Original Research Article

Effect of Nitrogen Management at the Reproductive Phase in Transplanted Rice

Running title:Nitrogen Management at the Reproductive Phase of Rice

ABSTRACT

Topdress of nitrogen (N) at reproductive stage is harmful or useful for rice cultivation. Considering the above facts, two field experimentswere 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 evaluate the effect of four different nitrogen 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 (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} only 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 phasegives better performance to the transplanted aman and boro rice crops.

Keywords: *Aman rice; Boro rice; nitrogen management; reproductive phase; sterility.*

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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 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].In order to exploit the full yield potential of modern rice cultivars, N fertilizer application is necessary in 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 inthe early, mid tillering and panicle initiation stages for better grain development [7].According to ICAR, 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. 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 flash flood, farmers have to go for early crop establishment allowing it prone to sterility problem. 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 [8].The application of urea at the reproductive stage of rice crops, increased sterility and reduced grain yield[9]. So, it needs to investigate whether the top dress of urea at 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, Bangladeshduringthe T. Aman season (July to November), 2018-19 and the Boro season (December to May), 2019-20.

2.2 Treatments and Design

The study evaluates the effects of four different nitrogen management in the form of urea. In T. Aman season, 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), 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), 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.

2.3 Planting Material

Short duration variety BRRI dhan75 for T. Aman season and long durationvariety BRRI dhan89 for Boro season were used as test crops.

2.4 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.

2.5 Fertilization

The full doses of PKSZ were applied as basal dosesduring 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.

2.6 Uprooting of Seedlingsand 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. Manual weeding was done for three times at 15 DAT, 30 DAT and 50 DAT followed by first, second and third top dressing of urea. Irrigation was done by alternate wetting and drying 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. Water was removed from the plots during the ripening stage.

2.7Harvesting 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^2area 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.

2.8Data 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 hillsm^{-2}, each panicle was divided into three equal parts by eye estimation. The apical, middle and lower parts were termedthe top,middle, and bottom portions of the panicle, respectively. The sterility pattern for each portion wascalculated.

2.9 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 Bremner and Mulvaney [10].

2.10 Statistical Analysis

The data were analyzed statistically. Analysis of variance were performed using cropstat7.2 software. The mean differences among treatments were compared by multiple comparison tests using the least significant test at the 0.05 probability label [11].

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3. RESULTS AND DISCUSSION

3.1 Initial Soil Status

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Initial soil status of the experimental field was pH = 6.5, Total N = 0.13%, P = 40.1 µg/g, K = 0.146 me/100 g, S =14.06 µg/g and Zn = 0.81 µg/g.

3.2 Growth Characters

3.2.1 Plant Height and Leaf Area Index

Plant height differed significantly among cultivars and nitrogen managements.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.The LAI wassignificantly 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 T_0 treatment (3.15 and 2.82), respectively (Fig. 1).

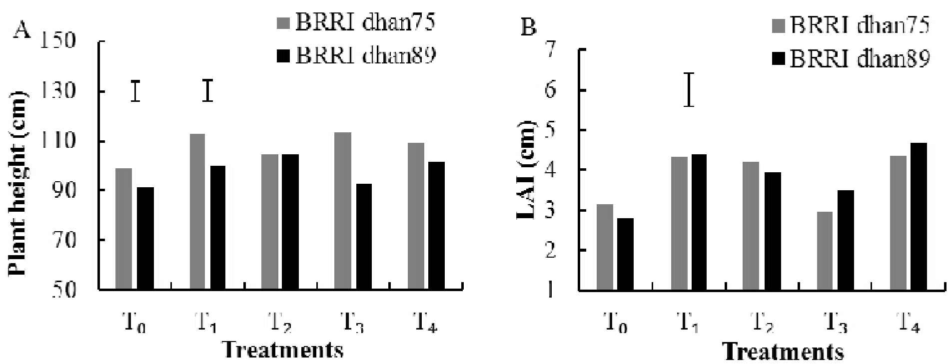

Fig.1: Plant height (A) and Leaf area index (B) of BRRI dhan75 (T. Aman) and BRRI dhan89 (Boro) at heading stage influenced by different N management (Vertical bars represent the LSD at 5% level of significance)

3.2.2 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. 3A). In 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. 3B). The results are in conformity work of Zhang et al. [12] who found that integrative crop management with judicious use of the N fertilizer not only increased grain yieldbut also enhanced agronomic performance with an improved tillering ability.

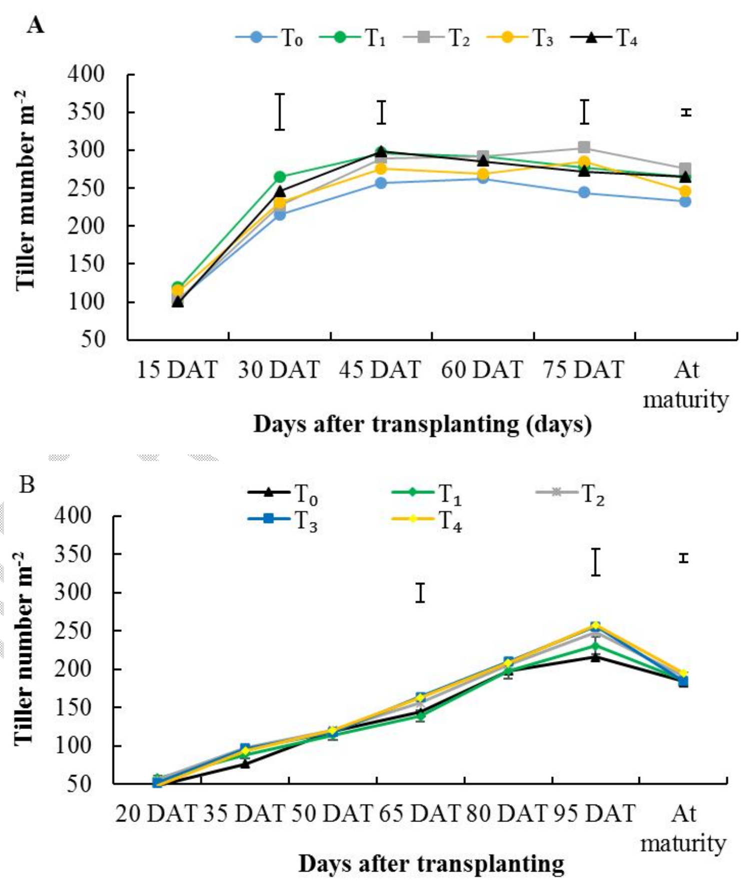

Fig.3. Tillering pattern of BRRI dhan75 (a) and BRRI dhan89 (b) affected by different N management(Vertical bars represent the LSD at 5% level of significance).

3.2.3 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 figure2 A, B, 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 (Fig. 2 A & B). Lower dry matter yield is associated with a higher temperature at the heading stage in the Boro season than in theT. Aman season [13].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.

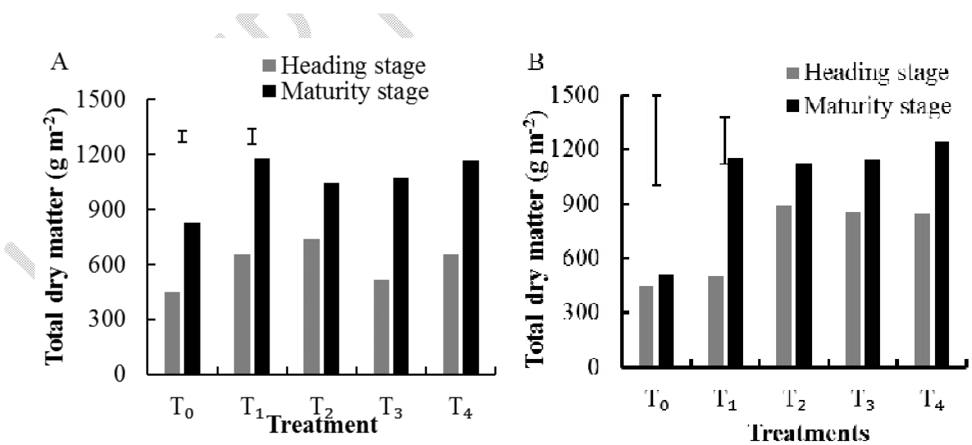

Fig. 2:Dry matter production (g m^{-2}) of BRRI dhan75 (a) and BRRI dhan89 (b) affected by different N management(Vertical bars represent the LSD at 5% level of significance)

3.3 Yield and Yield components

Among N management treatments,BRRI recommendedmanagement (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 the 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 [14].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), straw yield and harvest index.Yoshida [9] reported that grain weight is a fairly stable yield component and trait of the cultivar. The result agreed with the findings of Fageria et al. [15]who have also found that N rates had no effect on grain weight of rice genotypes. There was significant difference among different N management techniques in panicle m^{-2} and sterility (%) (Table1 a). Highest sterility (%) was found in T_0 (42.2%) and lowest sterility% was found in T_1 (26.3%), T_4 (32.8%), T_3 (36.7%)and T_2 (40.3%), respectively.InBoro season, among N management treatments T_5 produced the highest grain yield (7.64 t ha^{-1}) followed by T_3 (7.35 t ha^{-1}). The lowest grain yield was observed from T_1 and T_0 treatment (6.17 and 4.66 t ha^{-1}) respectively. There was significant difference among different N management techniques in panicle^{-2} and sterility (%) (Table1b).Fageria et al. [15] 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.

Table 1 a. 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 1 b. 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.)	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	177	113	23.0	6.71	34.0

(DAPI)/Booting					
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

3.3.1 Sterility pattern at the top, middle and bottom portion of panicle

Nitrogen management showed significant variation for producing the spikelet sterility pattern at top, middle and bottom portion of panicle in both varieties. In most of the cases, the highest sterility was found at bottom portion and lowest at top portion of panicle whereas middle portion of panicle showed intermediate level of sterility. In both varieties, highest spikelet sterility was found for T_0 for bottom and middle portions (except top portion) followed by T_3, T_2, T_4, and T_1. In top portion T_4 showed the lowest spikelet sterility (Fig. 4 A, B).The results are in conformity with SalamatUllah et al.[16]

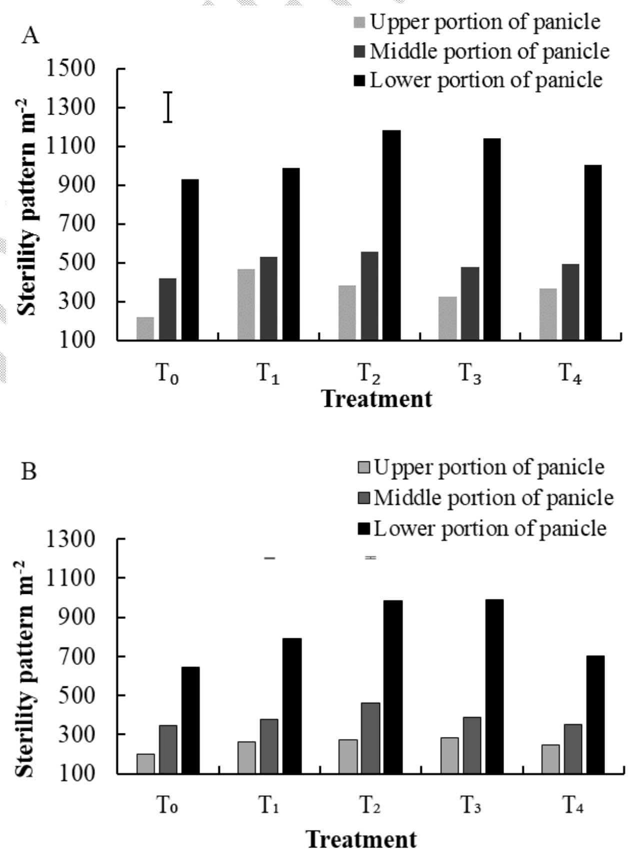

Fig. 4:Sterility pattern (m^{-2}) of BRRI dhan75 (A) and BRRI dhan89 (B) affected by different N management(Vertical bars represent the LSD at 5% level of significance).

3.3.2 Nitrogen uptake

In T. Aman season, treatment T_1 [69 Kg Nha^{-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 2 A).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 2 B).The grain N uptake, 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. [17].

Table 2 a. 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	25.62	78.13

recom. practice)		
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 2 b. 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

4. CONCLUSIONS

This studyrevealed theN 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_2) 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_5) would be a better option for higher yield by reducing sterility% in Boro rice.From the results, it can be said that application of N @10 kg ha^{-1} only at heading stage would be reduce sterility and gave higher yield than BRRI recommended management.

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