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Effect of Nitrogen Management at the Reproductive Phase in Transplanted Rice

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Authors' contributions

This work was carried out in collaboration among all authors. Author MAB wrote the protocol. Author NA conducted the experiment, lab analyses, wrote the first draft and came out with the final draft. Authors MAS, RA, SAI and MSI took part in preparing and editing the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Nitrogen (N) is not only a major nutrient but also the most limiting nutrient element for rice cultivation. Efficient N fertilizer management is critical for the economic production of rice and the long-term protection of environmental quality. Considering the above facts, two field experiments were designed at Bangladesh Rice Research Institute (BRRI) farm, Gazipur, Bangladesh during the transplanting Aman season (July to November), 2018-19 and the Boro season (December to May), 2019-20 to study the effects of four different N management on growth, yield attributes, yield and nitrogen uptake by rice variety BRRI dhan75 and BRRI dhan89. The experiment was laid out in a randomized complete block design involving four different N management at different stages

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(Active tillering, Panicle initiation, Flowering and Heading) replicated three times. Results revealed that 69 kg N ha^{-1} (29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at heading) would be a better option for higher yield in T. Aman rice While 120 kg N ha^{-1} (23 kg as basal + 40 kg at 20 DAT + 40 kg at 40 DAT + 17 kg ha^{-1} at heading) significantly improved growth, yield attributes and grain yield as well as nitrogen uptake by grain and straw. From the results, it can be said that application of N @10 kg ha^{-1} for T. Aman rice and N @17 kg ha^{-1} for Boro rice at the heading stage would reduce sterility and give a higher yield than BRRI recommended management. Hence, the study suggests that nitrogen management at the reproductive phase gives better performance to the T. Aman and Boro rice.

Keywords: Aman rice; boro rice; nitrogen management; reproductive phase; sterility.

1. INTRODUCTION

"Rice is one of the most important cereal crops in the world and contributes to food security in several developing countries including Bangladesh. With an increase in population, the demand for rice is increasing over the years. Nutrient management is a prime strategy to achieve the demand for food and sustainable production for the rapidly increasing population in the world and to improve food and nutritional quality" [1,2]. "Among the plant nutrients, nitrogen (N) is the most essential element in determining the yield potentiality of intensified agricultural systems" [3]. To exploit the full yield potential of modern rice cultivars, N fertilizer application is necessary for most rice soils. Nitrogenous fertilizer has an immense effect on rice yield throughout a positive influence on the production of effective tillers" [4]. But the efficiency of added N fertilizer in rice depends on N sources, rate of N as well as management practices as evidenced by the ^{15}N tracer studies [5,6]. "Nitrogen not only enhances the yield of rice but also reduces spikelet sterility. Nitrogen is required in an adequate amount in the early, mid tillering and panicle initiation stages for better grain development" [7]. There are two stages of rice crop growth when N is essential; early vegetative-promotes tillering leading to higher yield and panicle initiation stage- which helps to produce more spikelets and heavier grains per panicle. Rational application of nitrogen and appropriate proportions of basal, tillering and panicle fertilizer help to coordinate high yields and nitrogen-use efficiency. Understanding the physiological role of N in the grain-filling stage is also important for improving N management. Several studies have shown that nitrogen application at the reproductive phase significantly increases rice yield" [8,9]. Jiang et al. [10] found that "higher panicle fertilizer proportions could significantly improve nitrogen-use efficiency independent of variety and growing season. Sometimes in Bangladesh, farmers become unable to apply urea (3rd top dress) due to a lack of irrigation water or do not follow the prescribed fertilizer schedule due to early recession of floodwater in intensive boro cultivation area (haor area) and inundation due to heavy rainfall or severe flood in T. Aman season. Therefore, the farmers in these areas achieve lower yields. To escape the flash flood, farmers have to go for early crop establishment allowing it prone to sterility problems. Grain yield reduction in rice is often associated with spikelet sterility, which in turn, usually reflects the effects of adverse growing conditions on reproductive development. So, it needs to investigate whether the top dressing of urea at the reproductive stage is harmful or useful for rice cultivation. This study was undertaken to evaluate the response of different modern varieties with the application of different nitrogen management for obtaining optimum yield by reducing spikelet sterility of T. Aman and Boro rice".

2. MATERIALS AND METHODS

2.1 Experimental Period

The experiment was conducted at BRRI farm, Gazipur, Bangladesh during the T. Aman season (July to November), 2018-19 and the Boro season (December to May), 2019-20.

2.2 Soil Conditions of the Experimental Fields

The soil conditions of the experimental fields were silty clay loam in texture having pH: 6.5, organic carbon: 1.31%, total N: 0.13%, available phosphorus: 40.1 µg g^{-1}, exchangeable potassium: 0.146 meq 100 g $soil^{-1}$, available sulfur: 14.06 µg g^{-1} and available zinc: 0.81 µg g^{-1}.

2.3 Treatments and Design

The study evaluates the effects of four different nitrogen management in the form of urea. In T. Aman season, the fertilizer rate was (N:P:K:S @ 69:10:41:16 kg ha^{-1} and N was splitted as, T_0 = No fertilizer, T_1 = 23 kg as basal + 23 kg at 15 DAT + 23 kg at before panicle initiation (BPI) (BRRI recommended practice) [11], T_2 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at 10 days after PI (DAPI), T_3 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at 20 days after PI (DAPI)/Booting and T_4 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at heading stage. In Boro season, Fertilizer rate was (N:P:K:S:Zn @ 120:18:75:40:4 kg ha^{-1} and N was splitted as, T_0 = No fertilizer, T_1 = 40 kg at 15 DAT + 40 kg at 30 DAT + 40 kg at BPI (BRRI recommended) [11], T_2 = 23 kg as basal + 40 kg at 20 DAT + 40 kg at 40 DAT + 17 kg at 10 days after PI (DAPI), T_3 = 23 kg as basal + 40 kg at 20 DAT + 40 kg at 40 DAT + 17 kg at 20 days after PI (DAPI)/Booting, T_4 = 23 kg as basal + 40 kg at 20 DAT + 40 kg at 40 DAT + 17 kg at heading stage. The experiment was conducted in RCB design with three replications.

2.4 Planting Material

Rice variety BRRI dhan75 for T. Aman season and BRRI dhan89 for Boro season were used as test crops to conduct the study. BRRI dhan75 and BRRI dhan89 were developed by BRRI, Gazipur, Bangladesh. The grains of BRRI dhan75 are long-slender and BRRI dhan89 are medium bold; and the growth duration of BRRI dhan75 and BRRI dhan89 are 115 and 156 days, respectively [12].

2.5 Collection and Preparation of Initial Soil Sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth by means of an auger from different locations covering the whole experimental plot and mixed thoroughly to make a composite sample. After the collection of soil samples, the plant debris was picked up and removed. Then the sample was air-dried and sieved through a sieve and stored in a clean plastic container for chemical analysis.

2.6 Fertilization

The full doses of PKSZn were applied as basal doses during the final land preparation of individual plots. The BRRI recommended dose of urea in inbred Boro varieties 120 kg ha^{-1} and short duration T. Aman varieties 69 kg ha^{-1} respectively. Urea was applied to the T_1 treatment plot in three equal splits on 15, 30 and 55 DAT for BRRI dhan89 and in case of BRRI dhan75, the splits were 0, 15 and 45 DAT, respectively.

2.7 Uprooting of Seedlings and Transplanting

Twenty-five days old seedlings of BRRI dhan75 and forty-day-old seedlings of BRRI dhan89 respectively were uprooted from the nursery beds carefully. Seedlings were transplanted in the well-puddled experimental plots. Spacing was given 20 cm × 20 cm for BRRI dhan75 and BRRI dhan89. Two seedlings for BRRI dhan75 and BRRI dhan89 were transplanted $hill^{-1}$. Seedlings of some hills died off and these were replaced by gap filling after one week of transplanting with seedlings from the same source.

2.8 Irrigation and Drainage

Irrigation was maintained with 1 cm standing water from transplanting to the maximum tillering stage. From panicle initiation (PI) to the hard dough stage, a thin layer of water (2-3 cm) was kept on the plots. Bunds around the individual plots were repaired as necessary to control the water flow between the plots. Water was removed from the plots during the ripening stage.

2.9 Weed and Pest Management

Post-emergence herbicides Bensulfuran methyl + Acetachlore (18 WP) applied after 3-6 days after transplanting@66 g $bigha^{-1}$. Two-hand weeding was done at 30 DAT and 50 DAT followed by the second and third top dressing of urea to keep the fields weed-free. Virtako (chlorantraniliprole 20% + thiamethoxam 20%) pesticide@0.075 kg ha^{-1} was applied to control stem borer infestation.

2.10 Harvesting and Processing

The crop of each plot was harvested separately at full maturity when 80% of the grains become golden yellow in color. At maturity, plants of 5 m^2 area were harvested for the determination of yield and yield components. The grain yield was adjusted at a 14% moisture level. The vegetative plant parts were oven-dried at 72 °C to constant weight and then weighed to calculate the stem dry weight of the respective stage.

2.11 Data Collection

Data were collected on the following parameters - plant height, leaf area, number of tillers, total dry matter, number of filled grains, spikelet sterility (%), spikelet sterility at the top, the middle and bottom portion of panicle, 1000-grains weight, and grain yield.

The percentage of sterility was calculated by the following formula;

Sterility (%) = (Number of sterile spikelets per panicle ÷ number of total spikelets per panicle) × 100

From the sample hills m^{-2}, each panicle was divided into three equal parts by eye estimation. The apical, middle and lower parts were the top, middle, and bottom portions of the panicle, respectively. The sterility pattern for each portion was calculated.

2.12 Determination of Nitrogen

"Straw and grain N concentration was measured at maturity. After dry weight measurement, straw and grain were ground using a mixer mill homogenizer. Approximately 0.5 g sample was used to measure N concentration using an Auto nitrogen analyzer". Nitrogen uptake at maturity was calculated according to Peng et al. [13].

2.13 Statistical Analysis

The data were analyzed statistically. Analysis of variance was performed using Statistix 10 software. The mean differences among treatments were compared by multiple comparison tests using the least significant test at the 0.05 probability label [14].

3. RESULTS AND DISCUSSION

3.1 Growth Characters

3.1.1 Plant height and leaf area index

Plant height differed significantly among cultivars and nitrogen management. Plant height of BRRI dhn75 ranged from 98.8 to 113.6 cm and BRRI dhan89 from 91.07 to 104.6 cm among the treatments. These results are consistent with the findings of Hossain et al. [15]. The variation in leaf area might be due to the variation in leaf number and length and breadth of leaves in plants. The LAI was significantly affected by N application at the heading stage in both varieties. The highest LAI was observed in the T_4 treatment (4.37 and 4.39) followed by the T_1 treatment (4.35 and 4.70) in BRRI dhan75 and BRRI dhan89. The lowest LAI was observed in T_3 treatment (2.96 and 3.39) followed by the T_0 treatment (3.15 and 2.82), respectively (Fig. 1). Similar results were corroborated by Guo et al. [16].

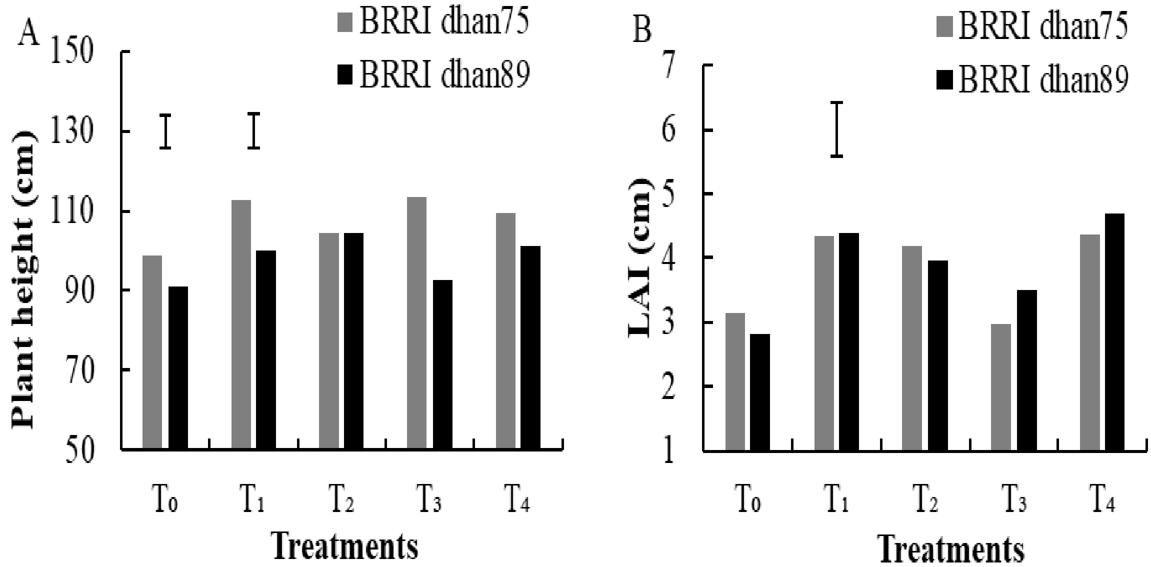

Fig. 1. Plant height (A) and Leaf area index (B) of BRRI dhan75 (T. Aman) and BRRI dhan89 (Boro) at heading stage influenced by different N management (Vertical bars represent the LSD at 5% level of significance)

3.1.2 Tillering pattern

In T. Aman season, tiller number was recorded from 15 DAT and continued up to 90 DAT. It was significantly varied with N management techniques at 45 DAT and at 90 DAT. The maximum number of tillers (297 per m^2) was observed at 45 DAT for all N management techniques except T_0 treatment (256 per m^2). T_1, T_2, and T_4 produced a higher number of tillers up to 60 DAT and then declined slightly for all N management (Fig. 2A). In the Boro season, tiller number was recorded from 20 DAT and continued up to maturity. It was significantly varied with N management techniques at 80-95 DAT. The maximum number of the tiller (258 m^{-2}) was observed at 95 DAT for all N management techniques except T_0 and T_1. The lowest number of tiller (202-213 m^{-2}) was observed in T_0 and T_1 at 65-95 DAT, it was due to a lack of nitrogen fertilization. At maturity tiller number declined slightly for all N management (Fig. 2B). The results are in conformity work of Zhang et al. [17] who found that "integrative crop management with judicious use of the N fertilizer not only increased grain yield but also enhanced agronomic performance with an improved tillering ability".

3.1.3 Total dry matter

Accumulation of dry matter is essential for crop yield formation, and dry weight is an extensively used parameter for assessing the growth conditions of plants. As shown in Figs. 3A, 3B the total dry matter gradually increased until the maturity (MA) stage in both varieties, which was also significantly affected by nitrogen fertilizer. The treatment T_1 produced the highest dry matter (1176.7 g m^{-2}) in comparison to other treatments of N management in BRRI dha75. The rapid increase of dry matter was observed at the heading stage. During maturity, the highest dry matter (1241.1 g m^{-2}) was found from T_4 treatment in BRRI dhan89 (Figs. 3A, 3B). "Lower dry matter yield is associated with a higher temperature at the heading stage in the Boro season than in the T. Aman season" [18]. The higher dry matter with proper nitrogen management was due to an increased amount of photosynthate accumulation which was provided by more availability of photosynthetically active radiant.

3.2 Yield and Yield Components

Yield contributing characters were significantly different due to nitrogen effect (Table 1a, 1b). Among N management treatments, BRRI recommended management (T_1) and 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at the heading stage (T_4) gave the significantly highest grain yield (5.5 and 5.2 t ha^{-1}). "More grain and biomass yield might be explained by the higher capability of the rice cultivar to utilize more nitrogen through a better growth pattern and more dry matter. It is confirmed that an increase in aboveground-biomass production through the nitrogen application during the reproductive stage is the primary factor in increasing grain number in rice" [19]. Variations in yield and yield contributing characters might be due to genetic variability and environmental adaptability of the varieties. In T. Aman season, the lowest grain yield was observed in T_0, T_2 and T_3 treatment (4.2, 4.62 and 4.95 t ha^{-1}), respectively. No significant difference was observed in grains $panicle^{-1}$, thousand grain weight (g). The result agreed with the findings of Fageria et al. [20] who also found that N rates had no effect on the grain weight of rice genotypes. There was a significant difference among different N management techniques in panicle m^{-2} and sterility (%) (Table 1a). The highest sterility (%) was found in T_0 (42.2%) and the lowest sterility% was found in T_1 (26.3%), T_4 (32.8%), T_3 (36.7%) and T_2 (40.3%), respectively. In Boro season, among N management treatments T_4 produced the highest grain yield (7.64 t ha^{-1}) followed by T_1 (7.35 t ha^{-1}). The lowest grain yield was observed from T_1 and T_0 treatments (6.17 and 4.66 t ha^{-1}) respectively. There was a significant difference among different N management techniques in $panicle^{-2}$ and sterility (%) (Table 1b). Fageria et al. [20] reported that "spikelet sterility in irrigated rice is a genotypic trait and can be reduced with proper management of N" which is consistent with our results.

3.3 Sterility Pattern at the Top, Middle and Bottom Portions of Panicle

Nitrogen management showed significant variation in producing the spikelet sterility pattern at the top, middle and bottom portions of the panicle in both varieties. In most cases, the highest sterility was found at the bottom portion and lowest at the top portion of the panicle whereas the middle portion of the panicle showed an intermediate level of sterility. In both varieties, the highest spikelet sterility was found for T_0 for the bottom and middle portions (except the top portion) followed by T_3, T_2, T_4, and T_1. In the top portion, T_4 showed the lowest spikelet sterility (Figs. 4A, 4B). The results are in conformity with SalamatUllah et al. [21].

3.4 Nitrogen Uptake

In T. Aman season, treatment T_1 [69 Kg N ha^{-1}: 23 kg as basal + 23 kg at 15 DAT + 23 kg at BPI (BRRI recommended practice)] showed significantly the highest nitrogen uptake compared to other treatments (Table 2a). In Boro season, T_1 [120 kg/ha: 40 kg at 15 DAT + 40 kg at 30 DAT + 40 kg at BPI (BRRI recommended)] and T_3 [120 kg/ha: 23 kg as basal + 40 kg at 20 DAT + 40 kg at 40 DAT + 17 kg at 20 days after PI (DAPI)/Booting] showed the significantly highest nitrogen uptake compared to other treatments (Table 2b). The grain N uptake and straw N uptake increased during the Boro season, while an opposite trend was seen during the T. Aman season. The results are obtained in line with Deng et al. [22].

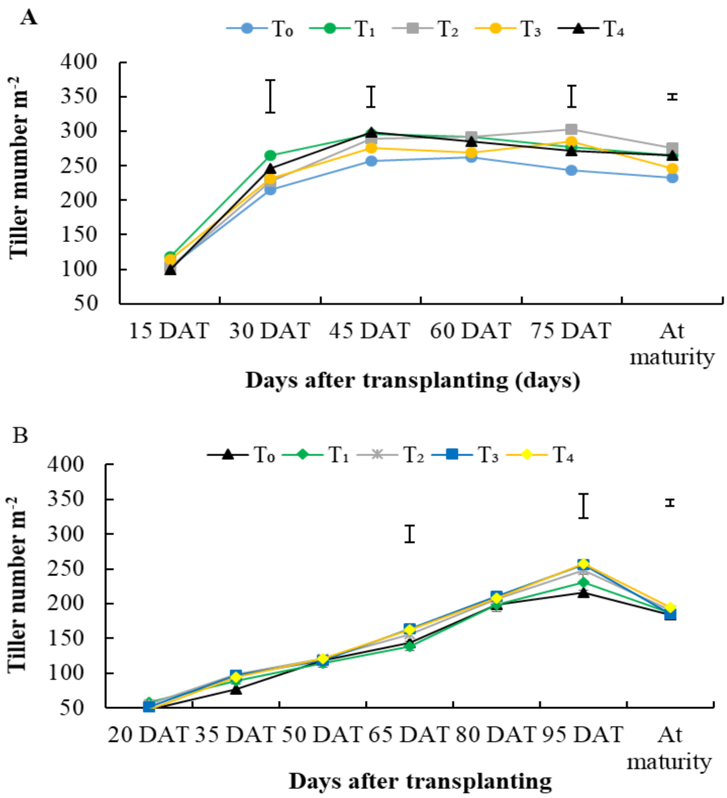

Fig. 2. Tillering pattern of BRRI dhan75 (A) and BRRI dhan89 (B) affected by different N management (Vertical bars represent the LSD at 5% level of significance)

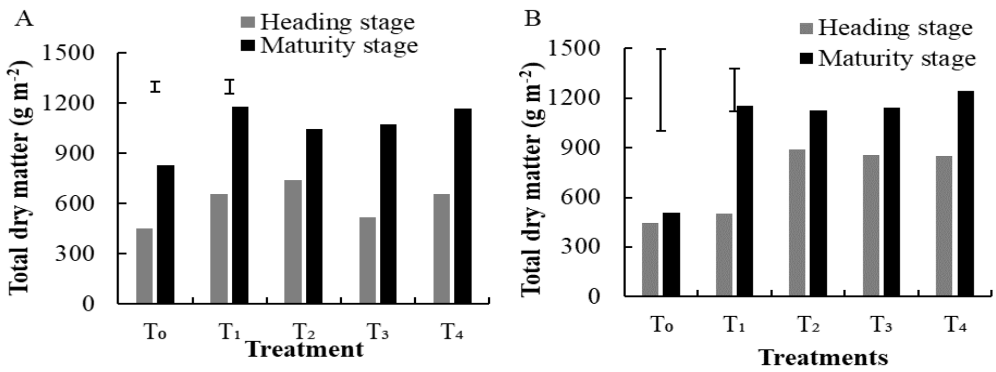

Fig. 3. Dry matter production (g m^{-2}) of BRRI dhan75 (A) and BRRI dhan89 (B) affected by different N management (Vertical bars represent the LSD at 5% level of significance)

Table 1a. Yield and yield components affected by different N management in BRRI dhan75

Treatments	Panicle m^{-2}	Grains $panicle^{-1}$	1000 grain wt. (g)	Grain yield (t ha^{-1})	Sterility (%)
T_0 = No fertilizer	223	86	22.6	4.20	42.2
T_1 = 23 kg as basal + 23 kg at 15 DAT + 23 kg at BPI (BRRI recom. practice)	267	82	22.1	5.50	26.3
T_2 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at 10 days after PI (DAPI)	295	88	22.4	4.62	40.3
T_3 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at 20 days after PI (DAPI)	279	90	23.0	4.95	36.7
T_4 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at heading	264	82	23.4	5.22	32.8
$LSD_{(0.05)}$	7.40	NS	NS	0.30	4.58
CV (%)	5.5	20.5	5.7	3.2	6.9

Table 1b. Yield and yield components affected by different N management in BRRI dhan89

Treatment	Panicle m^{-2}	Grains $panicle^{-1}$	1000 grain wt. (g)	Grain yield (t ha^{-1})	Sterility (%)
T_0 = No fertilizer	175	125	24.0	4.66	11.2
T_1 = 40 kg at 15 DAT + 40 kg at 30 DAT + 40 kg at BPI (BRRI recom. practice)	189	138	24.3	7.35	17.1
T_2 = 23 kg as basal + 40 kg at 20 DAT + 40 kg at 40 DAT + 17 kg at 10 days after PI (DAPI)	180	156	23.4	6.67	15.4
T_3 = 23 kg as basal + 40 kg at 20 DAT + 40 kg at 40 DAT + 17 kg at 20 days after PI (DAPI)/Booting	177	113	23.0	6.71	34.0
T_4 = 23 kg as basal + 40 kg at 20 DAT + 40 kg at 40 DAT + 17 kg at heading stage	191	157	24.0	7.64	14.6
$LSD_{(0.05)}$	10.01	NS	NS	1.23	14.30
CV (%)	3.2	17.4	8.0	10.4	44.8

Table 2a. Effect of different N management on nitrogen uptake (kg ha^{-1}) of BRRI dhan75

Treatments	Nitrogen uptake (kg ha^{-1})	
	Straw	Grain
T_0 = No fertilizer	17.81	23.42
T_1= 23 kg as basal + 23 kg at 15 DAT + 23 kg at BPI (BRRI recom. practice)	25.62	78.13
T_2 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at 10 days after PI (DAPI)	15.13	48.51
T_3 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at 20 days after PI (DAPI)	18.1	57.2
T_4= 29.5 kg as basal+29.5 kg at 15 DAT+10 kg ha^{-1} at heading	24.5	77.10
$LSD_{(0.05)}$	7.04	8.94
CV (%)	18.5	8.3

Table 2b. Effect of different N management on nitrogen uptake (kg ha^{-1}) of BRRI dhan89

Treatments	Nitrogen uptake (kg ha^{-1})	
	Straw	Grain
T_0 = No fertilizer	7.68	33.83
T_1 = 40 kg at 15 DAT + 40 kg at 30 DAT + 40 kg at BPI (BRRI recommended)	19.40	85.33
T_2 = 23 kg as basal + 40 kg at 20 DAT + 40 kg at 40 DAT + 17 kg at 10 days after PI (DAPI)	22.6	71.80
T_3 = 23 kg as basal + 40 kg at 20 DAT + 40 kg at 40 DAT + 17 kg at 20 days after PI (DAPI)/Booting	19.5	85.2
T_4 = 23 kg as basal + 40 kg at 20 DAT + 40 kg at 40 DAT + 17 kg at heading stage	18.4	82.40
$LSD_{(0.05)}$	NS	14.10
CV (%)	37.0	10.9

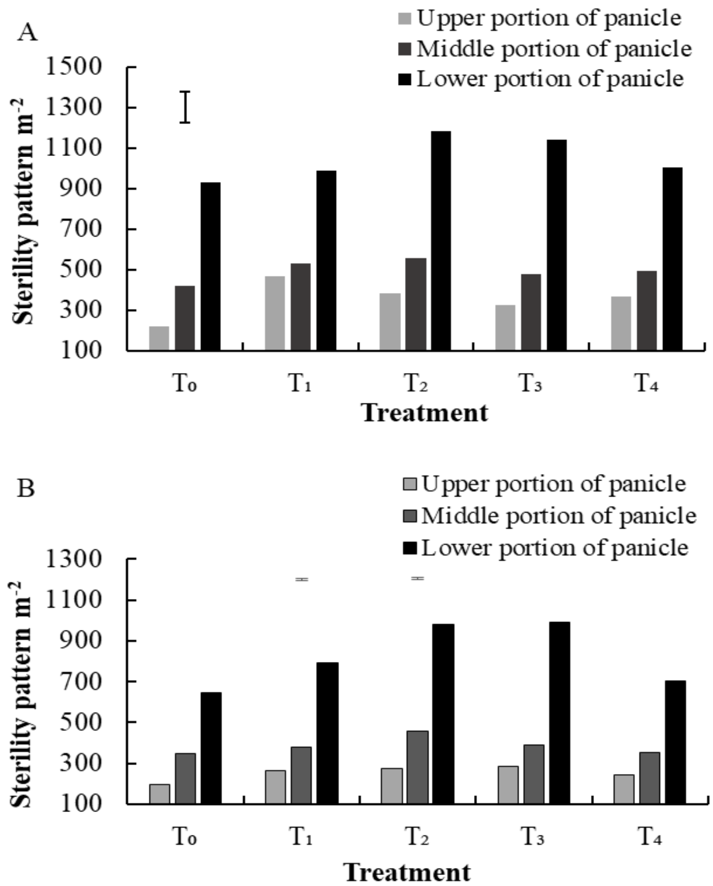

Fig. 4. Sterility pattern (m^{-2}) of BRRI dhan75 (A) and BRRI dhan89 (B) affected by different N management (Vertical bars represent the LSD at 5% level of significance)

4. CONCLUSIONS

Nitrogen applied to the heading stage of rice had the most impact on the nitrogen uptake of the rice crop ensuring high yield. This study revealed the N management**;** application of 69 kg N ha^{-1} ($^1/_3$ as basal + $^1/_3$ at 15 DAT + $^1/_3$ at BPI) (T_1) followed by 69 kg N ha^{-1} (29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at heading) (T_4) would be a better option for higher yield in T. Aman rice. While 120 kg N ha^{-1} ($^1/_3$ at 15 DAT + $^1/_3$ at 30 DAT + $^1/_3$ at BPI) (T_1) and 120 kg N ha^{-1} (23 kg as basal + 40 kg at 20 DAT + 40 kg at 40 DAT + 17 kg ha^{-1} at heading) (T_4) would be a better option for higher yield by reducing sterility% in Boro rice. From the results, it can be said that the application of N @10 kg ha^{-1} for T. Aman rice and N @17 kg ha^{-1} for Boro rice at the heading stage would be reduce sterility and gave a higher yield than BRRI recommended management.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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