Bangladesh Agron. J. 2023, 26(1): 84-95

DETERMINATION OF ECONOMIC NITROGEN RATE FOR TRANSPLANTED AUS RICE VARIETIES OF BANGLADESH

Munmun Akter[1], Md. Khairul Alam Bhuiyan[2] and Sheikh Muhammad Masum[1*]

[1]Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh
[2]Agronomy Division, Bangladesh Rice Research Institute
*Corresponding author, Email: smmasum607@yahoo.com

(Received: 24 July 2023, **Accepted:** 28 September 2023**)**

Keywords: Rice, nitrogen, nitrogen uptake, nitrogen use efficiency, yield

Abstract

A field experiment was conducted at the Agronomy field, Bangladesh Rice Research Institute, Gazipur, Dhaka, from April to September 2019 to determine the economic nitrogen rates for popular transplanted *Aus* varieties. The experiment was carried out in a randomized complete block design (RCBD), with two factors. Factor A: three varieties as- BR26, BRRI dhan48, and BRRI dhan82; and Factor B: five levels of nitrogen rates as- 0, 40, 60, 80, 100 kg ha^{-1}. The experimental data show the individual effect of variety and nitrogen (N) rate was significant in the case of N concentration, N uptake in grain and straw, and nitrogen harvest index (NHI). Overall, increasing N rate increases grain and straw's concentration irrespective of varieties. But higher N concentration and uptake were observed in the N rate of N_{60}-N_{100} kg ha^{-1} in all varieties. Among the varieties, BRRI dhan82 observed higher N uptake (61.23 kg ha^{-1}) in grain. Higher total N uptake was also observed in BRRI dhan48 at 80 kg N ha^{-1}. NHI ranged from 55 to 72 % in different N levels, indicating 55 to 72% of the absorbed N translocated to the grains, and 45% to 32% remained in the dry matter within varieties. The estimated economic nitrogen dose for maximum yield was determined by regression analysis, and found that N rates of BR26, BRRI dhan48, and BRRI dhan82 were 97, 95, and 55 kg ha^{-1}, respectively. The findings of this study indicated that the response of different N rates on three *Aus* varieties was linear up to 80 kg N ha^{-1} might be owing to better N uptake that made yield increase after that decreasing.

Introduction

Rice (*Oryza sativa* L.) belongs to the family Poaceae, it's the most important cereal crop in the developing world and the main source of carbohydrates for the people of Bangladesh, and it is the staple food of more than half of the people in the world (BRRI, 2021). About 90% of annual rice is produced and consumed in Asia. The average yield in Asia is lower than the global mean yield (Haider, 2018). About 35-60% world's population derives most of its calories from rice (Tayefe *et al.,* 2014). The possible way to meet this increased demand is by improving rice yield hectare^{-1} (Liu *et al.,* 2016). Bangladesh is the 3rd largest rice-producing country in the world (USDA, 2020). About 75% area and over 80% of the total irrigated area of Bangladesh is covered by rice (Nasim *et al.,* 2017).

Bangladesh's *Aus* rice (summer rice) is a significant crop for drought-prone, low-water-requiring environments. *Aus* is usually planted in March-April and harvested in June-July, and the climate is practically combined with hot summer (March-May). *Aus* rice occupies about 12.53% of the total cultivable area from where modern varieties cover 10.67%, local varieties cover 1.86 %, and 7.49% of the total production comes from *Aus* rice, where modern varieties cover 6.87% and local varieties cover 0.62%. In Bangladesh, the current status of the total area and production of *Aus* rice is 1.08 million ha and 2.71 million MT (BBS, 2021).

Nitrogen (N) fertilizer is required to grow and develop rice and grain production. N fertilizer is the main input in rice production and the optimum rate and profitability of management during the application and stability of the production system (Djaman *et al.,* 2018). Improving leaf N concentration, photosynthetic rate, delaying leaf senescence, and increasing dry matter for grain filling, N helps to increase rice productivity (Hasegawa *et al.,* 1994). During the *Aus* season, deep placement of fertilizer above 52 and 78 kg N ha^{-1} had no significant effects on grain yields but reduced N recovery (Islam *et al.,* 2016). N can improve panicle size and grain weight and reduce spikelet sterility (Fageria, 2009). The application of N fertilizer in rice has also been reported to significantly increase the grain and straw N uptake and N use efficiency (Hassan *et al.,* 2009).

Balanced fertilization is more important for realizing potential grain yield and nutrient uptake than a single application of fertilizer, particularly N (Talashilker and Vimol, 1986). Farmers generally apply more fertilizers than the recommended amount with the idea that using N will always increase the yield, which can result in change, negatively affect the sustainability of the production system, and increase production costs (Fan *et al*., 2012). On the other hand, the application of excess N can result in groundwater pollution, increased production costs, reduced yields, environmental pollution (Djaman *et al.,* 2018), and vegetative growth, which makes the plant susceptible to insects, pests, and diseases and ultimately reduces yield (Chamely *et al.,* 2015). The maximum output of rice was recorded due to the application of 90 to 250 kg N fertilizer ha^{-1} (Meena *et al.,* 2003).

Nitrogen fertilizers are considered to have dominant influences on different agronomic characteristics of rice, such as plant height, tiller number, filled grains panicle^{-1}, spikelet panicle^{-1}, grain yield, straw yield, biological yield, harvest index, etc. Nitrogen also influences the interception of sunlight, leaf area index (LAI), crop growth rate, total dry matter production (TDM), and N uptake (NUP) to the plant. Under these circumstances, it is essential to determine the N-responsive stages of plant growth to ensure its maximum requirement to utilize the applied N effectively. Moreover, an economic N rate is required for the farmers to get maximum profit. Nitrogen fertilizer varies in different locations, ecosystems, and different varieties depending on the initial N status of the soil (Masum *et al*., 2008)

A suitable combination of variety and rate of N is required for better yield. Therefore, the research objectives were to find the performance of T. *Aus* rice varieties in different N levels and the economic N rate of T. *Aus* rice varieties.

Materials and Methods

The experiment was conducted at the experimental farm of Bangladesh Rice Research Institute in *Aus* season (summer rice) during the period from April to August 2019. The experimental location's climate is subtropical and characterized by heavy rainfall from April to September and scanty rainfall from October to March, with an average annual rainfall of 2000 mm. The soil of the experimental site belongs to the order Inceptisols in the USDA soil classification system. Before the initiation of the experiment, soil samples from the top layer (20 cm) were collected and analyzed. The soil was silty clay loam in texture having pH 6.45, organic matter 1.54 (%), total N .014% (Kjeldahl digestion method), available P 24.65 ppm, exchangeable K 0.18 (me/100 g soil) and available S 19.55 ppm. Five rates (0, 40, 60, 80, and 100 kg ha^{-1}) of N were tested on three high-yielding rice varieties (BR26, BRRI dhan48, and BRRI dhan82). Sprouted seeds were sown in the wet nursery bed on 10 April 2019. Proper care was taken to raise healthy seedlings in the seedbed. Weeding irrigation was done when was necessary. The experiment was laid out in 2 factors randomized complete block design with three replications. There were 45 unit plots in the experiment. Each replication was divided into 15 unit plots where the treatment combinations were allocated at random. The size of each unit plot was (2.5 m x 4.0

m =10 m^2). The spacing between block to block and plot to the plot was 0.6 m and 0.4 m, respectively. The N was applied as urea in three equal splits: the first at the time of final land preparation, the second at maximum tillering stage and the third at panicle initiation. All the treatments received an equal amount of phosphorus (P), potassium (K), and sulfur (S) fertilizers and applied as basal. The application of fertilizer in the experiment is shown in Table 1.

Table 1. Application of fertilizer in the experimental plot

Treatment	Fertilizer (kg ha^{-1})	Application of fertilizer in the experimental plot (g 10 m^{-2})			
		Total	1st installment	2nd installment	3rd installment
N_0	N_0	0	0	0	0
N_1	N_{40}	87	29	29	29
N_2	N_{60}	130	43.3	43.3	43.3
N_3	N_{80}	174	58	58	58
N_4	N_{100}	217	72.3	72.3	72.3
TSP	53	53	53	0	0
MoP	82	82	82	0	0
Gypsum	28	28	28	0	0

Twenty days old seedlings were transplanted on 30 April 2019. In each plot, spacing (plant to plant and row to row) was 20 x 20 cm with two seedlings hill^{-1}. The field was investigated occasionally to detect the visual difference between the treatment and any infestation by weeds, insects, and diseases to minimize considerable losses by pests. Experimental data collection began at 15 days after transplanting and continued until harvest.

The necessary data on yield contributing characters were collected from twelve selected hills (2 x 2) x 3 from each plot in the field, and at the harvest plot, yield was harvested from a 5 m^2 plot and adjusted to 14% moisture content expressed as t ha^{-1}. After harvest, grain and straw were taken from respective plots, and all samples were oven-dried at 70°C for 72 h, weighed, ground, and then subsamples were taken for N determination. The standard micro-Kjeldahl procedure measured n content in the grains and straw (Bremner and Mulvaney, 1982). N uptake in grain and straw was calculated by following formulae.

$$\text{Nitrogen uptake by grain (kg ha}^{-1}) = \frac{\%\text{ N in grain} \times \text{Grain yield (kg ha}^{-1})}{100}$$

$$\text{Nitrogen uptake by straw (kg ha}^{-1}) = \frac{\%\text{ N in straw} \times \text{straw yield (kg ha}^{-1})}{100}$$

The optimum N dose for the tested *Aus* rice variety was determined by regression of the grain yield with the N rates: $Y = a + bN + cN2$ Where Y is rice yield (kg ha^{-1}), N is nitrogen dose (kg ha^{-1}), a is intercept (estimated yield without N application), b and c are coefficients, respectively. Differentiating Y with respect to N of the equation gives the N dose for the maximum yield.

The optimum N dose for maximum yield is calculated by N= -b/2c, and the equation of economic N rate is $x = (E_N - b)/2c$. Where, $E_N = p_f/p_y$. Here, p_f indicates the price of N fertilizer (18 Tk kg^{-1} and p_y indicates the price of paddy (Tk kg^{-1}).

The data obtained for different characters were statistically analyzed with the computer-based software CropStat V. 7.2, and mean separation was done by the least significance difference test (LSD) at a 5% level of significance. Regression analyses were done to determine the economic N rates of the respective varieties.

Results and Discussion

Nitrogen concentration (N%) in plant parts during growth stage

Nitrogen is the only nutrient that has not a common soil mineral source. Nitrogen in beneficial forms of plants is probably the most limited nutrient for plant growth. Most of plants' nutritional dynamics and supply rates are related to Model N. Nitrogen concentration (N%) was significantly influenced by different varieties used in the present study (Table 2).

Table 2. Nitrogen concentration (%) of BR26, BRRI dhan48, and BRRI dhan82 as affected by nitrogen rates at BRRI farm, Gazipur

Treatment		Days after transplanting					
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Maturity
Variety							
BR26		0.41	1.01	1.16	1.01	0.69	0.59
BRRI dhan48		0.35	1.03	1.18	0.98	0.69	0.63
BRRI dhan82		0.36	1.13	1.22	0.93	0.65	0.60
LSD (0.05)		0.52	0.98	ns	0.56	ns	ns
Nitrogen rate							
N_0		0.23	0.51	0.54	0.52	0.24	0.21
N_1		0.29	0.83	0.90	0.85	0.60	0.53
N_2		0.39	1.07	1.17	1.04	0.79	0.69
N_3		0.47	1.29	1.60	1.14	0.84	0.78
N_4		0.49	1.58	1.73	1.32	0.89	0.84
LSD (0.05)		0.68	0.13	0.11	0.72	0.66	0.60
CV (%)		18.6	12.4	9.5	7.7	10.1	10.2
Variety × Nitrogen rate							
BR26	N_0	0.25	0.47	0.52	0.57	0.29	0.20
	N_{40}	0.34	0.84	0.89	0.90	0.67	0.48
	N_{60}	0.45	1.01	1.14	1.07	0.79	0.69
	N_{80}	0.50	1.16	1.52	1.18	0.83	0.79
	N_{100}	0.52	1.54	1.74	1.31	0.87	0.82
BRRI dhan48	N_0	0.23	0.53	0.55	0.46	0.22	0.21
	N_{40}	0.26	0.76	0.92	0.84	0.59	0.59
	N_{60}	0.39	1.02	1.15	1.05	0.83	0.70
	N_{80}	0.43	1.31	1.58	1.15	0.88	0.81
	N_{100}	0.45	1.54	1.70	1.39	0.91	0.87
BRRI dhan82	N_0	0.21	0.53	0.53	0.49	0.21	0.23
	N_{40}	0.29	0.88	0.90	0.80	0.55	0.52
	N_{60}	0.34	1.18	1.22	1.01	0.75	0.69
	N_{80}	0.46	1.41	1.71	1.09	0.83	0.76
	N_{100}	0.52	1.65	1.74	1.25	0.91	0.82
LSD (0.05)		ns	ns	ns	ns	ns	ns
CV (%)		18.6	12.4	9.5	7.7	10.1	10.2

Note: ns= Non-significant; N_0= 0 (Control), N_1= 40 kg ha^{-1}, N_2 60 kg ha^{-1}, N_3= 80 kg ha^{-1}, N_4= 100 kg ha^{-1}

At 15 DAT (days after transplanting), in BR26, the N concentration was recorded as 0.41. The results obtained from BRRI dhan48 showed the lowest N concentration (0.35). On 30

DAT, BRRI dhan82 (1.13) recorded the highest N percentage and the lowest (1.01) from BR26. At 45 DAT, the highest N concentration was recorded by BRRI dhan82 (1.22) and the lowest (1.16) from BR26. At 60 DAT, the highest N concentration (0.98) was obtained from BRRI dhan48 and the lowest (0.56) from BRRI dhan82. At 75 DAT, the highest N concentration (0.69) was obtained from BRRI dhan48 and BR26 and the lowest (0.65) from BRRI dhan82. At maturity, the highest N concentration (0.63) was obtained from BRRI dhan48 and the lowest (0.59) from BR26. Nitrogen concentration in plant parts increased over time due to the application of nitrogenous fertilizer and plant demand. Thereafter it seems to decline trend towards maturity. Similar research findings were also reported by Zhang *et al.* (2009), Haque *et al.* (2015a), and Djaman *et al.* (2016). Different levels of N application showed statistically significant variations in N concentration (N%) of *Aus* rice at 15, 30, 45, 60, 75 DAT, and maturity (Table 2). At 15 DAT, the highest N concentration (0.49) was recorded by N_{100} (100 kg ha^{-1}), closely followed (0.47) by N_{80} (80 kg N ha^{-1}). The results obtained from N_0 (0 kg ha^{-1}) showed the lowest N concentration (0.23). On 30 DAT, the highest N concentration (1.58) was recorded by N_{100} (0 kg ha^{-1}) and the lowest (0.51) from N_0 (0 kg ha^{-1}). At 45 DAT, the highest N concentration (1.73) was recorded by N_{100} (100 kg ha^{-1}) and the lowest (0.54) from N_0 (0 kg ha^{-1}). At 60 DAT, the highest N concentration (1.32) was obtained from N_{100} (100 kg ha^{-1}) and the lowest (0.52) from N_0 (0 kg ha^{-1}). At 75 DAT, the highest N concentration (0.89) was obtained from N_{100} (100 kg ha^{-1}) and the lowest (0.24) from N_0 (0 kg ha^{-1}). At maturity, the highest N concentration (0.84) was obtained from N_{100} (100 kg ha^{-1}) and the lowest (0.21) from N_0 (0 kg ha^{-1}). Perez *et al.* (1996), Cassman *et al.* (2003), and Djaman *et al.* (2018) reported that improvement in crop yields is attributed to the increase in fertilizer use, especially N fertilizer. The combination effect of variety and different N rates application had an insignificant influence on N concentration at different growth stages of the three varieties of *Aus* rice (Table 2) However, at 45 DAT, the highest N concentration (1.74) was observed from BRRI dhan82 and BR26 N_{100}, (100 kg ha^{-1}). At maturity, the lowest N concentration (0.20) was found from the combination of BR26 x N_0 (0 kg ha^{-1}). Similarly, many researchers recorded N concentrations for different rice varieties with N rates (Peng *et al.,* 2004; Djaman *et al.,* 2016; Djaman *et al.,* 2018).

Nitrogen uptake by plants during growth stage

Nitrogen uptake (NUP) was significantly influenced by different varieties used in the present study (Table 3) during 15, 30, and 60 DAT. At 15 DAT, the highest NUP was recorded by BR26 (3.85 kg ha^{-1}). The results obtained from BRRI dhan48 showed the lowest NUP (2.99 kg ha^{-1}). On 30 DAT, the highest NUP was recorded by BRRI dhan82 (26.29 kg ha^{-1}) and the lowest (23.18 kg ha^{-1}) from BR26. At 45 DAT, the highest NUP was recorded by BRRI dhan82 (53.67 kg ha^{-1}) and the lowest (50.50 kg ha^{-1}) from BR26. At 60 DAT, the highest NUP (63.58 kg ha^{-1}) was obtained from BR26, and the lowest (56.26 kg ha^{-1}) from BRRI dhan82. At 75 DAT, the highest NUP (56.33 kg ha^{-1}) was obtained from BR26 and the lowest (52.66 kg ha^{-1}) from BRRI dhan82. At maturity, the highest NUP (42.63 kg ha^{-1}) was obtained from BRRI dhan48 and the lowest (42.05 kg ha^{-1}) from BR26. Arthanari *et al.* (2007) reported that the response of rice to nutrient uptake may vary with varieties. Similar research findings were also reported by Koutroubas and Ntanos (2003) and Artacho *et al.* (2009). Different N levels showed statistically significant variations in the NUP of *Aus* rice at 15, 30, 45, 60, 75 DAT, and maturity (Table 3). At 15 DAT, the highest NUP (4.69 kg ha^{-1}) was recorded by N_{100} (100 kg ha^{-1}), closely followed (4.59 kg ha^{-1}) by N_{80} (80 kg N ha^{-1}). The results obtained from N_0 (0 kg ha^{-1}) showed the lowest NUP (1.67 kg ha^{-1}). On 30 DAT, the highest NUP (35.97 kg ha^{-1}) was recorded by N_{100} (0 kg ha^{-1}) and the lowest (10.11 kg ha^{-1}) from N_0 (0 kg ha^{-1}). At 45 DAT, the highest NUP (75.14 kg ha^{-1}) was recorded by N_{100} (100 kg ha^{-1}) and the lowest (21.51 kg ha^{-1}) from N_0 (0 kg ha^{-1}). At 60 DAT, the highest NUP (82.34 kg ha^{-1}) was obtained from N_{100} (100 kg ha^{-1}) and the lowest (48.79 kg ha^{-1}) from N_0 (0 kg ha^{-1}). At 75 DAT, the highest NUP (72.67 kg ha^{-1}) was obtained from N_{100} (100 kg ha^{-1}) and the lowest (17.85) from N_0 (0 kg ha^{-1}).

Table 3. Nitrogen uptake (kg ha^{-1}) of BR26, BRRI dhan48, and BRRI dhan82 as affected by nitrogen rates at BRRI farm, Gazipur

Treatment		Days after transplanting					
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Maturity
Variety							
BR26		3.85	23.18	50.50	63.58	56.33	42.05
BRRI dhan48		2.99	22.22	50.67	58.94	53.60	42.63
BRRI dhan82		3.22	26.29	53.46	56.26	52.66	42.36
LSD (0.05)		0.45	2.25	ns	3.63	ns	ns
Nitrogen rate							
N_0		1.67	10.11	21.51	27.79	17.85	11.95
N_1		2.38	17.45	37.47	48.79	45.75	32.12
N_2		3.49	24.49	50.50	64.32	63.93	49.22
N_3		4.54	31.47	73.09	74.74	70.78	58.62
N_4		4.69	35.97	75.14	82.34	72.67	59.82
LSD (0.05)		0.59	2.91	4.56	4.68	5.46	4.35
CV (%)		18.1	12.6	9.2	8.1	10.4	10.6
Variety	Nitrogen rate						
BR26	N_0	1.92	9.45	21.04	31.71	21.79	11.57
	N_{40}	2.82	17.72	36.89	52.71	51.19	30.32
	N_{60}	4.03	23.31	49.23	67.11	64.79	49.24
	N_{80}	5.02	29.73	69.81	82.70	71.95	59.19
	N_{100}	5.47	35.69	75.52	83.69	71.89	59.93
BRRI dhan48	N_0	1.57	9.99	21.85	24.55	16.15	11.30
	N_{40}	1.99	15.73	38.11	47.49	44.54	33.95
	N_{60}	3.39	22.73	49.76	63.55	64.75	48.46
	N_{80}	4.09	28.66	70.86	74.70	71.58	59.17
	N_{100}	3.89	33.99	72.76	84.39	70.99	60.26
BRRI dhan82	N_0	1.53	10.89	21.64	27.09	15.62	12.97
	N_{40}	2.30	18.91	37.42	46.18	41.51	32.09
	N_{60}	3.06	27.42	52.51	62.29	62.25	49.97
	N_{80}	4.51	36.04	78.59	66.80	68.79	57.49
	N_{100}	4.71	38.23	77.13	78.94	75.11	59.26
LSD (0.05)		ns	ns	ns	ns	ns	ns
CV (%)		18.1	12.6	9.2	8.1	10.4	10.6

Note: ns= Non-significant; N_0= 0 (Control), N_1= 40 kg ha^{-1}, N_2 60 kg ha^{-1}, N_3= 80 kg ha^{-1}, N_4= 100 kg ha^{-1}

At maturity, the highest NUP (59.82 kg ha^{-1}) was obtained from N_{100} (100 kg ha^{-1}) and the lowest (11.95 kg ha^{-1}) from N_0 (0 kg ha^{-1}). Present research results indicate that total N uptake by rice plants increased with increased N rates up to a certain level, then decreased. Yesuf and Balcha (2014) also reported similar findings. Sharma and Mittra (1990), Paikaray *et al.* (2001), Jahan *et al.* (2014), Islam *et al.* (2015), and Hussain *et al.* (2016) reported that the use of an optimum dose of N might have helped for good vegetative growth and root system, which increased the higher N uptake by plants and hence increased yield and yield components of rice. The combination effect of variety and different N rate applications had a non-significant influence on NUP at different growth stages of the three varieties of *Aus* rice (Table 3). Therefore, at 60 DAT, the highest NUP (84.39 kg ha^{-1}) was observed from BRRI dhan82 N_{100} (100 kg ha^{-1}), closely followed (83.69 kg ha^{-1}) by N_{100} (100 kg N ha^{-1}) from BR26. At 15 DAT, the lowest NUP (1.52 kg ha^{-1}) was found from the combination of BRRI dhan82 N_0 (0 kg ha^{-1}) closely followed (1.57 kg ha^{-1}) by N_0 (0 kg N ha^{-1}) from BRRI dhan48. Similar research findings were also reported by Paikaray *et al.* (2001) and Jahan *et al.* (2014).

Nitrogen concentration (N%) in grains

Nitrogen concentration of grain yield was significantly influenced by different varieties used in the present study (Table 4). The highest N concentration (N%) of grain yield was recorded by BRRI dhan48 (0.93). The results obtained from BR26 showed the lowest N concentration (N%) of grain yield (0.82). Different N levels showed statistically significant variations in N concentration (N%) of grain yield of *Aus* rice (Table 4).

Table 4. Nitrogen concentration (N%) and nitrogen uptake (kg N ha^{-1}) of BR26, BRRI dhan48, and BRRI dhan82 as affected by nitrogen rates at BRRI farm, Gazipur

Treatment		N (%) in grain	N (%) in straw	N (%) in grain + straw	N uptake grain (Kg ha^{-1})	N uptake in straw (kg ha^{-1})	N uptake (grain+ straw) (Kg ha^{-1})	Nitrogen harvest index (%)
Variety								
BR26		0.82	0.41	1.22	31.93	19.91	51.84	60.41
BRRI dhan48		0.93	0.34	1.27	43.31	19.03	62.34	68.15
BRRI dhan82		0.89	0.33	1.21	35.04	16.38	51.42	66.68
LSD (0.05)		0.58	0.22	ns	5.13	2.43	7.11	2.36
Nitrogen rate								
N_0		0.52	0.26	0.78	14.96	10.13	25.09	59.43
N_1		0.72	0.33	1.06	26.49	16.03	42.52	62.17
N_2		0.99	0.37	1.36	45.37	20.47	65.83	68.52
N_3		1.07	0.41	1.48	52.36	23.24	75.60	69.12
N_4		1.08	0.43	1.51	44.61	22.35	66.95	66.15
LSD (0.05)		0.75	0.28	0.74	6.63	3.14	9.18	3.05
CV (%)		8.9	8.1	6.2	18.7	17.6	17.2	4.8
Variety × Nitrogen rate								
BR26	N_0	0.48	0.29	0.76	12.51	10.10	22.61	55.38
	N_{40}	0.68	0.38	1.06	22.24	16.82	39.06	57.20
	N_{60}	0.89	0.42	1.31	37.58	21.86	59.44	63.01
	N_{80}	1.01	0.48	1.49	45.27	26.01	71.28	63.70
	N_{100}	1.02	0.47	1.49	42.03	24.77	66.80	62.75
BRRI dhan48	N_0	0.61	0.26	0.87	17.89	10.69	28.58	62.84
	N_{40}	0.79	0.34	1.13	29.29	16.23	45.52	64.19
	N_{60}	1.01	0.34	1.36	53.39	20.82	74.21	71.89
	N_{80}	1.10	0.37	1.47	61.48	23.46	84.94	72.37
	N_{100}	1.12	0.39	1.52	54.49	23.96	78.46	69.44
BRRI dhan82	N_0	0.47	0.22	0.69	14.48	9.60	24.08	60.06
	N_{40}	0.70	0.28	0.98	27.94	15.04	42.98	65.12
	N_{60}	1.06	0.34	1.40	45.14	18.72	63.85	70.67
	N_{80}	1.12	0.37	1.48	50.34	20.25	70.59	71.29
	N_{100}	1.10	0.41	1.51	37.29	18.31	55.59	66.24
LSD (0.05)		ns	ns	ns	ns	ns	ns	ns
CV (%)		8.9	8.1	6.2	18.7	17.6	17.2	4.8

Note: ns= Non-significant; N_0= 0 (Control), N_1= 40 kg ha^{-1}, N_2 60 kg ha^{-1}, N_3= 80 kg ha^{-1}, N_4= 100 kg ha^{-1}

The highest N concentration (N%) of grain yield (1.08) was recorded by N_{100} (100 kg ha^{-1}), which was closely followed (1.07) by N_{80} (80 kg N ha^{-1}). The results obtained from N_0 (0 kg ha^{-1}) showed the lowest N concentration (N%) of grain yield (0.52). The combination effect of variety and different N rate application had no significant influence on the grain yield of the three *Aus* rice varieties (Table 4). The highest N concentration (N%) of grain yield (1.12) was observed from BRRI dhan48 × N_{100} (100 kg ha^{-1}) and BRRI dhan82 × N_{80} (80 kg ha^{-1}), and the lowest N concentration (N%) of grain yield (0.47) was found from the combination of BRRI dhan82 × N_0 (0 kg ha^{-1}).

Nitrogen uptake by grains

Nitrogen uptake of grain yield was significantly influenced by different varieties used in the present study (Table 4). The highest NUP of grain yield was recorded by BRRI dhan48 (43.31 kg N ha^{-1}). The results obtained from BR26 showed the lowest NUP of grain yield (31.93 kg ha^{-1}). Different N levels showed statistically significant variations in NUP of grain yield of *Aus* rice (Table 4). The highest NUP of grain yield (52.36 kg ha^{-1}) was recorded by N_{80} (80 kg ha^{-1}). The results obtained from N_0 (0 kg ha^{-1}) showed the lowest NUP of grain yield (14.96 kg ha^{-1}). The combination effect of variety and different N applications had no significant influence on the NUP of grain yield of the three varieties of *Aus* rice (Table 4). The highest NUP of grain yield (61.48 kg ha^{-1}) was observed from BRRI dhan48 × N_{80} (80 kg ha^{-1}), and the lowest NUP of grain yield (12.51 kg ha^{-1}) was found from the combination of BR26 × N_0 (0 kg ha^{-1}).

Nitrogen concentration (N%) in straw

The N concentration of straw was significantly influenced by the different varieties used in the present study (Table 4). The highest N concentration of straw yield was recorded by BR26 (0.41). The results obtained from BRRI dhan82 showed the lowest N concentration of straw (0.33). Different N levels showed statistically significant variations in terms of N concentration of straw of *Aus* rice (Table 4). The highest N concentration of straw yield (0.43) was recorded by N_{100} (100 kg ha^{-1}). The results obtained from N_0 (0 kg ha^{-1}) showed the lowest N concentration of straw yield (0.26). The combination effect of variety and different N applications had no significant influence on the N concentration of straw of the three varieties of *Aus* rice (Table 4). The highest N concentration of straw (0.48) was observed from BR26 × N_{80} (80 kg ha^{-1}), and the lowest N concentration of straw yield (0.22) was found from the combination of BRRI dhan82 × N_0 (0 kg ha^{-1}).

Nitrogen uptake by straw

Nitrogen uptake of straw yield was significantly influenced by different varieties used in the present study (Table 4). The highest NUP of straw yield was recorded by BR26 (19.91 kg ha^{-1}). The results obtained from BRRI dhan82 showed the lowest NUP of straw yield (16.38 kg ha^{-1}). Different N levels showed statistically significant variations in NUP of the straw yield of *Aus* rice at days after transplanting (Table 4). The highest NUP of straw yield (23.24 kg ha^{-1}) was recorded by N_{80} (80 kg ha^{-1}). The results obtained from N_0 (0 kg ha^{-1}) showed the lowest NUP of straw yield (10.23 kg ha^{-1}).

The combination effect of variety and different N applications had no significant influence on the NUP of the straw yield of the three varieties of *Aus* rice (Table 4). The highest NUP of straw yield (26.01 kg ha^{-1}) was observed from BR26 × N_{80} (80 kg ha^{-1}), and the lowest NUP of straw yield (9.60 kg ha^{-1}) was found from the combination of BRRI dhan82 × N_0 (0 kg ha^{-1}).

Nitrogen harvest index

N accumulation in grains (N accumulation in grains plus dry matter/ straw) explain the N harvest index. The N harvest index was significantly influenced by different varieties used in the present study (Table 4). The highest N harvest index was recorded by BRRI dhan48 (68.15%). The results obtained from BR26 showed the lowest N harvest index (60.41%). Different N levels showed statistically significant variations in terms of the N harvest index of *Aus* rice (Table 4). The highest N harvest index (69.12) was recorded by N_{80} (80 kg ha^{-1}). The results obtained from N_0 (0 kg ha^{-1}) showed the lowest N harvest index (59.43). The combination effect of variety and different N rates had no significant influence on the N harvest index of the three varieties of *Aus* rice (Table 4). The highest N harvest index (72.37%) was observed from BRRI dhan48 × N_{80} (80 kg ha^{-1}), and the lowest N harvest index (55.38%) was found from the combination of BR26 × N_0 (0 kg ha^{-1}).

Relationship between grain yield and grain N uptake and grain yield with total N uptake

Grain yield of varieties and N uptake in grain and total N uptake were significantly and linearly related ($R^2 = 0.8863^{**}$ and 0.8619^{**}) (Figure 1 "A, B"), indicating that higher grain yield would be due to higher N uptake. Nitrogen use efficiency is largely influenced by grain yield, N fertilizer input, and N uptake (Qiao *et al.,* 2012).

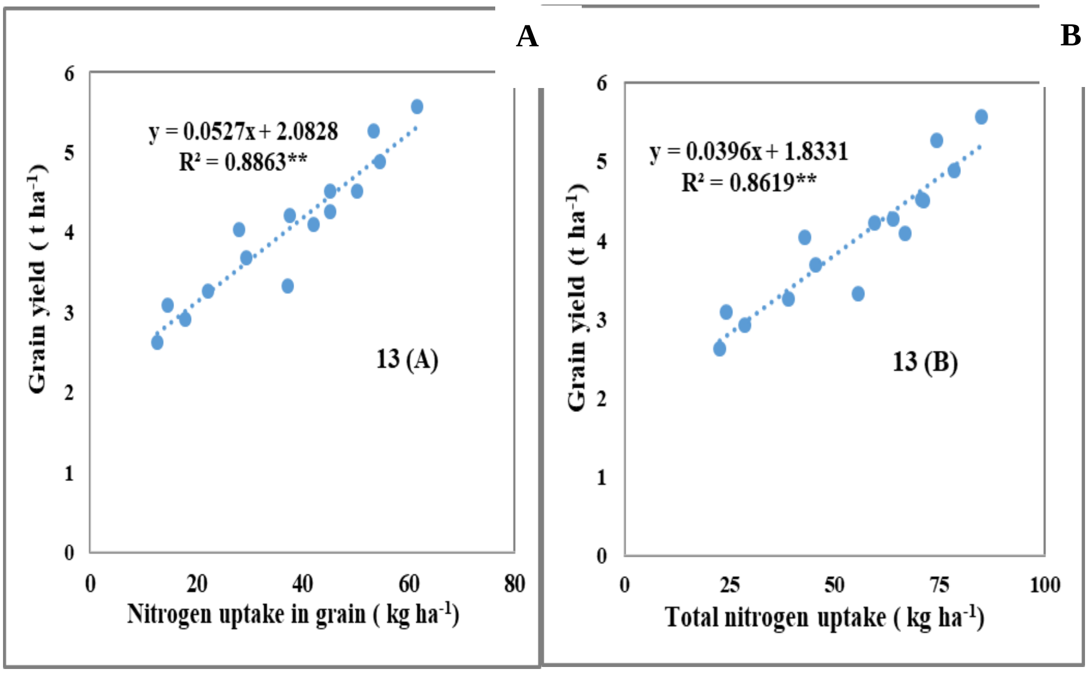

Fig. 1. Relationship between grain yield and grain N uptake and grain yield with total N uptake (**= significant at 1% level).

Determination of optimum and economic of N doses

The variation of grain yield of BR26, BRRI dhan48, and BRRI dhan82 at different N rates was determined through regression equation (Figure 2). Differentiating the quadratic equation of yield response concerning applied different N doses, the optimum N rate appeared as 99, 95 and 57 kg ha^{-1} for BR26, BRRI dhan48, and BRRI dhan82, respectively. Considering economic N rate would be 97, 93, and 53 kg ha^{-1} for BR26, BRRI dhan48, and BRRI dhan82, respectively. Fageria and Santos (2014) also found efficient and moderately efficient rice varieties in N use efficiency, and none were grouped as inefficient.

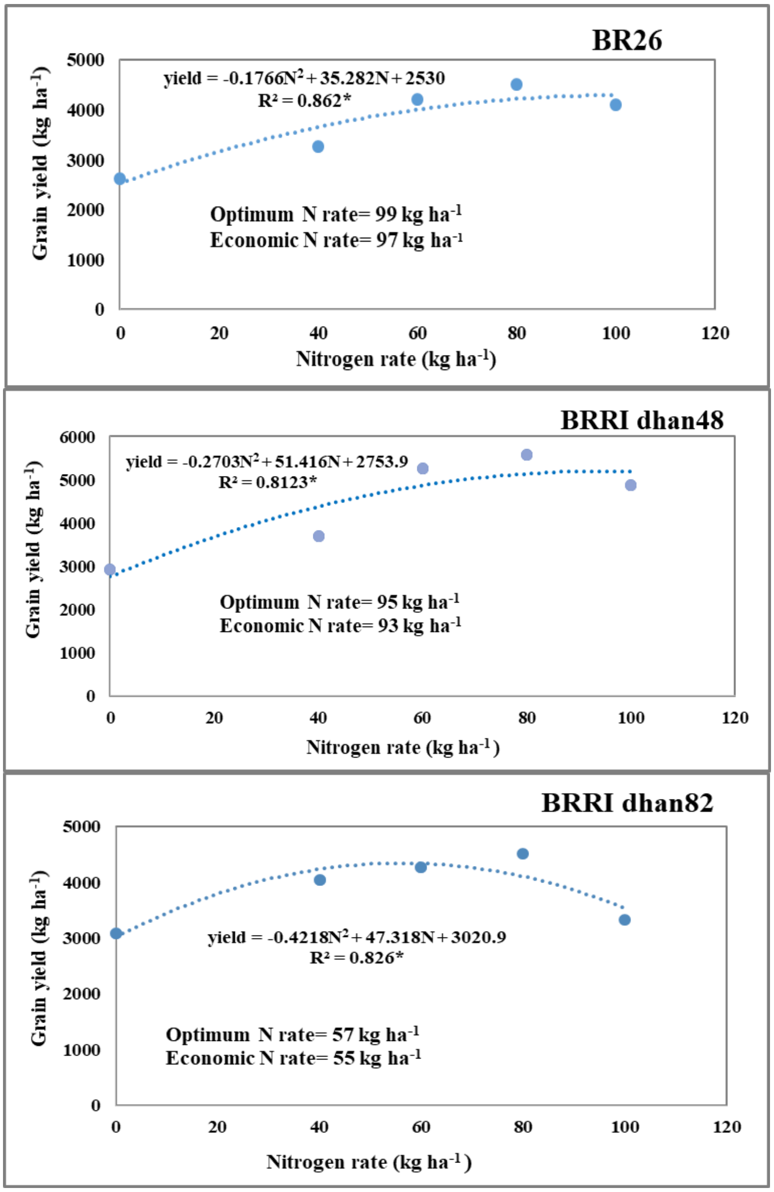

Fig. 2. Grain yield responses to N fertilization and determination of optimum and economic N doses in different *Aus* varieties during *Aus* 2019 at BRRI, Gazipur (*=significant at 5% level)

Conclusion

The economic N rates calculated from the quadratic regression equations were 97 kg ha^{-1}, 95 kg ha^{-1}, and 55 kg ha^{-1} for BR26, BRRI dhan48, and BRRI dhan82, respectively. Therefore, the N fertilizer requirement of *Aus* rice crops should be based on variety, and the inherent capacity of soil N supply to improve *Aus* rice yield furthermore minimize the excessive use of chemical fertilizer. After all, to reach a specific conclusion and recommendation, more research works on varieties and N rates for better growth and yield of *Aus* rice should be done over different agroecological zones of Bangladesh to make a promising practice to the farmers.

References

Artacho, P., C. Bonomelli and F. Meza. 2009. Nitrogen application in irrigated rice grown in Mediterranean conditions: Effects on grain yield, dry matter production, nitrogen uptake, and nitrogen use efficiency. J. Plant Nutr. 32: 1574-1593.

Arthanari, P.M., S. Ramasamy and M.M. Amanullah. 2007. Nutrient uptake as influenced by post panicle initiation nutrient management in rice plant organ. Res. J. Agric. Biol. Sci. 3: 621-624.

BBS. 2021. National Accounts Statistics. Bangladesh Bureau of Statistics, Government of the People's Republic of Bangladesh.

Bremner, J.M. and C.S. Mulvaney. 1982. Total nitrogen. In: Methods of soil analysis: Part 2 Chemical and microbiological properties, A.L. Page, R.H. Miller and D.R. Keeney (Eds.). American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin. pp. 595-624.

BRRI. 2021. Adhunik Dhaner Chash (Cultivation of Modern Rice). Bangladesh Rice Research Institute, Gazipur, Bangladesh. pp. 5-93.

Cassman, K.G., A. Dobermann, D.T. Walters and H. Yang. 2003. Meeting cereal demand while protecting natural resources and improving environmental quality. Annu. Rev. Environ. Resour. 28: 315-358.

Chamely, S., N. Islam, S. Hoshain, M. Rabbani, M. Kader and M. Salam. 2015. Effect of variety and nitrogen rate on the yield performance of *boro* rice. Progressive Agric. Sci. 26(1): 6-14.

Djaman, K., B.V. Bado and V.C. Mel. 2016. Effect of nitrogen fertilizer on yield and nitrogen use efficiency of four aromatic rice varieties. Emir. J. Food Agric. 28: 126-135.

Djaman, K., V.C. Mel, F.Y. Ametonou, R.E. Namakyand and M.D. Diallo. 2018. Effect of nitrogen fertilizer dose and application timing on yield and nitrogen use efficiency of irrigated hybrid rice under semi-arid conditions. J. Agric. Sci. Food Res. 9: 223.

Fageria, N.K. 2009. The use of nutrients in crop plants. CRC Press, Boca Raton, FL. pp. 20-50.

Fageria, N.K. and A.B. Santos. 2014. Lowland rice genotypes evaluation for nitrogen use. J. Plan. Nutr. 37(9): 1410-1423.

Fan, M., J. Shen, L. Yuan, R. Jiang and X. Chen. 2012. Improving crop productivity and resource use efficiency to ensure food security and environmental quality in China. J. Exp. Bot. 63: 13-24.

Haider, I.K. 2018. Appraisal of biofertilizers in rice: To supplement inorganic chemical fertilizer. Rice Sci. 25: 357-362.

Haque, M.A., A.H.M. Razzaque, A.N.A. Haque and M.A. Ullah. 2015. Effect of plant spacing and nitrogen on yield of transplant *aman* rice var. BRRI Dhan52. J. Biosci. Agric. Res. 4(2): 52-59.

Hasegawa, T., Y. Koroda and N.G. Eligman. 1994. Response to spikelet number of plant nitrogen concentration and dry weight in paddy. Agron. J. 86: 673-676.

Hassan, M.S., A. Khair, M.M. Haque, A.K. Azad and A. Hamid. 2009. Genotypic variation in traditional rice varieties for chlorophyll content, SPAD value and nitrogen use efficiency. Bangladesh J. Agric. Res. 34(3): 505-515.

Hussain, J., M.A. Siddique, M.M. Mia, G.N. Hasan, A.S. Seajuti, M.R. Mallik and E. Zaman. 2016. Effect of different doses of nitrogen fertilizer on T. *aman* rice. Int. J. Bus. Soc. Sci. Res. 4(4): 328-332.

Islam, M.S.M., Y.K. Gaihre, A.L. Shah, U. Singh, M.I.U. Sarkar, M.A. Satter, J. Sanabria and J.C. Biswas. 2016. Rice yields and nitrogen use efficiency with different fertilizers and water management under intensive lowland rice cropping systems in Bangladesh. Nutr. Cycl. Agroecosystems. 106: 143-156.

Islam, S.M.M., A. Khatun, F. Rahman, A.T.M.S. Hossain, U.A. Naher and M.A. Saleque. 2015. Rice response to nitrogen in tidal flooded non-saline soil. Bangladesh Rice J. 19(2): 65-70.

Jahan, N., M.R. Islam, A.B. Siddique, M.R. Islam, M.M. Hassan, S.M. Shamsuzzaman and A.W. Samsuri. 2014. Effects of integrated use of prilled urea, urea super granule and poultry manure on yield of transplant *aus* rice and field water quality. J. Life Sci. 11: 101-108.

Koutroubas, S.D. and D.A. Ntanos. 2003. Genotypic differences for grain yield and nitrogen utilization in *Indica* and *Japonica* rice under Mediterranean conditions. Field Crops Res. 83: 251-260.

Liu, X., H. Wang, J. Zhou, F. Hu, D. Zhu, Z. Chen and Y. Liu. 2016. Effect of N fertilization pattern on rice yield, N use efficiency and fertilizer-N fate in the Yangtze River Basin, China. Plos One, 11(11): e0166002.

Masum, S.M., M.H. Ali and M.J. Ullah. 2008. Growth and yield of two T. *aman* rice varieties as affected by seedling number per hill and urea supper granules. J. Agric. Educ. Technol. 11(1 & 2): 51-58.

Meena, S.L., S. Surendra, Y.S. Shivay and S. Singh. 2003. Response of hybrid rice (*Oryza sativa*) to nitrogen and potassium application in sandy clay loam soils. Indian J. Agric. Sci. 73(1): 8-11.

Nasim, M., S.M., Shahidullah, A. Saha, M.A. Muttaleb, T.L. Aditya, M.A. Ali and M.S. Kabir. 2017. Distribution of crops and cropping patterns in Bangladesh. Bangladesh Rice J. 21(2): 1-55.

Paikaray, R.L., B.S.L. Mahapatra and G.L Sharma. 2001. Integrated nitrogen management in rice (*Oryza sativa*), wheat (*Tricum aestivum*) cropping system. Indian J. Agron. 46(4): 592-600.

Peng, S., J. Huang, J.E. Sheehy, R.C. Laza and R.M. Visperas. 2004. Rice yields decline with higher night temperature from global warming. Proc. Natl. Acad. Sci. U.S.A. 101: 9971-9975.

Perez, C.M., B.O. Juliano, S.P. Liboon, J.M. Alcantara and K.G. Cassman. 1996. Effects of late nitrogen fertilizer application on head rice yield, protein content, and grain quality of rice. Cereal Chem. 73: 556-560.

Qiao, J., L. Yang, T. Yan, F. Xue and D. Zhao. 2012. Nitrogen fertilizer reduction in rice production for two consecutive years in the Taihu Lake area. Agric. Ecosyst. Environ. 146(1): 103-112.

Sharma, A.R. and B.N. Mittra. 1990. Effect of N and P on rice and their residual effect on succeeding wheat/gram crop. Indian J. Agron. 34: 40-44.

Talashilker, S.C. and O.P. Vimol. 1986. Studies on increasing the use efficiency of N and P fertilizers in combination with city solid waste. J. Indian Soc. Soil Sci. 34(4): 780-784.

Tayefe, M., A. Gerayzade, E. Amiri and A.N. Zade. 2014. Effect of nitrogen on rice yield, yield components and quality parameters. Afr. J. Biotechnol. 13(1): 91-105.

USDA. 2020. USDA, World Agricultural Outlook Board, World Agricultural Supply and Demand Estimates, Washington, DC 20250, United States.

Yesuf, E. and A. Balcha. 2014. Effect of nitrogen application on grain yield and nitrogen efficiency of rice (*Oryza sativa* L.). Asian J. Crop Sci. 6(3): 273-280.

Zhang, H., Y. Xue, Z. Wang, J. Yang and J. Zhang. 2009. Alternate wetting and moderate soil drying improves root and shoot growth in rice. Crop Sci. 49: 2246-2260.