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Nitrogen Management Options in Winter Rice under Boro- Fallow-T. Aman Cropping System

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ABSTRACT

Nitrogen (N) is commonly applied in equal split during different growth stages of rice. However, higher requirement of N during panicle initiation (PI) stage emphasizes relatively higher N dose at that particular stage. A field experiment was conducted during dry seasons (November-May) of two consecutive years from 2013 to 2015 to determine appropriate timing and amount of N application and its effect on yield and N use efficiency. Two modern rice varieties (BRRI dhan28 and BRRI dhan29) under six N management options viz. i) One third of N was applied at initiation of tillering (IT) stage + one third at active tillering (AT) stage + one-third at panicle initiation (PI) stage (N_1)(Recommended practice); ii) One-half at IT stage + another-half at PI stage (N_2); iii) One third at IT stage + two-third at PI stage (N_3); (iv) One-fourth at IT stage + one-fourth at AT stage+ half at PI stage (N_4); v) One-half at IT stage + another half at AT stage (N_5); and vi) N-control (N_6) were evaluated in randomized complete block design with three replications. Recommended practice and application of higher dose at PI stage gave similar yields in BRRI dhan28 and BRRI dhan29 in both the years. Agronomic use efficiency showed similar trend of results. Therefore, inadequate N application at early growth stages for any inevitable circumstances could be compensated by higher N application at PI stage.

Keywords: *Oryza sativa* L., Timing of nitrogen application, Nitrogen rates, Agronomic use efficiency, Grain and straw yields

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for about 160 million people of Bangladesh and about 90% of world's rice is produced and consumed in Asia. About one-third of the World's total area planted to cereals is occupied by rice and it provides 35-40% of the calories consumed by 2.7 million people (Fageria and Baliga, 2001). Rice yield must be increased in Asia by about 25% from 2000 to 2020 with the increased yield of 4.9 t/ha from the present yield of 3.9 t/ha for meeting the demand of increased population (Dobermann *et al*., 2004). In this context, there is no alternative other than yield increase per unit area. It is possible either by using improved technologies or developing management practices.

Nitrogen (N) is one of the most yield-limiting nutrients in rice production around the world and almost every farmer has to apply the costly N fertilizer to get a desirable yield of rice (Saleque *et al*., 2004). Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice. Given the importance of N fertilization on the grain yield, it is necessary to know what the best dose is for each variety as well as its influence on yield components and other agronomic parameters (Chaturvedi, 2005). An efficient N supply can increase as much as 60% rice production over control. Selection of the most appropriate rate and time of N fertilization can affect both economic viability of crop production and impact of agriculture on the environment. Proper timing in combination with adequate rate of N application is crucial to minimize N losses and improve N use efficiency (Datta and Buresh, 1989).

Timely and split application of N may improve a crop's response to N, especially at high rates. Split application of N also allows for more efficient use of N throughout the growing season as it provides specific amounts of nutrient to the crop during peak periods of growth and may reduce leaching of nitrate-N in the soil (Fageria and Baligar, 1999). Crop-N uptake capacity is generally low at the beginning of the growing season, increasing rapidly during vegetative growth, and dropping sharply as the crop approaches maturity. Hence, synchronous timing of fertilizer N application with plant N demand is an important factor in determining soil N availability, crop N content and uptake capacity, dry matter and yield of rice crop (Balasubramanian, 2002).

As N fertilizers are highly dynamic in soils, its careful management is needed, while grain yields and crop uptake efficiency increased (Lopez-Bellido *et al*., 2015). Most of the studies on N fertilizer management for low land rice as affected by timing of application have examined the effect of only one or two split application in the early stage of crop growth. The daily requirement of N at 45 to 60 DAT was much higher than 15 to 30 DAT which emphasizes application of relatively higher dose at PI stage compared to early growth and active tillering stage (Khatun *et al*., 2015). The current N management recommendation of three equal splits needs a thorough attention for its modification. Understanding the N use efficiency and how it is affected by splitting and variety would provide a scientific basis for rationally applying and appropriately assessing the environmental impacts of N fertilizers. Therefore, the present study was undertaken to determine appropriate timing of split application of N for making accurate N fertilizer recommendation for rice.

MATERIALS AND METHODS

The study was conducted at the experimental farm of the Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh during winter seasons (November-April/May) of two consecutive years from 2013-15. The site is located at 23°59 N latitude, 90°24 E longitude and attitude of 16 feet. It belongs to Agro-Ecological Zone (AEZ) number 28 known as Madhupur Tract. The soil of the experimental field is Chhiata clay loam, a member of the fine, hypothermic Vertic Endoaquept (Saleque *et al*., 2004). The initial soil chemical properties at 0-15 cm soil depth were as follows: pH 6.1, organic matter 2.02%, total N content 0.07%, available phosphorus (P) 10.14 mg kg^{-1} (0.5 M $NaHC0_3$ extracted), exchangeable potassium (K) 0.17 meq/100 g soil (neutral 1.0 N NH_40Ac extracted), available sulphur (S) 20 mg kg^{-1} [$Ca(H_2P0_4)_2$ extracted], and available Zinc (Zn) 2.8 mg kg^{-1} (0.01 N HCl extracted).

Treatment consisted of six N management options: i) One third of N was applied at initiation of tillering (IT) stage + one third at active tillering (AT) stage + one-third at PI stage (N_1); ii) One-half at IT stage + another-half at PI stage (N_2); iii) One third at IT stage + two-third at PI stage (N_3); (iv) One-fourth at IT stage + one-fourth at AT stage+ half at PI stage (N_4); v) One-half at IT stage + another half at AT stage (N_5); and vi) N-control (N_6). Two mega winter rice varieties in Bangladesh context-BRRI dhan28 and BRRI dhan29 were grown under fully irrigated conditions. BRRI dhan28 is a short duration (growth duration 140 days) and BRRI dhan29 is a long duration (growth duration 160 days) variety, respectively. Each treatment received 119 kg N ha^{-1} and 136 kg N ha^{-1} as urea for BRRI dhn28 and BRRI dhan29, respectively. Phosphorus, K, S and Zn were applied at 18, 75, 20 and 4.7 kg ha^{-1} for BRRI dhan28 and 19.4, 82, 20 and 4.7 kg ha^{-1} for BRRI dhan29 as triple super phosphate, muriate of potash, gypsum and zinc sulphate, respectively, during final land preparation Rice was transplanted in the first week of January with 40-45 day-old seedlings and harvested in last week of April to 2^{nd} week of May for both the years. Two to three seedlings were transplanted maintaining 20 cm x 20 cm spacing. The treatments were arranged in randomized complete block design with three replications in both years. Plot size was 5 m x 4 m. All plots were surrounded by soil leaves of 30 cm high to avoid N contamination between plots. After transplanting the seedlings, intercultural operations like weeding, irrigation and control of pest were done as and when necessary for better growth and development of rice plants. At maturity the crop was harvested manually at ground level, however, 16 hills from each plot were harvested for measuring yield components and straw yield. Rice plants from 5 m^2 area of the middle of each plot were harvested and threshed. The grain yield was adjusted to 14% moisture content and converted in to t ha^{-1}. The straw yield was recorded as oven dry basis following standard procedures as described by Yoshida *et al*. (1976).

Harvest index (HI) was computed by dividing the grain yield by the total day matter (grain yield + straw yield) and was expressed as percentage as follows:

$$HI = \left(\frac{\text{Grain yield}}{\text{Grain yield} + \text{Straw yield}} \right) \times 100$$

Sterility was computed by dividing the number of unfilled spikelets by the total number of spikelets (filled grains unfilled spikelets) and was expressed as percentage as follows:

$$Sterility\,(\%) = \left(\frac{\text{Sterile spikelets}}{\text{Sterile spikelets} + \text{filled grains}} \right) \times 100$$

Agronomic use efficiency (AUE) is expressed as difference in grain yield between fertilized and unfertilized plot divided by the quantity of nutrient applied. It is expressed as kg/kg.

$$AE = \frac{\left(G_f - G_u\right)}{Na}$$

Where, Gf is the grain yield of the fertilized plot (kg), Gu is the grain yield of the Unfertilized plot (kg), Gu is the grain yield of the unfertilized plot (kg), and *Na* is the quantity of N applied (kg).

Analysis of variance of the measured parameters was performed and the treatment means were compared using least significant difference (LSD) at the 5% level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Grain and straw yield

Interaction effects of treatment, variety and year for grain and straw yield were not significant (p>0.05). However, the interaction effects of treatment and year, variety and year for grain and straw yield were significant (p<0.01) (Table 1). The main effect of treatment, variety and year for both grain and straw yield was significant (p<0.01) (Table 2.). During 2013-14 in BRRI dhan28, the treatment N_3 gave the higher grain yield (6.04 t/ha) followed by the treatment N_1 (5.80 t/ha). The treatments N_2 and N_4 gave similar grain yields and the lowest was obtained from N6 treatment. The grain yield producing order under different treatments was $N_3> N_1> N_2> N_4> N_5> N_6$. In 2014-15, the treatments N_3 (6.17 t/ha), N_1 (5.97 t/ha) and N_2 (5.70 t/ha) gave statistically similar grain yields. The treatments N_2 and N_4 gave similar grain yield. The treatment N_6 gave the lowest grain yield (3.69 t ha^{-1}) compared to all other treatments. Grain yields under different N treatments were in the order of $N_3> N_1> N_2> N_4> N_5>N_6$. In BRRI dhan29, significantly higher grain yield (6.69 t ha^{-1}) was produced in N_4 treatment followed by N_1 (6.40 t ha^{-1}) treatment during 2013-14. The treatments N_3, N_2 and N_5 produced statistically similar grain yields and the grain yields under different N treatments were in the order of $N_4> N_1>N_3>N_2>N_5>N_6$. In 2014-15, the treatments N_4, N_1 and N_3 gave statistically similar grain yields. The treatments N_2 and N_5 gave similar grain yield and the grain yield producing order under different treatments was $N_4> N_1> N_3> N_2> N_5> N_6$. The N_6 treatment gave the lowest grain yield in both the years. Mean grain yield of BRRI dhan29 was significantly higher compared to that of BRRI dhan28 irrespective of treatments (Table 2).

Table 1. F-probability values of different yield contributing characters

Source of variation (SV)	df	F-probability values							
		Grain yield (t/ha)	Straw yield (t/ha)	Harvest index	Agronomic use efficiency	Panicle/ m^2	Grains/ panicle	1000-grain wt (g)	Sterility (%)
Replication (R)	2	0.905	0.478	0.943	0.031	0.023	0.840	0.707	0.040
Treatment (T)	5	0.000	0.000	0.000	0.030	0.000	0.341	0.153	0.122
Variety (V)	1	0.000	0.007	0.166	0.975	0.015	0.000	0.188	0.525
Year(Y)	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V × Y	1	0.003	0.000	0.068	0.119	0.171	0.652	0.000	0.000
T × Y	5	0.000	0.000	0.002	0.577	0.019	0.513	0.040	0.000
V ×T	5	0.383	0.401	0.062	0.766	0.862	0.522	0.167	0.922
V × T × Y	5	0.871	0.160	0.251	0.730	0.605	0.412	0.457	0.318

Table 2. Grain and straw yields of BRRI dhan28 and BRRI dhan29 as affected by N management options in Boro – Fallow - T.Aman cropping system, Gazipur

Treatment	Grain yield (t/ha)			Straw yield (t/ha)		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
			BRRI dhan28			
N_1	5.80	5.97	5.89	5.84	8.93	7.39
N_2	5.33	5.70	5.52	6.33	8.77	7.55
N_3	6.04	6.17	6.11	6.64	7.97	7.31
N_4	5.24	5.41	5.33	6.23	7.96	7.10
N_5	5.01	5.22	5.12	5.90	7.04	6.47
N_6	4.15	3.69	3.92	5.22	4.62	4.92
Mean	5.26	5.36	5.31	6.03	7.55	6.79
			BRRI dhan29			
N_1	6.40	7.11	6.76	7.70	8.07	7.89
N_2	5.82	6.13	5.96	7.42	7.73	7.58
N_3	5.97	6.83	6.40	6.90	7.51	7.21
N_4	6.69	7.17	6.93	7.66	7.74	7.70
N_5	5.70	5.86	5.78	6.93	7.68	7.31
N_6	4.11	4.23	4.17	6.19	4.93	5.56
Mean	5.78	6.22	6.01	7.13	7.28	7.21
CV (%)		8.6			9.0	

For grain yield (t/ha): LSD $_{(0.05)}$ 0.43 (for treatment), 0.25 (Variety), 0.25 (Year), 0.35 (Year × Variety), NS (Treatment ×Variety), 0.60 (Treatment × Year), NS (Treatment × Year × Variety)

For straw yield (t/ha): LSD $_{(0.05)}$ 0.52 (for treatment), 0.30 (Variety), 0.30 (Year), 0.42 (Year ×Variety), NS (Treatment × Variety), 0.73 (Treatment × Year), NS (Treatment × Year × Variety)

The higher yield of BRRI dhan29 may be attributed due the high yield potential of BRRI dhan29. Mean grain yield for the treatment N_3 in BRRI dhan28 and N_4 in BRRI dhan29 showed higher performance apparently. Fageria and Baligar (2001) reported that maximum grain yield of 6.47 t ha^{-1} of Metica 1 low land rice cultivar in Central Brazil was observed from topdressing at sowing, 45 days after sowing (DAS) and 70 DAS with three equal rates of 171 kg/ha N application. Grain yield in rice is a function of panicles per unit area, number of spikelet per panicle, 1000- grain weight and spikelet sterility or filled spikelet (Fageria *et al.*, 1997).

Therefore, it is very important to understand the management practices that influence yield components and consequently grain yield (Fageria and Baligar, 2001). Fageria *et al.*, (2006) reported that maximum grain yield of upland rice in a Brazilian Oxisol was obtained with the application of 400 mg N kg^{-1} of soil through ammonium sulphate under green house condition. Fageria and Baligar (1999) reported that application of nitrogen in the reproductive growth stage (booting and flowering) did not improve lowland rice grain yield as compared to N applied during early growth stages. Dry matter production exhibited a greater response to late-season application of N than did grain yield. The N fertilization significantly increased grain yield and shoot dry weight. The variation in grain yield with nitrogen fertilization varied from 66 to 93% depending on genotypes (Fageria *et al.*, 2004). Late application of N during reproductive growth stage did not improve grain yield. Dry matter production exhibited a greater response to late season application of N than did grain yield. This may be due to the number of panicles and the number of grains which were already fixed when the plants received a major part of N at the booting and flowering growth stages (Castillo *et al.*, 1992).

During 2013-14 in BRRI dhan28, higher straw yield was produced under N_3 treatment followed by N_2 and N_4 treatments (Table 2).

The N_5 and N_1 treatments gave statistically similar straw yield. In 2014-15, the treatments N_1 and N_2 gave significantly higher straw yield compared to all other treatments. The N_3 and N_4 treatments produced statistically similar straw yield. Significantly higher straw yield was observed in N_1, N_2, N_3 and N_4 treatments compared to N_5 treatments. The lowest straw yield was in N_6 treatment in both the year. The straw yields under the N treatments were in the order of $N_3 > N_2 > N_4 > N_5 > N_1 > N_6$ in 2013-14 and $N_1 > N_2 > N_3 > N_4 > N_5 > N_6$ in 2014-15. During 2013-14, the higher straw yield of BRRI dhan29 was obtained with the N_1 treatment followed by the N4 and N2 treatments, and minimum under N_3, N_5 and N_6 treatments. The N_5 and N_3 treatments gave statistically similar straw yield. In 2014-15, higher straw yield of BRRI dhan29 was obtained with the N_1 treatment followed by N_4, N_2, N_5 and N_3 treatments. The lowest straw yield was observed in N6 treatment in both the year. The straw yield producing order of BRRI dhan29 under different treatments was $N_1 > N_4 > N_2 > N_5 > N_3 > N_6$ in 2013-14 and $N_1 > N_4 > N_2 > N_5 > N_3 > N_6$ in 2014-15(Table 1). Fageria and Baligar (2001) and Fageria *et al*. (2004) also reported quadratic relationship between shoot dry weight and grain yield in rice. Variation in shoot dry weight and grain yield among genotypes may be associated with differences in the amount of intercepted photosynthetically active radiation by the canopy, the radiation use efficiency, and grain harvest index (Fageria and Baligar, 2005).

Harvest index and agronomic use efficiency

Interaction effects of treatment, variety and year; treatment and variety; and variety and year were insignificant ($p>0.05$) for harvest index (HI). Interaction effect of treatment and year was significant ($p<0.05$) for HI. However, ANOVA for HI showed significant main effects of treatment and year (Table 1). In BRRI dhan28, the treatments Nl, N2, N3 and N4 gave statistically similar HI during 2013-14. The N5 treatment gave significantly lower HI in comparison to all other treatments. During 2014-15, the higher HI was obtained from the N3 and N5 treatments, followed by N4 treatment. The N2 and N4 treatments showed statistically similar HI. The treatment N6 gave the lowest higher HI in, both years. In BRRI dhan29, the HI during 2013-14 ranged from 0.43 to 0.49 irrespective of treatments. Higher HI was produced under N3 treatment followed by N2 and N4 treatments. In 2014-15, the HI ranged from 0.44 to 0.48 irrespective of treatments. Statistically similar HI were observed in N_1, N2, N3, N4 and N5 treatments. The N6 treatment gave the lowest HI in both the year (Table 3).

The main effect of variety and the interaction effect of treatment, variety and year; treatment and variety; treatment and year; and variety and year were insignificant for agronomic use efficiency (AUE). The main effect of treatment and year were significant for AUE ($p<0.05$) (Table 1). During 2013-14, the higher AUE was obtained with N3 treatment, followed by N2 and N4 treatments in BRRI dhan28. The AUE ranged from 7 to 16 kg/kg among the treatments and the lowest was observed in N5 treatment. During 2014-15, the AUE varied from 27 to 35 kg/kg among the treatments. Higher AUE was produced in N3 treatment followed by N2 treatment. The Nl and N4 treatments gave similar AUE and the lowest was observed in N5 treatment The AUE of BRRI han28 in 2014-15 was significantly higher compared to that of 2013-14 irrespective of treatments. In BRRI dhan29, the AUE ranged from 8 to 18 kg/kg among the treatments during 2013-14. Apparently the higher AUE was observed in N4 treatment followed by Nl and N2 treatments and minimum under N3 and N5 treatments. In 2014-15, the AUE ranged from 27 to 30 kg/kg among the treatments and apparent the higher AUE was observed in N4 treatment. The AUE of BRRI dhan29 was higher in 2014-15 in comparison to that of 2013-14 (Table 3). Fageria and Baligar (2001) also reported that AUE was 23 kg grain produced per kg N applied across N rates. Agronomic efficiency in low land rice in the tropics is reported to be in the range of 15 to 25 kg grain produced per kg of applied N (Yoshida, 1981).

Table 3. Harvest index and Agronomic use efficiency (AUE) of BRRI dhan28 and BRRI dhan29 as affected by N management options in Boro – Fallow - T.Aman cropping system, Gazipur

Treatment	Harvest index			Agronomic use efficiency (AUE)		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
			BRRI dhan28			
N_1	0.48	0.43	0.46	10	29	20
N_2	0.48	0.45	0.47	14	32	23
N_3	0.48	0.47	0.48	16	35	23
N_4	0.48	0.46	0.47	14	29	25
N_5	0.46	0.47	0.47	7	27	17
N_6	0.44	0.41	0.43	-	-	-
Mean	0.47	0.45	0.46	12	30	21
			BRRI dhan29			
N_1	0.47	0.47	0.47	16	29	23
N_2	0.48	0.48	0.48	16	28	22
N_3	0.49	0.48	0.49	14	27	21
N_4	0.48	0.48	0.48	18	30	24
N_5	0.45	0.46	0.46	8	28	18
N_6	0.43	0.44	0.44	-	-	
Mean	0.47	0.47	0.47	14	28	21
CV (%)		3.5			24.0	

For harvest index (%): $LSD_{(0.05)}$ 0.013 (for treatment), NS (Variety), 0.008 (Year), NS (Year ×Variety), NS (Treatment × Variety), 0.019 (Treatment × Year), NS (Treatment × Year × Variety)
For AUE (kg/kg): $LSD_{(0.05)}$ 4.22 (for Treatment), NS (Variety), 2.67 (Year), NS (Year × Variety), NS (Treatment × Variety), NS (Treatment × Year), NS (Treatment × Year ×Variety)

Panicle production and grains per panicle

ANOVA for panicle/m^2 reflected significant main effects of treatment, variety and year; and the interaction effect of treatment and year (Table 1). In BRRI dhan28, the N3, N2, N_1 and N4 treatment produced statistically similar number of panicles. The N5 treatment gave significantly lower number of panicle compared to all other treatments except N6 treatment in both years. In 2014-15, the higher number of panicles was obtained from N3 treatment followed by N_1, N4 and N2 treatments. The lowest number of panicles was observed in N6 treatment in both years. In BRRI dhan29, statistically similar number of panicles was produced in N4 and N_1 treatments during 2013-14. The N2, N3 and N5 treatments gave similar panicle number. In 2014-15, the higher number of panicles was observed in Nl treatment followed by N2 and N4 treatments. The N3 treatment gave significantly higher number of panicles compared to that of N5 treatment and the N6 treatment gave the lowest number of panicles in both the year (Table 4). Increased panicles per unit area is the single most important component of yield associated with rice yield, with percent filled grains per panicle and total grains per panicle of secondary or tertiary importance (Gravois and McNew, 1993).

Interaction effects of treatment, variety and year; treatment and year; variety and year and treatment and variety and the main effect of treatment for filled grain/panicle were not significant. However, the main effect of variety and year showed significant ($p<0.0l$) for filled grains/ panicle (Table 1). Mean filled grain for the treatment ranged from 72 to 90 in BRRI dhan28 and 85 to 102 in BRRI dhan29. In BRRI dhan28, the number of filled grains was higher in 2013-14 compared to that in 2014-15. Similar result was observed in BRRI dhan29. On the other hand, BRRI dhan29 gave higher number of filled grains compared to BRRI dhan28 in both the year (Table 4).

Table 4. Yield components of BRRI dhan28 and BRRI dhan29 as affected by N management options in Boro – Fallow - T.Aman cropping system, Gazipur

Treatment	Panicle/m2			Grains/panicle		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
				BRRI dhan28		
N_1	278	401	340	85	75	80
N_2	284	360	322	86	63	75
N_3	278	405	342	87	69	78
N_4	309	392	351	91	88	90
N_5	242	311	277	88	78	83
N_6	209	233	221	75	69	72
Mean	267	350	309	85	74	80
				BRRI dhan29		
N_1	313	459	386	112	84	98
N_2	260	442	351	103	100	102
N_3	279	410	344	104	78	91
N_4	323	436	380	89	84	87
N_5	267	320	294	91	94	93
N_6	227	266	27	90	79	85
Mean	278	389	333	98	87	92
CV (%)		13.2			17.6	

For panicle/m^2 (no.): LSD $_{(0.05)}$ 34.72 (for treatment), 20.04 (Variety), 20.04 (Year), NS (Year × Variety), NS (Treatment × Variety), 49.10 (Treatment × Year), NS (Treatment × Year × Variety)
For grain/ panicle (no.): LSD $_{(0.05)}$ NS (for treatment), 7.09 (Variety), 7.09 (Year), NS (Year × Variety), NS (Treatment × Variety), NS (Treatment × Year), NS (Treatment × Year × Variety)

Thousand grain weight and grain sterility

ANOVA for 1000-grain weight reflected significant main effect of year, variety and the interaction effect of variety and year ($p<0.01$) (Table 1). In BRRI dhan28, the 1000-grain weight ranged from 21 to 23 for 2013-14 and 19 to 23 for 2014-15, respectively. In BRRI dhan29, the 1000 grain weight varied from 22 to 24 g for 2013-14 and 22 to 23 g for 2014-15, respectively (Table 5). Grain weight was typically of minor importance in determining rice yield (Gravois and McNew, 1993). Another study also observed that 1000-grain weight is of minor importance in increasing rice yield and under most conditions, 1000-grain weight of field crops is a very stable varietal character (Yoshida, 1981).

The main effect of year; and the interaction effect of variety and year were significant for sterility percentage. Significantly higher sterility (%) was observed in 2014-15 in comparison to that of 2013-14 both in BRRI dhan28 and BRRI dhan29 (Table 5). In BRRI dhan28, the sterility (%) ranged from 8 to 19 for 2013-14 and 24 to 30 for 2014-15, respectively. In BRRI dhan29, sterility (%) varied from 17 to 23 g for 2013-14 and 22 to 31 g for 2014-15, respectively. Fageria *et al*. (2011) found a quadratic pattern of grain sterility and 1000-grain weight of rice with a range of nitrogen application from 0 to 400 mg kg^{-1} under pot culture. Fageria and Baligar (1999) estimated that the panicle number accounted for 87% of the variation in yield, while spikelet sterility and 1000-grain weight accounted for 7 and 3%, respectively, yield variation in rice. Zeng and Shannon (2000) observed that filled grain per panicle and sterility percentage accounted for 71.1 and 38.0% variation, respectively, while 1000-grain weight accounted for only 1.1% variation in the rice yield. Chaturvedi (2005) reported that grain weight is a genetically controlled trait, which is greatly influenced by environment during the process of grain filling. Yoshida (1981) also reported that panicles per unit area, filled spikelet percentage and 1000 grain weight were major contributors to increase grain yield in modern high yielding rice varieties. According to Datta (1986), there is a very close relationship between the yield and its components, especially with number of filled grains per panicle. The improved growth attributes, such as plant height and dry-matter production, might be responsible for improved yield attributes. It was found that application of nitrogen improves various crop parameters like 1000-grain weight, more productive tillers and grain yield thus resulting in higher yields (Chaturvedi, 2005).

Table 5. Yield components of BRRI dhan28 and BRRI dhan29 as affected by N management options in Boro – Fallow - T.Aman cropping system, Gazipur

Treatment	1000 grain weight (g)			Sterility (%)		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
				BRRI dhan28		
N_1	23	21	22	19	30	25
N_2	23	22	23	9	24	17
N_3	22	22	23	10	27	19
N_4	24	19	22	9	23	16
N_5	23	23	23	14	24	19
N_6	23	21	22	8	25	17
Mean	23	21	22	12	26	19
				BRRI dhan29		
N_1	22	23	23	19	30	25
N_2	22	22	22	17	25	21
N_3	21	23	24	19	31	25
N_4	23	22	23	23	30	27
N_5	22	22	22	18	25	22
N_6	20	22	21	20	22	21
Mean	22	22	22	19	27	23
CV (%)		4.8			19.7	

For 1000 grain weight (g): LSD $_{(0.05)}$ NS (for treatment) , 0.51 (Variety), 0.51 (Year), 0.72 (Year ×Variety), NS (Treatment × Variety), NS (Treatment ×Year), NS (Treatment × Year × Variety)

For sterility (%): LSD $_{(0.05)}$ NS (for treatment), NS (Variety), 3.29 (Year), 4.66 (Year × Variety), NS (Treatment × Variety), NS (Treatment × Year), NS (Treatment × Year), NS (Treatment × Year ×Variety)

Based on the findings, it can be concluded that this study gave an insight for the further consideration of the recommendation of nitrogen splitting for winter rice. It has opened that rice producers could compensate inadequate N application at early growth stages by higher N application at PI stage for their economic benefit.

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