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Can nitrogen fertilizer rates affect the yield response of Boro rice (*Oryza sativa* L.) variety on the Old Brahmaputra floodplain soil of Bangladesh?

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Abstract

This study observed the yield response to nitrogenous fertilizer for a popular Boro rice variety BRRI dhan29 under silty loam texture soil with satisfactory organic matter (2.96%). Sequential elevated doses of nitrogen (N_0, N_{70}, N_{80}, N_{90}, N_{100}, and N_{110} kg ha^{-1}) along with recommended phosphorus (P), potassium (K), and Sulphur (S) significantly increased grain yield up to 50%. Tested rice variety yielded the highest from N_{110} kg ha^{-1} treated plot, 6.30-ton grain ha^{-1} and 7.57-ton straw ha^{-1}, which were statistically similar with the 100 kg ha^{-1} nitrogen application. The N uptake from soil by the plant was also statistically equivalent for N_{100} and N_{110} kg ha^{-1} application. Panicle m^{-2}, filled grain per panicle, and 1000-grain weight showed the same trends as N uptake and yield. The overall results demonstrate that the application of 100 kg N ha^{-1} was the best treatment for obtaining higher yield and the N content for both grain and straw of BRRI dhan29 at Old Brahmaputra Floodplain Soil.

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Introduction

Rice (*Oryza sativa* L.) belongs to the cereal crop under the Graminae family. It is the essential food grain in Asia, accounting for about 92% of the world's rice production (Gnanamanickam, 2009). Bangladesh is a densely populated country where rice is considered a staple food. The geographical situation, as well as climate and edaphic conditions of this country, are favorable for year-round rice cultivation. A considerable part of Bangladesh's economy is based on agriculture and this contributes to her gross domestic product by about 22% (BBS, 2014). According to BBS (2014), Bangladesh produces 34.71 million tons of rice per annum from 11.4 million ha of land. It provides about 75% of the calories and 55% of the protein in the average daily diet of this country's people (Bhuiyan and Karim, 1999). Although Bangladesh ranks 4th in the world in terms of both acreage and production, the yield of rice is much lower (2.87 ton ha^{-1}) compared to that in other leading rice-growing countries such as China (6.23 ton ha^{-1}), Korea (6.95 ton ha^{-1}), Japan (6.88 ton ha^{-1}) and the USA (7.55 ton ha^{-1}) (FAO, 2014).

Nitrogenous fertilizer is the key component of rice production. An increase in yield by 70-80% may be obtained by applying nitrogenous fertilizer (Jun *et al.*, 2013). In rice farming, Nitrogenous fertilizer is called the lynchpin for maximizing rice yield. This nutrient is required in an adequate amount at early, mid-tillering, panicle initiation and ripening stages for better grain development. Researchers have done different fertilizer experiments on the reaction of certain varieties to various nitrogen levels. Nitrogen fertilizer enhances tillering and vegetative growth and increases plant height, grain and biomass when applied to the soil at an optimum dose (Ebaid and Ghanem, 2000). Almost all the soils of Bangladesh are low in organic matter and nitrogen. Among many factors, the deficiency of N is considered a significant reason for the low yield of rice in Bangladesh. Most of the farmers of Bangladesh tend to apply more amount of nitrogen to obtain a higher yield. Our farmers frequently use urea as N fertilizer which accounts for about 75% of the total fertilizer used in Bangladesh. Most of the rice cultivating soils of Bangladesh are deficient in N, and consequently, the response of modern rice varieties to nitrogen application has always been remarkable. Nitrogen use efficiency for rice crops broadly ranges from 25% to 35% and seldom exceeds 50% (Singh *et al.,* 2001). The loss of N from the soil is mainly due to crop removal and leaching, but under certain conditions, gaseous loss seldom exceeds 30-40% applied to wetland rice when higher N use efficiency is, however, possible through appropriate N management techniques. Higher N use efficiency is possible through proper N application techniques. N should apply in three equal splits e. g. 15, 30 and 45 days after transplanting of rice, followed by incorporation along with weeding. Two to three splits for other irrigated upland crops are recommended for better efficiency. For wetland rice, N loss in gaseous forms may be reduced by applying urea in saturated soil rather than in standing water. There are thirty Agro-Ecological Zones (AEZ) in Bangladesh where Old Brahmaputra Floodplain Soil is one of them and Mymensingh belongs to this AEZ. According to the fertilizer recommendation guide, the soils of different AEZ need different fertilizer rates for higher crop production. Considering the socio-economic importance of farmers in Bangladesh perspective, the study will show better performance in maximizing the yield of BRRI dhan29 at Old Brahmaputra Floodplain Soil. As urea is the most commonly used nitrogen fertilizer for rice production in our country, it is necessary to determine the optimum rate for this fertilizer implementation. Hence, the present study was undertaken to estimate the effect of different levels of N on yield with the yield contributing characters and N uptake of BRRI dhan29 under irrigated rice ecosystem.

Materials and methods

Study area and crop variety

The field laboratory of the Soil Science Department, Bangladesh Agricultural University, Mymensingh, Bangladesh, was utilized for this experiment. Fig. 1 demonstrates the location details of our study area. The physical and chemical soil status of our study site is shown in Table 1.

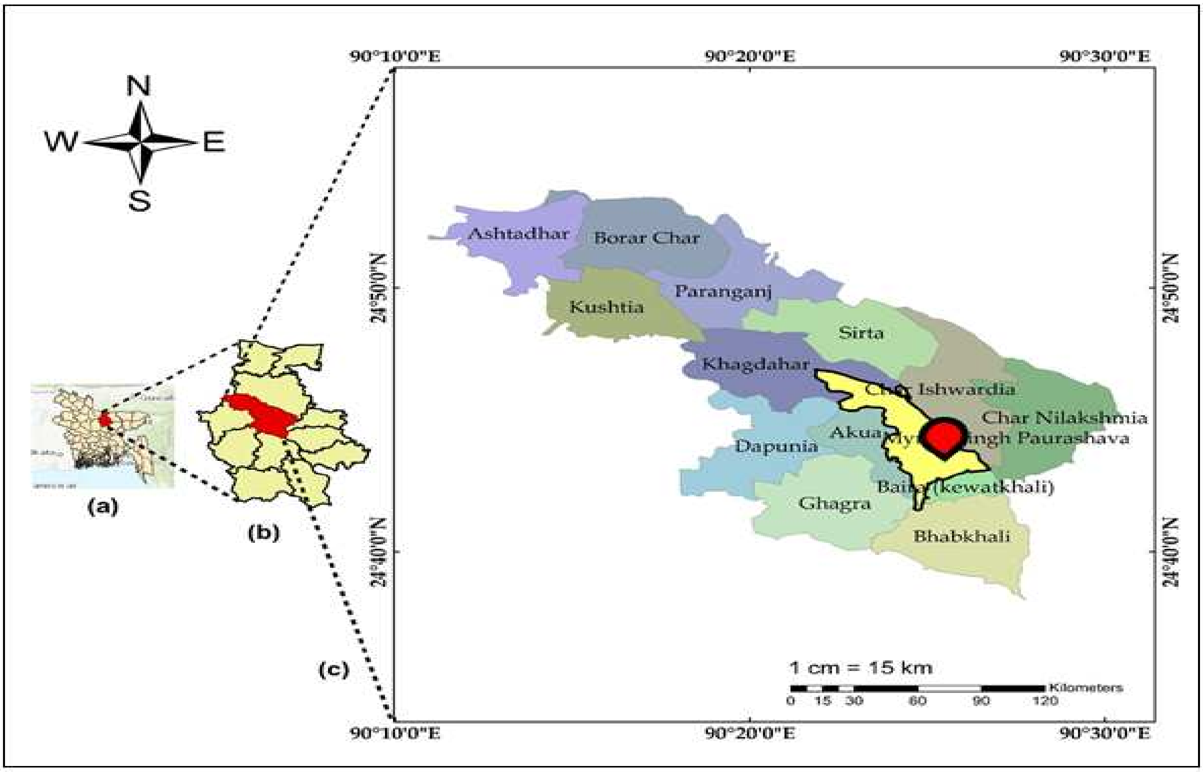

Fig. 1. Map of the study site: (a) Location of study site in Bangladesh, (b) Mymensingh district with study site and (c) The specific area of our interest.

We selected a popular high-yielding Boro rice variety, BRRI dhan29, as a test crop. It is a long-duration variety (around 155 to 160 days) with high yield potential (*BRRI Rice Varieties | Bangladesh Rice Knowledge Bank, n.d.*).

Experimental design and treatments

The experiment was designed in Randomized Complete Block Design (RCBD) with four replications. The unit plot size was 4 m × 2.5 m; the plots were separated from each other by 0.5 m bunds. There were 1 m drains between the blocks. The treatments were randomly distributed to each block. The test crop was treated with 7 different fertilizer dose (treatment) combinations based on N application rates (including one control treatment). Except for control in all other treatments, recommended fertilizer dose (RFD) of 74 kg TSP ha^{-1}, 60 kg MoP ha^{-1} and 37 kg Gypsum ha^{-1} were applied. The treatment combinations for the experiment were T_1= Control (No fertilizer); T_2= N_0; T_3= N_{70}; T_4= N_{80}; T_5= N_{90}; T_6= N_{100}; T_7= N_{110}. Except for N, all other fertilizers were applied during final land preparation. Urea was broadcasted three times after transplanting every 15 days of interval. Necessary-based intercultural operations were practiced for better and smooth crop growth.

Data collection

Yield and yield contributing characters

Adjacent five hills were randomly selected from each plot at maturity to record yield contributing characters like plant height (cm), number of effective tillers $hill^{-1}$, panicle length (cm), number of grains $panicle^{-1}$, and 1000-grain weight (g). The selected hills were collected before the crop harvest and necessary information was recorded accordingly. Grain and straw yields were recorded treatment-wise and expressed as t ha^{-1} on a fresh weight basis.

Nutrient uptake by the plant (Grain and straw analysis)

The collected grain and straw sample from each plot was dried in an oven at 65°C for about 24 hours, after which they were ground by a grinding mill. Later the ground samples were sieved through a 20-mesh sieve. Similarly, straw samples were also prepared. For determining nitrogen content, a sub-sample weighing

0.1 g was taken into a clean dry 100 ml Kjeldahl flask and then 1.1 g catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$ in the ratio of 100: 10) and 5 ml conc. H_2SO_4 was added to the flask.

The content was swirled and allowed to stand for about 10 minutes. After that, the flask was heated continuously until the digest became clear and colorless. After cooling, the digest was transferred into a 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was also prepared in a similar manner.

This digestion was performed for nitrogen determination. Only the element N in the digest was determined in the same method as used in soil chemical analysis.

Formula

After chemical analysis of straw and grain samples, the nutrient uptake was calculated from the nutrient content and yield of the rice crop by the following formula:

$$\text{Nutrient uptake} = \frac{\text{Nutrient content (\%)} \times \text{yield (kg per ha)}}{100}$$

Statistical analysis

The analysis of variance for various crop characters and also for nutrient concentrations and nutrient uptake was done following the F-test. Mean comparisons of the treatments were made by Duncan's Multiple Range Test, DMRT (Gomez and Gomez, 1984).

Results and discussion

Effect of increased dose of N fertilizer on crop yield contributing parameters

Plant height

Plant height of BRRI dhan29 was significantly influenced by different nitrogen levels applied (Table 3). Plant height ranged from 72.0 cm to 85.14 cm.

The tallest plant (85.14 cm) was found in T_7 (Recommended Fertilizer Doses of PKS + N_{110}) which was identical to that observed in the treatment T_6 (85.12 cm). Hoque *et al.* (2021) applied different levels of N in the field and obtained the highest plant height at the highest N levels. Adhikari *et al.* (2018) found that up to a fixed N level sharply affected plant height and then the increase is very identical.

Table 1. Soil physical and chemical properties.

Properties	Methods	Values
% Sand	Hydrometer method	13.28
% Silts		74.00
% Clay		12.72
Textural class		Silt loam
pH	pH meter (glass electrode)	6.88
Organic matter (%)	Walkley and Black method	2.96
Total N (%)	Micro-Kjeldahl distillation method	0.18
Available P (ppm)	Olsen method	12.23
Exchangeable K (me $100g^{-1}$ soil)	1 N NH_4OAc method	0.13
Available S (ppm)	0.01 M $Ca(H_2PO_4)_2$ extraction method	11.90
Cation Exchange Capacity, CEC (me $100g^{-1}$ soil)	Sodium Acetate method	12.70

Panicles m^{-2}

A close identical effect of gradually increased N level (T_4 to T_7) was found on panicle number of BRRI dhan29 per one square meter (Table 3). The maximum panicles number (303.00) was recorded from the T_7 treated plot. Djaman *et al.* (2016) reported that a gradual increase of N nutrient on five aromatic rice varieties greatly affected panicles number per square meter were up to a certain limit N increase resulted identical. Roshan *et al.* (2011) observed the highest number of bearer tillers from the highest N applied plot.

Table 2. Nutrients' doses and their sources used for the experiment.

Source	Nutrient element	Percentage (%)
Urea	N	46
TSP	P	20
MoP	K	50
Gypsum	S	18

Filled grains panicle^{-1}

Applied nitrogen fertilizer doses significantly increased the filled grains panicle^{-1} (Table 3). The highest filled grains (115) were found in 110 kg N ha^{-1}. The lowest number of filled grains panicle^{-1} (73) was found without fertilized plot. Zhang *et al.* (2009) demonstrated that the spikelets per square meter were influenced by the N application in both farm and station conditions. The number of grains per panicle was significantly affected when N application was gradually increased (Roshan *et al.*, 2011).

1000-grain weight

There was a significant effect of higher dose N level on 1000-grain weight of rice variety (BRRI dhan29) (Table 3). Results revealed that the higher the N dose, the higher the 1000-grain weight. Statistically, the highest grain weight 23.24 g from 110 kg N ha^{-1} found insignificant to 100 kg N ha^{-1} (23.24 g). Chamely *et al.* (2015) evaluated three popular Boro rice varieties with different N levels and found the highest grain weight from the highest N level. R.M. Lampayan *et al.* (2010) reported a similar effect of nitrogen on grain weight though a maximum weight was scored from the highest N level.

Grain yield

Across treatments, rice yield significantly varied from 3.15 t ha^{-1} to 6.30 t ha^{-1} (Table 3). N 100 kg and 110 kg ha^{-1} gave identical grain yield (6.30 t ha^{-1} and 6.23 t ha$^{-1,}$ respectively).

The lowest grain yield 3.81 t ha^{-1} was recorded from the control plot that was statistically different from all other treatments. Lampayan *et al.* (2010) harvested maximum grain from the highest N treated plot. Zhang *et al.* (2009) got on average 14% yield advantage with the highest N level applied.

Table 3. Yield components, grain and straw yield of rice (BRRI dhan29) influenced by Nitrogen application.

Treatments	Plant height (cm)	Panicles m^{-2}	Filled grains panicle^{-1} (No.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1 (Control)	72.00 e	181.00 e	73.00 f	21.65 e	3.15 e	3.81 f
T_2 (N_0)	75.50 d	213.00 d	83.00 e	21.87 d	3.65 d	4.38 e
T_3 (N_{70})	78.80 c	238.00 bc	91.00 d	22.08 c	5.19 c	6.22 d
T_4 (N_{80})	81.00 b	263.00 abc	100.00 c	22.58 bc	5.62 b	6.74 c
T_5 (N_{90})	82.00 b	269.00 ab	105.00 b	22.66 b	5.93 b	7.11 b
T_6 (N_{100})	85.12 a	300.00 a	114.00 a	23.23 a	6.23 a	7.46 a
T_7 (N_{110})	85.14 a	303.00 a	115 .00 a	23.24 a	6.30 a	7.57 a
CV%	6.15	17.22	15.52	2.65	5.25	6.68
SE (±)	0.93	0.33	2.84	0.11	0.23	0.31

Figures in a column having common letter(s) do not differ significantly at 5% level of significance. CV and SE denote coefficient of variation and stand error of means, respectively.

Straw yield

The average straw yield was significantly influenced by the treatments (Table 3). The straw yield obtained from different treatments ranged from 3.81 to 7.57 t ha^{-1}. The highest straw yield of 7.57 t ha^{-1} was obtained in 110 kg N ha^{-1} which was significantly different from the maximum of the treatments. Biomass production was very much proportionate to the increased dose of N level (R.M. Lampayan *et al.*, 2010). Lucrative dry matter was harvested when N application was maximum (Zhang *et al.*, 2009).

Elevated Nitrogen relation to N content and uptake by grain and straw of rice

A gradual increase of N enrichment in both grain and straw was reported with an increase in N application (Table 4). Maximum N content in grain (1.004%) and straw (0.522%) was recorded from the 110 kg N ha^{-1} plot. A similar trend repeated in the case of N uptake by both grain and straw. Rice grain up has taken the highest amount of N 63.25 kg ha^{-1} in T_7 plot where in straw 39.51 kg ha^{-1}. In both the N content (%) and N uptake (kg ha^{-1}) case the highest dose 110 kg N ha^{-1} performed identically to 100 kg N ha^{-1}.

Table 4. Effect of different nitrogen rates on nitrogen content and uptake by grain and straw of rice (BRRI dhan29).

Treatments	N content (%)		N uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw
T_1 (Control)	0.987 e	0.505 f	31.09 f	19.24 f
T_2 (N_0)	0.952 d	0.474 e	34.74 e	20.67 e
T_3 (N_{70})	0.992 c	0.510 d	51.48 d	31.72 d
T_4 (N_{80})	0.996 bc	0.514 c	55.97 c	34.64 c
T_5 (N_{90})	0.999 b	0.517 b	59.24 b	36.75 b
T_6 (N_{100})	1.002 a	0.520 a	62.42 a	38.79 a
T_7 (N_{110})	1.004 a	0.522 a	63.25 a	39.51 a
CV%	6.30	5.23	7.03	11.16
SE (±)	0.01	0.02	2.31	2.93

Figures in a column having common letter(s) do not differ significantly at 5% level of significance. CV and SE denote coefficient of variation and stand error of means, respectively.

These findings are similar to the observation of Al-Gusaibi (2004), who observed the highest N uptake from the highest N applied plot. Mashkar and Thorat (2005), in their field experiment, identified that the application of 120 kg N ha^{-1} recorded significantly higher N uptake in rice compared to the rest of the N levels.

Conclusion

The results of our study represented that N fertilizer applied at the rate of 100 kg (217.39 kg Urea) per ha was best for achieving the highest yield with all the other parameters for BRRI dhan29 variety in Old Brahmaputra Floodplain Soil. Therefore, 100 kg N ha^{-1} can be recommended for this rice production in this specific area. As fertilizer doses vary with the soil condition, cultivars and weather parameters, broad research is crucial to recommend suitable nitrogen rates for sustainable crop production practice.

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