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DETERMINATION OF OPTIMUM NITROGEN LEVEL FOR MAXIMIZING YIELD OF TWO HYV BORO RICE VARIETIES IN BOGURA REGION, BANGLADESH

S.M.M.S. Tonmoy[1*], T.K. Roy[2], A. Sannal[3], M.A.U. Razu[4] and M.M. Rana[5]

[1]Farm Management Division, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh
[2] Entomology Division, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh
[3] Plant Pathology Division, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh
[4] Rice Farming Systems Division, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh
[5]Agronomy Division, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh
*Corresponding author, Email: smstonmoy47@gmail.com

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Abstract

Application of N fertilizer is very crucial for rice, but both excessive and mild reduced productivity. A field experiment was conducted during the *Boro* 2021-2022 season to find out the optimum dose of N fertilizer for higher yield. The trial was conducted in a factorial RCBD design with three replications. Factor A: Two varieties of rice viz. BRRI dhan89 and BRRI dhan100 and B: Five Nitrogen levels i.e., 0, 90, 120, 150, and 180 Kg ha^{-1}. Yield and yield-contributing traits varied significantly with N levels. BRRI dhan89 outyielded BRRI dhan100 due to its varietal potential and longer life cycle. The highest tiller number hill^{-1}, panicle number hill^{-1}, panicle length, filled grain panicle^{-1}, grain yield, biological yield and harvest index and lowest spikelet sterility were obtained from 120 kg N ha^{-1} irrespective of variety. The result revealed that the combination of both varieties with 120 kg N ha^{-1} followed by 90 Kg N ha^{-1} in maximizing rice productivity while avoiding excess use of N fertilizer.

Introduction

Bangladesh stands as the third-largest global producer of rice, trailing only China and India, boasting a production volume of 36 million tons (Rahman *et al.*, 2021). In Bangladesh, rice cultivation is categorized into three main classes based on the seasons: *Aus*, *Aman*, and *Boro*. *Boro* rice covered largest area, encompassing over 40.91% of the total rice cultivation area of 11.828 million acres and production 19.885 million metric tons (BBS, 2022). Production of rice depends many factors including variety, soil, environment, cultural practice etc.

Fertilizer management and time of planting also influenced grain yield (Rana *et al*., 2023). To maximize yields on limited land resources, the application of nitrogen (N) fertilizer is crucial for modern rice cultivars. Rice demand is anticipated to rise at an annual rate of approximately 1% (Rosegrant *et al.*, 2001). There's limited lands for expansion in rice cultivation areas or additional irrigated land. Hence, enhancing the efficiency of N fertilizer usage to maintain economically viable input levels for boosting rice production. Moreover, N fertilizer is one of the most important nutrient components for plant growth, yield as well as grain quality. Applying top-dressed nitrogen during the rapid growth phase of rice can be absorbed very effectively. Applying higher concentrations of N has been shown to boost both plant growth and N metabolism. In plants, applying an excess of N extends the crop's duration, leading to a reduction in the period between leaf appearance and leaf yellowing, ultimately decreasing grain yield and increasing N loss (Wang *et al.*, 2016). Utilizing an appropriate N rate is crucial not just for achieving optimal economic yields but also for mitigating environmental pollution. The application of N fertilizers is crucial for unlocking the maximum yield capacity of contemporary rice cultivars (Chamely *et al.*, 2015).

However, the effectiveness may vary due to factors like soil fertility, fertilizer application, and crop responsiveness to nutrient inputs. Moreover, excessive N application can result in ground water contamination, elevated production expenses, diminished crop yields and environmental harm (Djaman *et al.,* 2018). Considering the above factors, the specific purpose of this study was to find out the optimum dose of N fertilizer for better yield performance in Bogura region, Bangladesh.

Materials and Methods

Experimental site, design and materials

In the *Boro* (dry) season of 2021-2022, a field trial was conducted at the regional station of Bangladesh Rice Research Institute (BRRI) in Sirajganj. The climate in the area are characterized by alternating periods of cold in seedling to maximum tillering stage and alternate hot rainy season in flowering to maturity stage. The experiment adhered to a factorial Randomized Complete Block Design (RCBD) with three replications. Factor A: encompassed two high-yielding varieties of *Boro* rice namely BRRI dhan89 and BRRI dhan100. Factor B: five different levels of Nitrogen viz., 0, 90, 120, 150, and 180 Kg ha^{-1}.The experimental plot was situated on medium-high elevation land with soil characterized as sandy loam.

Agronomic management practices

The seeds were immersed in water within a bucket for duration of 24 h. and pre-germinated seeds were sown in a moist seedbed at the BRRI regional station in Sirajganj research field on November 22, 2021. Seedlings aged 45 days were transplanted with one seedling per hill asSpacing was maintained at 20cm x 20cm.The experimental plot received with Triple Super Phosphate (TSP), Muriate of Potash (MoP), Gypsum, and Zinc Sulphate at rates of 50, 80, 45, and 2.0 Kg ha^{-1}, respectively. The total quantities of TSP, Gypsum, Zinc Sulphate, and two-third of MoP were applied during final land preparation.

Nitrogen was applied according to the designated treatment in three equal split: The first top dress of N at 15 days after transplanting (DAT), the 2nd at 30 DAT, and the 3rd at 45 DAT. While, rest one-third of MoP fertilizer was applied during 3rd top dressing of Urea at 45 DAT. Weeds were managed through the application of a pre-emergence herbicide called Rifit 500 EC (Pretilachlor) at a rate of 988 mL ha^{-1} within 5 DAT. Hand weeding by using a "Khurpi" was also done at 25 days after transplanting for further weed management. Irrigation was administered as needed until the rice reached the soft dough stage. To prevent insect infestation, the Suntap Plus 50WP (Cartap+Fipronil) insecticide was applied at a rate of 750 g ha^{-1} at the heading stage. Throughout the experiment, fungal diseases were controlled by applying Amistar Top 325SC (Azoxystrobin + Difenoconazole) fungicide at a rate of 500 mL ha^{-1}.

Data collection

To record panicle length and the number of spikelets, five hills were randomly selected from each experimental plot. The plant height was measured from ground level upto the tip of the panicle after flowering. The 1000-grain weight, grain yield and straw yields were determined after harvesting. The biological yield and harvest index (%) were calculated by using the following formula:

$$\text{Biological yield (t ha}^{-1}\text{)} = \text{Grain yield (t ha}^{-1}\text{)} + \text{Straw yield (t ha}^{-1}\text{)}$$

$$\text{Harvest Index (HI\%)} = \frac{\text{Grain Yield}}{\text{Biological Yield}} \times 100$$

Statistical analysis

All data were subjected to separate statistical analyses using the analysis of variance technique implemented in R software (versions 4.2.1, 2022) and differences among treatment means, the Least Significant Difference (LSD) test was employed at level of 5%.

Results and Discussion

Effect of variety on yield and yield contributing traits

There were significant different of plant height between two rice varieties. From Table 1 it was observed that plant height of BRRI dhan89 (110.60 cm) was taller than BRRI dhan100 (104.62 cm). No significance difference was found in case of tiller hill^{-1} and panicle hill^{-1}. Between two rice varieties longest panicle length (26.71 cm), highest filled grain panicle^{-1} (152.59), highest unfilled grain panicle^{-1} (10.76), highest sterility percent (10.76), highest straw yield (8.75 t ha^{-1}), biological yield (15.99 t ha^{-1}) and highest HI (45.08) were observed in BRRI dhan89 as compared to BRRI dhan100. The highest grain yield (7.24 t ha^{-1}) was observed in BRRI dhan89 due to its highest panicle length, filled grain panicle^{-1}, tiller number, panicle number, panicle length. The research findings were also supported by Azad *et al.*, 2022; Chakma, 2006; Roy *et al.*, 2021; Roy *et al.*, 2024; Hossain *et al.*, 2010 and Dutta *et al.*, 2002).

Table 1. Effect of variety on yield and yield contributing traits

Variety	Yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
BRRI dhan89	7.24 a	8.75 a	15.99 a	45.08 a
BRRI dhan100	5.12 b	6.84 b	11.96 b	42.73 b
		***	***	***
$LSD_{(0.05)}$	0.2740711	0.2658882	0.4265024	1.159781
CV (%)	5.782148	4.447491	3.979089	3.443713

Effect of N levels on yield and yield contributing traits

There was no significance difference of plant height at different N levels (Table 2). The number of tillers hill^{-1}, panicle hill^{-1}, panicle length, filled grain panicle^{-1} were varied significantly due to different level of N rates (Table 2). The maximum number of tiller hill^{-1} (11.65) was found due to application of 180 Kg ha^{-1} N followed by N_{120} (11.52), N_{50} (11.40), and N_{150} (10.88). Lowest number of tiller hill^{-1} (10.33) was found N_0 treatment. Higher number of panicle hill^{-1} (11.18) was found due to application of 120 Kg ha^{-1} N and which was statistically similar with N_{180} (11.03) and N_{90} (10.87) and lowest was found in N_0 (9.60) treatment.

The maximum panicle length (26.12 cm) was observed in N_{180} N level and which was statistically similar with N_{120} N levels and lowest panicle length was observed in N_0 (24.69 cm) N levels. Similar result also reported by Jahan *et al.,* (2020). Gewaily *et al.,* (2018) reported that the increase in panicle number and panicle length with N fertilization. The maximum number of filled grain panicle^{-1} (159.70) was found in N_{120} N level which was statistically similar with N_{90} (154.03) and N_{150} (153.75) N level. Highest number of unfilled grain panicle^{-1} was observed in N_{180} (18.80) N level while lowest in N_{50} (12.70) N levels. The highest sterility % was found in N_{180} (10.83) N level and lowest was found in N_{120} (7.68) N level. Hence, it might be concluded that unfilled grain panicle^{-1} increased by increased N levels. Similar result also concluded that Jahan *et al.* (2020). The increased number of filled grain with the increase in N rates indicates that N fertilization is important for both sources and sinks development reported by Jahan *et al*. (2020).

Table 2. Effect of N levels on yield and yield contributing traits

Nitrogen Level	Plant height (cm)	Number of tillers hill^{-1}	Number of panicle hill^{-1}	Panicle length (cm)	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Sterility percentage (%)
N_0	105.28	10.33 b	9.60 c	24.69 c	126.82 c	14.35	9.34 ab
N_{90}	107.31	11.40 a	10.87 ab	25.43 b	154.03 ab	12.70	8.13 b
N_{120}	107.85	11.52 a	11.18 a	25.74 ab	159.70 a	13.37	7.68 b
N_{150}	108.47	10.88 ab	10.21 bc	25.60 b	153.75 ab	16.97	9.87 ab
N_{180}	109.14	11.65 a	11.03 ab	26.12 a	150.00 b	18.80	10.83 a

$LSD_{(0.05)}$	NS	0.8998866	0.87815	0.494504	7.702076	NS	NS
CV (%)	2.32	6.650724	6.84557	1.597518	4.265603	28.68612	23.8302

Note: NS=Non-significant

Yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}), and HI (%) were varied significantly due to different level of N rates (Table 2.1**)**. Highest yield (7.02 t ha^{-1}) was found in N_{120} due to higher tiller number $hill^{-1}$, panicle length and highest number of panicle $hill^{-1}$, highest number of filled grain $panicle^{-1}$ and lowest percent of spikelet sterility. Grain yield is influenced by various yield contributing factors as reported by Jahan *et al.* (2020). This study also showed grain yield increased with increased N levels up to 120 Kg ha^{-1} and after that grain yield decreased with increasing N levels. Lowest yield (4.76 t ha^{-1}) was found N_0 level. The highest straw (8.33 t ha^{-1}) yield was found due to application of 180 Kg ha^{-1} N level and which was significantly differ from others N level. Lowest straw yield (6.83 t ha^{-1}) was found in N_0 level. Highest straw yield with higher N level might be due to better N uptake leading to greater dry matter accumulation and its translocation to their sink (Rajesh *et al.*, 2015). The maximum biological yield (14.92 t ha^{-1}) was found in N_{120} level and which was statistically similar with others N level except N_0 level. Higher HI was observed in N_{120} (46.91) and which was statistically similar with N_{90} (46.41). Lowest harvest index was found in N_0 (41.00) and which was statistically similar with N_{180} (41.43).

Table 2.1. Effect of N levels on yield and yield contributing traits

Nitrogen Level	Yield (t ha^{-1})	Yield increase over control (%)	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0	4.76 d	-	6.83 c	11.59 b	41.00 c
N_{90}	6.72 ab	41.18	7.71 b	14.43 a	46.41 a
N_{120}	7.02 a	47.48	7.90 b	14.92 a	46.91 a
N_{150}	6.29 bc	27.76	8.01 b	14.30 a	43.75 b
N_{180}	6.10 c	26.92	8.53 a	14.63 a	41.43 c
$LSD_{(0.05)}$	0.43	-	0.42	0.67	1.83
CV (%)	5.78	-	4.44	3.97	3.44

Interaction effects of variety and N levels on yield and yield contributing traits

Interaction effect of varieties and N levels did not vary plant height, tiller $hill^{-1}$ and panicle $hill^{-1}$ significantly (Table 3). The highest number of panicle $hill^{-1}$ was found in V_2N_{90} (BRRI dhan100 followed by N 90 Kg ha^{-1}) while lowest was found V_2N_0 (BRRI dhan100) and N 0 Kg ha^{-1}. The interaction effect between varieties and N levels was influenced significantly by panicle length. The maximum panicle length (27.37 cm) was observed in V_1N_{120} (BRRI dhan89 and N 120 Kg ha^{-1}) which was statistically similar with V_1N_{90}), V_1N_{150} and $V_1N_{180,}$ respectively. Lowest panicle length (23.44 cm) was found in V_2N_{90}. This result supported by Yoseftabar (2013) reported that the increase in panicle number and panicle length with N fertilization. The interaction effect of varieties and N levels was non-significance by the number of filled grains $panicle^{-1}$, number of unfilled grains $panicle^{-1}$, percent spikelet sterility and percent HI. The maximum percent of HI (47.91) was found in V_1N_{120} followed by V_1N_{90} and lowest HI (40.27) was in $V_2N_{0.}$ Alam *et al.* (2009) also reported that the interaction of variety and N had t significant effect.

Table 3. Interaction effects of variety and N levels on yield and yield contributing traits

Variety × Nitrogen Level	Plant height (cm)	Number of tiller $hill^{-1}$	Number of panicle $hill^{-1}$	Panicle length (cm)	Number of filled grains $panicle^{-1}$	Number of unfilled grains $panicle^{-1}$	Sterility percentage (%)	Harvest index (%)
$V_1×N_0$	108.45	10.47	9.73	25.66 b	131.17	17.00	11.51	41.72
$V_1×N_{90}$	109.77	10.60	10.33	26.83 a	156.60	16.73	9.62	47.48
$V_1×N_{120}$	110.40	11.63	11.33	27.37 a	163.97	14.73	8.24	47.91
$V_1×N_{150}$	112.13	11.07	10.30	26.80 a	157.17	19.53	10.98	45.24

$V_1 \times N_{180}$	112.25	11.70	11.13	26.90 a	154.07	24.47	13.46	43.03
$V_2 \times N_0$	102.12	10.20	9.47	23.74 c	122.47	11.70	7.13	40.27
$V_2 \times N_{90}$	104.84	12.20	11.40	23.44 d	151.47	8.67	6.64	45.34
$V_2 \times N_{120}$	105.29	11.40	11.01	24.03 c	155.43	12.00	7.13	45.92
$V_2 \times N_{150}$	104.68	11.68	10.11	24.41 c	150.33	14.40	8.75	42.26
$V_2 \times N_{180}$	106.15	11.60	10.93	25.34 b	145.93	13.13	8.20	39.84
LSD $_{(0.05)}$	NS	NS	NS	0.70	NS	NS	NS	NS
CV%	2.33	6.65	6.85	1.60	4.27	28.69	23.83	3.44

Note: NS=Non-significant

The interaction effect of varieties and N levels was influenced significantly by grain yield (t ha^{-1}) and biological yield (t ha^{-1}) and non-significant by straw yield (Fig. 1, 2, 3).

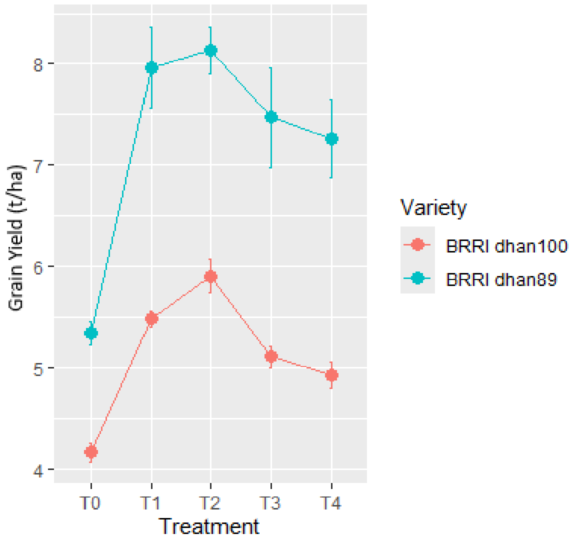

Fig. 1. Interaction effect of varieties and N levels on yields.
(where, T_0=0, T_1=90, T_2=120, T_3=150 & T_4=180 kg N ha^{-1})

The highest grain yield (8.14 t ha^{-1}) was obtained by V_1N_{120} (BRRI dhan89 and N 120 Kg ha^{-1}) combination followed by V_1N_{90} (BRRI dhan89 and N 90 Kg ha^{-1}) due to higher tiller number hill^{-1}, panicle number hill^{-1}, panicle length, number of filled grains panicle^{-1}, HI, and lower number of unfilled grains panicle^{-1} and percent spikelet sterility. The lowest yield (4.17 t ha^{-1}) was found in V_2N_0 (BRRI dhan100 and N 0 Kg ha^{-1}). Highest straw yield (9.61 t ha^{-1}) was produced by V_1N_{180} and lowest straw yield (6.18 t ha^{-1}) was produced by V_2N_0.

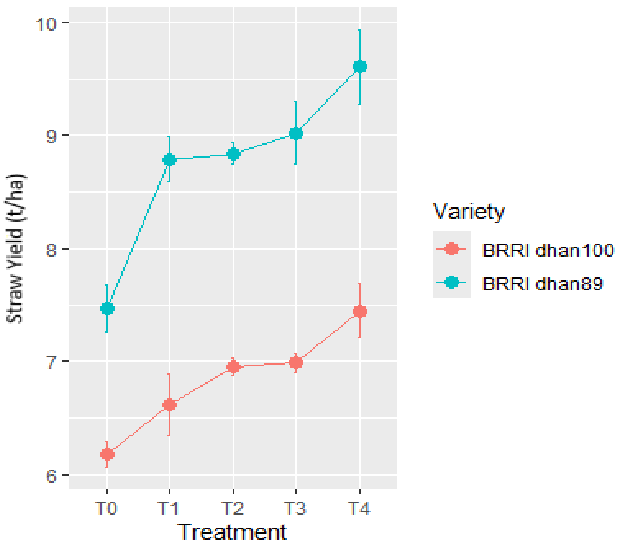

Fig. 2. Interaction effect of varieties and N levels on straw yield.
(where, T_0=0, T_1=90, T_2=120, T_3=150 & T_4=180 kg N ha^{-1})

Highest biological yield (16.96 t ha^{-1}) was observed in V_1N_{120} and lowest (10.35 t ha^{-1}) was V_2N_0. Similar findings also reported by Razib *et al.* (2023). The optimum N application rates for achieving maximum yield vary with both the rice cultivar and the specific growing season, highlighting the importance of tailoring N fertilization practices to the rice variety and prevailing climatic conditions (Jahan *et al.*, 2020).

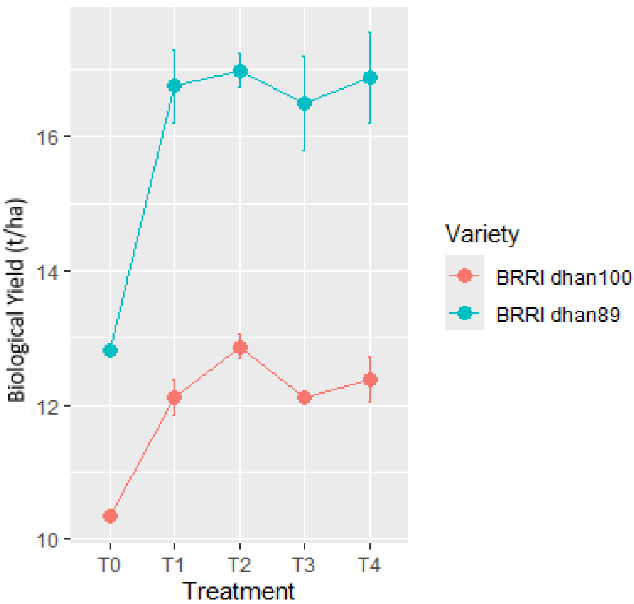

Fig. 3. Interaction effect of varieties and N levels on biological yield.
(where, T_0=0, T_1=90, T_2=120, T_3=150 & T_4=180 kg N ha^{-1})

Conclusion

The growth and yield repercussion of rice var. BRRI dhan89 and BRRI dhan100 were varied due to application of different N levels. Plant height, tiller number, panicle length, number of unfilled grains and straw yield increased due to increased levels of N in both rice varieties. But number of panicle hill^{-1}, number of filled grains panicle^{-1}, biological yield, and HI was aptitude to increase with the increased of N levels up to 120 Kg ha^{-1}and after that decreased with increasing N levels. It elicits that over N rates did not give additional benefit regarding to grain yield. Based on grain yield and yield contributing characters the order of N levels was N_{120}>N_{90}>N_{150}>N_{180}>N_0. So, N level 120 kg ha^{-1} could be recommended in combination with recommended dose of TSP, MoP, and Gypsum fertilizer to assure optimum requirement of nutrient for both BRRI dhan89 and BRRI dhan100.

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