2	94.99	13.33	11.89ab	1.44ab	22.24e	84.22abc	9.41f	28.70abc	8.72ab	14.00c-g	22.84a-d	38.82a
F_5H_3	90.89	14.66	13.00a	1.66ab	23.48a-d	87.45abc	13.35c-f	28.81abc	9.11a	14.74a-d	23.46ab	37.17a-d
F_6H_1	95.22	13.00	11.55b	1.44ab	23.06a-e	86.73abc	19.54ab	27.82de	7.71c-g	14.52a-e	22.23a-f	34.69b-e
F_6H_2	93.44	12.22	11.11b	1.11ab	23.58a-d	90.42ab	12.02def	28.54a-e	8.29a-e	14.18b-f	22.48a-e	37.10a-d
F_6H_3	93.11	13.22	12.00ab	1.22ab	22.68de	86.31abc	10.42ef	29.06a	8.62abc	12.76efg	21.38c-f	40.47a
$LSD_{(0.05)}$	6.38	3.60	2.55	1.75	0.91	9.88	5.34	0.83	0.96	1.77	2.03	4.08
Level of sig.	NS	NS	NS	*	NS	**	**	NS	**	**	**	**
CV (%)	4.12	15.87	12.62	7.26	2.37	6.94	13.00	2.76	7.20	7.46	5.46	6.84

Means with the same letters within the same column do not differ significantly. ** = Significant at 1% level of probability, * = Significant at 5% probability, NS = Not significant. All other details are as described in table 2 and 3.

3.4 PCA, Correlation and Heatmap

The PCA biplot explained 62.2% of the total variation, where Dim1 and Dim2 contributed 36% and 26.2%, respectively (Figure 3). Grain yield (GY), grain panicle^{-1} (GP), 1000-grain weight (TGW), and harvest index (HI) were positively associated and positioned on the positive side of Dim1, indicating strong contribution to productivity. Treatments F2H2, F1H3, and especially F3H3 showed close association with these yield traits, suggesting that tillering and combined soil+tillering applications improved grain performance at later harvest stages. In contrast, straw yield (SY), biological yield (BY), plant height (PH), and sterile spikelets were associated with the negative axis, mainly linked with F2H1 and F4H1. Biologically, later harvesting (H3) combined with split nutrient application enhanced effective assimilate partitioning toward grain formation and yield improvement.

The correlation analysis revealed (Figure 4) that grain yield (GY) had strong positive relationships with harvest index (HI, r = 0.87***), 1000-grain weight (TGW, r = 0.60**), and grain panicle^{-1} (GP, r = 0.49*), indicating that heavier grains and better assimilate partitioning increased yield performance. Total tiller (TT) was highly correlated with effective tiller (ET, r = 0.88***), confirming that productive tillers contributed directly to crop productivity. Straw yield (SY) showed positive association with biological yield (BY, r = 0.71***). In contrast, sterile spikelets (SP) had significant negative correlations with HI (r = -0.76***) and TGW (r = -0.72***), suggesting that spikelet sterility reduced grain filling efficiency and final yield formation.

The heatmap revealed (Figure 5) clear variation among growth stages and fertilizer timings. Treatments F4H3 and F5H3 showed strong positive associations with GY, HI, TGW, and BY, indicating improved productivity and grain filling at 35 DAF. In contrast, F2H1 and F3H1 displayed negative correlations with PH, ET, and SY, suggesting weaker crop performance at early flowering. Cluster analysis grouped GY, HI, and TGW closely, reflecting their biological interdependence in yield formation. NET and SSP showed contrasting patterns with productive traits, implying that increased sterile or noneffective tillers reduce yield efficiency. Overall, combined applications during tillering and panicle initiation enhanced crop vigor and productivity

Figure 3. Principal Component Analysis illustrating the Synergistic Effects of Vitamix Foliar Timing and Harvest Stage on Boro Rice Yield. Where, PH= Plant height, TT=Total tiller, ET= Effective tiller, NET= Noneffective tiller, GP= Grain panicle^{-1}, SSP= Sterile spikelet panicle^{-1}, TGW= 1000 grain wight, GY= Grain yield, SY= Straw yield, BY= Biological yield, HI= Harvest index. All other details are as described in Figures 1 and 2.

Figure 4. Correlation Analysis of the Synergistic Effects of Vitamix Foliar Timing and Harvest Stage on Boro Rice Yield. All other details are as described in Figures 3.

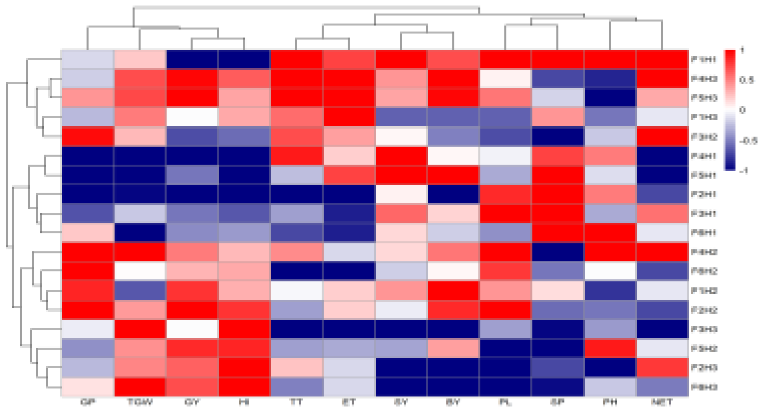

Figure 5. Analysis of heatmap of the Synergistic Effects of Vitamix Foliar Timing and Harvest Stage on Boro Rice Yield. All other details are as described in Figures 1, 2 and 3

DISCUSSION:

The present study demonstrated that foliar application timing of Vitamix and harvesting time significantly influenced the yield and yield-contributing traits of boro rice. Among the treatments, foliar application at tillering plus panicle initiation stage (F5) produced the highest grain yield, while harvesting at 35 days after flowering (H3) ensured better grain development and overall productivity. The interaction of F5H3 showed the best performance, highlighting the combined importance of proper nutrient management and optimum harvesting time. Such results corroborate the significance of strategic nutrient scheduling in optimizing sink capacity and facilitating the translocation of assimilates to improve overall grain filling (Swain et al., 2025). Moreover, the integration of balanced nutrient scheduling through soil and foliar methods helps mitigate spikelet sterility and optimize yield-contributing components such as 1000-grain weight and effective tiller number (Fakharzadeh et al., 2020; Tanjim et al., 2024). These findings align with previous research indicating that optimized nitrogen management significantly influences biological yield and overall harvest indices in Boro rice varieties (Mehraj, 2016; Razib et al., 2023).

The higher yield under F5 treatment may be attributed to the timely supply of N, P, K, and S during critical growth stages. Nutrient application at tillering enhanced productive tiller formation, whereas application at panicle initiation improved spikelet development and grain filling. Consequently, plants exhibited better assimilate translocation and higher reproductive efficiency. Furthermore, this synchronized nutrient availability promotes robust panicle development and increases the number of kernels per panicle, which are fundamental drivers of enhanced grain yield (Chattha et al., 2023).

Harvesting at 35 days after flowering significantly increased grain yield, 1000-grain weight, and harvest index compared with earlier harvesting. Early harvesting at 25 DAF resulted in lower grain weight and increased sterile spikelets due to incomplete grain filling. In contrast, delayed harvesting allowed sufficient time for carbohydrate accumulation and physiological maturity, which ultimately enhanced grain productivity. Furthermore, these results underscore that potassium and nitrogen synergy during the grain-filling phase facilitates optimal dry matter translocation, which effectively minimizes the occurrence of degenerate spikelets (Li et al., 2025). This extended duration for nutrient remobilization also delays leaf senescence, thereby maintaining higher photosynthetic rates during the final stages of maturation (Iqbal et al., 2021).

The interaction effect further indicated that appropriate nutrient timing combined with delayed harvesting improved yield efficiency. The highest grain yield under F5H3 was associated with increased effective tillers, higher grains panicle-2, and improved harvest index, whereas premature harvesting reduced grain filling and yield performance. These physiological advantages correlate with findings that strategic nutrient co-application optimizes dry matter accumulation and enhances the recovery efficiency of essential nutrients like nitrogen and potassium (Chen et al., 2024). Specifically, synchronized nutrient supply at panicle initiation activates key enzymatic pathways, such as nitrate reductase and pyruvate kinase, which accelerate the translocation of photoassimilates to developing spikelets (Li et al., 2025). Furthermore, this nutritional synchronization enhances the structural integrity of the intercalary meristem, thereby improving the plant's capacity to maintain physiological activity during the critical grain-filling period (Paiman et al., 2025).

Multivariate analyses also supported these findings. Grain yield showed strong positive relationships with harvest index, grain panicle^{-1}, and 1000-grain weight, indicating that efficient assimilate partitioning and grain filling played major roles in yield improvement. Conversely, the negative correlation between sterile spikelets and yield-contributing factors suggests that managing nutrient availability during the reproductive phase is essential for reducing spikelet degeneration and maximizing the total number of filled grains (Zhou et al., 2017). Overall, the study suggests that foliar application of Vitamix at tillering and panicle initiation stages combined with harvesting at 35 days after flowering can effectively improve the productivity and physiological efficiency of boro rice under subtropical conditions.

CONCLUSION:

The findings underscore that optimizing nutrient scheduling is essential for sustaining long-term food security and enhancing the yield potential of modern rice cultivars. Application of Vitamix at tillering + panicle initiation stage (F5) produced the highest grain yield (8.40 t ha^{-1}), while harvesting at 35 days after flowering (H3) achieved superior grain yield (8.52 t ha^{-1}) and harvest index (38.81%). The combined treatment F5H3 resulted in the maximum grain yield (9.11 t ha^{-1}), indicating that synchronized nutrient supply and delayed harvesting enhanced assimilate translocation, grain filling, and physiological efficiency. Correlation and multivariate analyses further confirmed the strong association of grain yield with harvest index and 1000-grain weight. Therefore, foliar application at tillering and panicle initiation followed by harvesting at 35 DAF can be recommended for maximizing Boro rice productivity under subtropical conditions.

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REFERENCES:

1 Alice, A. A., & Collins, K. T. (2022). Effect of soil-applied and foliar fertilizer on rice (Oryza sativa). *African Journal of Agricultural Research*, *18*(8), 657 663.https://doi.org/10.5897/ajar2022.16039

2 Alice, A. A., Maxwel, A., Ali, D. B., Jessica, A., Philip, L. B., & Quansah, A. D. (2023). Response of rice (Oryza sativa L.) to foliar fertilizer. *African Journal of Agricultural Research*, *19*(7), 698–704. https://doi.org/10.5897/ajar2023.16341

3 Alim, M. A., Hossain, S. I., Ditta, A., Hasan, M., Islam, M., Hafeez, A. S. M., Khan, M. A. H., Chowdhury, M. K., Pramanik, M. H., Al-Ashkar, I., Sabagh, A. E., Islam, M. S., Islam, M. S., & Islam, M. S. (2023). Comparative Efficacy of Foliar Plus Soil Application of Urea versus Conventional Application Methods for Enhanced Growth, Yield, Agronomic Efficiency, and Economic Benefits in Rice. *ACS Omega*, *8*(39), 35845–35855. https://doi.org/10.1021/acsomega.3c03483

4 Biswas, P., Samia, S., & Shome, S. (2022). Sustainable Soil Management for Nutrition Sensitive Agriculture Through Micronutrient Inclusion In Boro Rice Cultivation. *Bangladesh Agronomy Journal*, *25*(1), 97–103. https://doi.org/10.3329/baj.v25i1.62852

5 Chattha, M. B., Ali, Q., Subhani, M. N., Ashfaq, M. A., Ahmad, S., IQBAL, Z., Ijaz, M., Ayub, M. A., Anwar, M. R., Aljabri, M., Hassan, M. U., & Qari, S. H. (2023). Foliar applied zinc on different growth stages to improves the growth, yield, quality and kernel bio-fortification of fine rice. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *51*(2), 13221–13221. https://doi.org/10.15835/nbha51213221

6 Chen, G., Duan, Q., Wu, C., He, X., Hu, M., Li, C., Ouyang, Y., Peng, L., Yang, H., Zhang, Q., Jiang, Q., Yan, L., & Li, T. (2024). Optimizing rice yield, quality and nutrient use efficiency through combined application of nitrogen and potassium. *Frontiers in Plant Science*, *15*. https://doi.org/10.3389/fpls.2024.1335744

7 Fakharzadeh, S., Hafizi, M., Baghaei, M. A., Etesami, M., Khayamzadeh, M., Kalanaky, S., Akbari, M. E., & Nazaran, M. H. (2020). Using Nanochelating Technology for Biofortification and Yield Increase in Rice. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-60189-x

8 Iqbal, A., He, L., Ali, I., Ullah, S., Khan, A., Akhtar, K., Wei, S., Fahad, S., Khan, R., & Jiang, L. (2021). Co-incorporation of manure and inorganic fertilizer improves leaf physiological traits, rice production and soil functionality in a paddy field. *Scientific Reports*, *11*(1). https://doi.org/10.1038/s41598-021-89246-9

9 Islam, S., Mia, M. L., Sarker, A. K., Jubber, A., Zaman, F., & Islam, M. S. (2024). Allelopathic Effect of the Residues of Rumex Maritimus L. on the Yield Performance of Boro Rice. *International Journal of advanced Multidisciplinary Research and Studies*, *4*(2), 1053-1059. https://doi.org/10.62225/2583049X.2024.4.2.2621

10 Islam, Md. S., Rashid, M., Kabiraj, Md. S., Sarker, U. K., Sarkar, S. K., Uddin, F., & Paul, S. K. (2024). Foliar supplementation of phosphorus and zinc enhanced the yield of Boro rice. *Journal of Aridland Agriculture*, 74–81. https://doi.org/10.25081/jaa.2024.v10.8799

11 Kamran, A., Naveed, I., Jahan, S., Komal, L., Siddiqui, M. H., Alamri, S., & Khalil, A. (2025). Boron bioavailability enhanced by foliar applied fulvic acid to improve grain yield and quality of fine basmati rice. *Scientific Reports*, *15*(1). https://doi.org/10.1038/s41598-025-04747-1

12 Li, Z., Hu, M., Liu, T., Tang, Y., Liu, R., Peng, Z., Wang, C., Zhang, P., Wang, Z., Chen, Z., Yang, Z., Sun, Y., & Ma, J. (2025). Effects of N-K management strategies on nutrient uptake efficiency, lodging resistance, and yield in machine-transplanted rice. *Frontiers in Plant Science*, *16*. https://doi.org/10.3389/fpls.2025.1658245

13 Mahmoodi, B., Moballeghi, M., Eftekhari, A., & Neshaie-Mogadam, M. (2020). Effects of Foliar Application of Liquid Fertilizer on Agronomical and Physiological Traits of Rice (Oryza sativa L.). *Acta Agrobotanica*, *73*(3). https://doi.org/10.5586/aa.7332

14 Mehraj, H. (2016). Effect of Nitrogen Sources for Spikelet Sterility and Yield of Boro Rice Varieties. *Advances in Plants & Agriculture Research*, *5*(5). https://doi.org/10.15406/apar.2016.05.00192

15 Monira, Most. S., Hoque, Md. A., Haider, A., & Uddin, Md. M. (2024). Evaluation of effectiveness of foliar application of urea fertilizer on growth, development and yield of BRRI Dhan 84 in

barind tract, Bangladesh. *Mediterranean Journal of Basic and Applied Sciences*, *8*(4), 37–45. https://doi.org/10.46382/mjbas.2024.8404

16 Rakasiwi, N., Muadim, N., Sriwati, E., Wibowo, W. T., Laili, L. N., & Kusumastuti, C. T. (2025). RESPONSE OF RICE GROWTH AND YIELD UNDER DIFFERENT TIMING OF NPK-BASE FERTILIZERS APPLICATION IN THE SALIBU SYSTEM. *Applied Ecology & Environmental Research*, *23*(4). https://doi.org/10.15666/aeer/2304_66436656

17 Rahman, M. A., Sultana, N., Mia, M. L., Salim, M., Hasan, A. K., Salam, M. A., ... & Rahman, M. R. (2025). Effect of Nitrogen Level and Plant Spacing on Production Parameters of Boro Rice (cv. BRRI dhan28). *Asian Soil Research Journal*, *9*(4), 64-76. 10.9734/asrj/2025/v9i4207

18 Rajput, P. R., Singh, A., Kumar, M., VIVEK, Yadav, R. B., & Shahi, U. P. (2023). Effect of planting density and micronutrient application on growth, physiological parameters and yield of rice (Oryza sativa). *The Indian Journal of Agricultural Sciences*, *93*(11). https://doi.org/10.56093/ijas.v93i11.111426

19 Razib, M. A. H., Sarker, A. U., Sultana, N., Islam, M. N., & Podder, R. (2023). Performance of Three Boro Rice Varieties Under Different Levels of Nitrogen Application. *Research in Agriculture Livestock and Fisheries*, *9*(3), 267–278. https://doi.org/10.3329/ralf.v9i3.63963

20 Swain, J., Panda, R. K., Nayak, R. K., Satapathy, M. R., Das, J., & Panigrahy, M. (2025). Synergistic role of potassium fertilizer and kinetin in mitigating iron toxicity and enhancing yield in lowland rice. *Scientific Reports*, *15*(1). https://doi.org/10.1038/s41598-025-21573-7

21 Tanjim, F., Anwar, Md. P., Yeasmin, S., Amran, A. H., Faria, J. H., Priya, N. N., Biswas, M., & Sultana, A. (2024). YIELD ENHANCEMENT OF HYBRID BORO RICE THROUGH ZINC BORON AND TRIACONTANOL APPLICATION. *Reviews In Food And Agriculture*, *5*(1), 61–68. https://doi.org/10.26480/rfna.01.2024.61.68

22 Uddin, M. M., & Rahman, Md. A. (2024). Effect of Irrigation and Nitrogen Application at Early Tillering, Panicle Initiation and Flowering Stages on the Yield and Yield Attributes of Boro Rice. *Asian Journal of Research in Crop Science*, *9*(4), 67–79. https://doi.org/10.9734/ajrcs/2024/v9i4300

23 Zhou, W., Lv, T., Yang, Z., Wang, T., Fu, Y., Chen, Y., Hu, B., & Ren, W. (2017). Morphophysiological mechanism of rice yield increase in response to optimized nitrogen management. *Scientific Reports*, *7*(1). https://doi.org/10.1038/s41598-017-17491-y