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Effect of crop establishment method and N management practice on productivity of transplanted *aman* rice

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An experiment was conducted at the Bangladesh Rice Research Institute Regional Station, Rajshahi, Bangladesh to find the most suitable crop establishment method and best application of N management practice for transplanted *aman* rice. The monsoon-season rainfed rice is *aman*, which is planted in two ways: direct seeding in March or April and transplantation between July and August. Both types are harvested from November through December. T. *aman* rice variety, BRRI dhan44 was used as planting material where three crop establishment methods (T_1: direct wet seeding by drum seeder, T_2: hand broadcasting and T_3: transplanting) and four N management practices (N_1: ⅓ at 15 DAT+ ⅓ at 30 DAT +⅓ at panicle initiation (PI), N_2: ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI, N_3: leaf color chart (LCC) based N application, N_4: no nitrogen) were tested. Among crop establishment methods, the transplanting method (T_3) produced the highest plant density m^{-2} (143.16) and yield (5.05 t ha^{-1}). Among N management practices, N_2 gave the greatest yield (4.97 t ha^{-1}) and the highest benefit cost ratio (1.97). Treatment combination of T_3N_2 at 60 DAT produced the highest plant density m^{-2} (152.33). Therefore, from the current study, it can be concluded that the transplanting method (T_3) and N split fertilization of ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI (N_2), singly or together, would be the most productive application treatments during *aman* season.

Keywords: Crop establishment methods, nitrogen application, T. *aman* rice, productivity, yield.

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for nearly half of the world population (Sellamuthu et al., 2011). The demand for rice will be increasing in the future because of increasing population. In Bangladesh, rice alone provides 76% of the calorie intake and 66% of total protein requirement and shares about 95% of the total cereal food supply (Shahe Alam, 2012). It employs about 43.6% of total labor forces (BBS, 2010; HIES, 2009). Agriculture contributes to 19.3% of the gross domestic product (GDP) of Bangladesh (BBS, 2014). Among all crops, rice is the driving force of Bangladesh agriculture. In fact, food production in Bangladesh is dominated by this single crop and cultivation mainly occurs during a single season (*boro* which accounts for over 60% of total rice production) (MoFDM, 2012).

Rice is grown in Bangladesh under diverse ecosystems subject to irrigated, rainfed and deep water conditions in three distinct seasons, namely a*us*, *aman*, and *boro*. The annual productions of aus, aman and boro rice in 2011 were 2.30, 12.7, and 18.7 million t ha^{-1}, respectively, and *boro* rice represented about 49% of the total rice production (BBS, 2012). Rice has a strong role in the political stability of the country and provides a sense of food security to the people. Farming systems of Bangladesh are, thus, essentially rice-based. Bangladesh is one of the major rice growing countries in the world and ranks fourth both in area and production (BBS, 2012). Bangladesh has made notable progress in sustaining a respectable growth in rice production over the last three decades. However, the population of Bangladesh continues to grow and faces the tremendous challenge of maintaining its food security.

Transplanting has been the major traditional method of rice establishment in Asia. Manual transplanting is one of the most time-consuming, water-intensive, and laborious operations in rice cultivation. The area under transplanted rice cultivation in the world is decreasing due to scarcity of water and labor. Hence, there is need to search for alternate crop establishment methods to increase the productivity of rice (Farooq et al., 2011). Pandey and Valesco (2005) stated that transplanted rice cultivation is practiced in areas where low wages for labor and adequate water are available; whereas, direct seeded rice cultivation can be practiced in areas with high wages and low water availability. Direct seeding reduces labor requirements, shortens crop duration by 7-10 days and can yield as much grain as transplanted cultivation method. Nowadays, rising labor costs and need for intensification of rice production through double and triple cropping have been providing economic incentives for devising a direct seeding method. Direct seeding using a drum seeder, is an example of such crop establishment method where avoids any raising of nursery, pulling up seedlings and transplanting them so that labor requirement for crop establishment is negligible. In this method, the sprouted seeds of rice are sown on well-puddled soil in rows. In order to achieve desired performance from direct wet seeding, rice seeding has to be done before a certain cut-off date which is much earlier than the dates at which most farmer's transplant. This would lead to crop maturity occurring much earlier than possible flash flooding.

Application of nitrogen fertilizer either in excess or at less than the optimum level both affects yield and quality of rice to the significant extent (Manzoor et al., 2006); that is why appropriate fertilizer input is required not only for getting high grain yields, but also for attaining maximum profit. Nitrogen supply must be made available according to the needs of the plant for optimal yield (Azarpour et al., 2011). Leaf color chart (LCC)-based nitrogen management is being introduced, not only to increase N use efficiency, but also to reach higher or similar grain yields to the recommended split applications of N fertilizer. Moreover, Crop models could be used as tools for supporting reasonable nutrient management approaches for agricultural land (Lee et al., 2016). The present study was undertaken to evaluate alternative crop establishment methods and nitrogen management for *aman* rice with the following objectives: to evaluate the performance of different crop establishment methods on the productivity of *aman* rice and to determine the appropriate time of nitrogen fertilizer application in transplanting *aman* rice.

MATERIALS AND METHODS

The field experiment was carried out on the experimental field of the Bangladesh Rice Research Institute (BRRI) at Regional Station, Shyampur, Rajshahi, in 2013. The experimental field was located in the High Gangetic River Floodplain with soil belonging to the agro-ecological zone (AEZ-26) (BARC, 2005). Bangladesh has a tropical monsoon climate. There are three major cropping seasons in Bangladesh: Rabi, Kharif–I, and Kharif–II. Rabi season extends from the middle of October to the middle of March, Kharif–I from the middle of March to the end of June and Kharif–II from July to the middle of October. BRRI dhan44, a popular *aman* rice variety developed by BRRI, was used in the experiment for growing season of Kharif–II. T. *aman* rice variety, BRRI dhan44, was used as planting material. The following three crop establishment methods were chosen as the common treatments for the entire study: direct wet seeding by drum seeder (T_1), hand broadcasting (T_2) and transplanting (T_3). In addition, the following four of N management treatments were studied: ⅓ at 15 days after transplanting (DAT)+ ⅓ at 30 DAT +⅓ at panicle Initiation (PI) (N_1), ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI (N_2), leaf color chart (LCC) based N application (N_3) and no nitrogen (N_4). The unit plot size was 3 × 2 m. Two to three 30-day old seedlings were transplanted per hill with planting spacing of 20 × 15 cm. The plots were fertilized with 105, 15, 60, 15 and 1.5 kg ha^{-1} of N, P, K, S and Zn as urea, triple super phosphate (TSP), murate of potash (MoP), gypsum and zinc oxide, respectively. The experiment was laid out in a split–plot design with crop establishment methods as the whole-plot factor and combinations of N as the subplot factor. The treatments were replicated thrice. The crop was harvested at different dates at maturity. Furthermore, Kim et al., (2016) suggests that optimum transplanting and harvest timings play an important role for production of high quality rice in the plain area.

Procedures of sampling and data collection

Plant density was measured at 20 DAT. Rice seedlings from the direct–seeded method were counted inside a quadrate (50 cm × 50 cm) placed at random in two locations per plot. Plant height was taken from 5 randomly selected crop plants in a plot at 20, 40 and 60 DAT. Plant samples were collected from outside the area harvested for grain yield. Above ground dry matter (DM) was taken of rice plant at 20, 40 and 60 DAT.

Economic analysis

A simple economic analysis was done based on the different operational (variable) costs of cultivation under each planting method, from seeding to harvest but no fixed cost was considered. Cost of land preparation, labor, inputs, irrigation, intercultural operations and price of the product of rice (grain and straw) were collected from the farmers and local markets to compute total variable costs, gross return, gross margin and benefit–cost ratio (BCR). The gross margin and BCR were computed as follows:

Gross margin= Gross return – total variable cost.

$$\text{BCR} = \frac{\text{Gross return}}{\text{Total variable cost}}$$

The recorded data were analyzed using the analysis of variance technique. The mean differences were adjudged by Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

Different crop establishment methods significantly affected the plant density, plant dry matter and plant height of T. *aman* rice (Table 1). The number of rice plants was the lowest at 20 DAT and the highest at 60 DAT. Plant dry matters was the highest when using the transplanting method at 20 and 40 DAT. But at 60 DAT, similar results were found with hand broadcasting and transplanting systems. Plant height was higher with the transplanting method (73.48 cm) at 20, 40 and 60 DAT than that of direct wet seeding by drum seeder and the hand broadcasting. This might be because of the maintenance of proper distances from hill to hill and proper management of in-line sowing as compared to other methods. This result is also similar with the findings of Haque et al., (2012) for most of the vegetative parameters like plant height. Among the three systems, the tallest plant (117.18 cm) was found with the transplanting method (Table 2). The highest number of tillers (10.60 per hill) and number of panicles (86.1 per hill) were found with the transplanting system. Similarly, Ali (2005) also found significant variation in a number of panicle per hill due to crop establishment method.

The highest number of filled grain (Table 2) was produced with hand broadcasting followed by transplanting. The 1000–grain weight did not differ significantly from one crop establishment treatment to the other. The lowest grain yield (3.30 t ha^{-1}) was found using the method of direct wet seeding by drum seeder while the highest grain yield (5.05 t ha^{-1}) found using the transplanting system (Table 2). Grain yield with hand broadcasting did not significantly differ from the grain yield of transplanting methods. Direct seeding of rice may be practiced in the irrigated ecosystem. The findings of Husain et al. (2003) were confirmed with the result that grain yield in direct wet seeding by drum seeder is higher than that in other transplanting systems. The highest straw yield was found using the transplanting method (6.06 t ha^{-1}). This was similar to the reports of Dingkuhn et al., (1990).

The variable cost incurred by the transplanting (T_3) method was the highest at \$ 669.97 ha^{-1}, while it was the lowest in the treatment of direct wet seeding by drum seeder at \$ 579.52 ha^{-1} (Table 3). This might be due to the absence of the seedling uprooting step with direct seeding cultivation, which saves on labor costs. This was similar to the results of Balasabramanian and Hill (2002). It was found that the highest return (\$ 743.73) occurred using the method of hand broadcasting (T_2) due to its lower production costs and above average grain and straw yields. The economic efficiency according to benefit cost ratio (BCR) (2.33) was the highest with the method of hand broadcasting (T_2) (Table 4).

Table 1: Effect of crop establishment method on plant density, plant dry matter, and plant height of T. *aman* rice at different days after transplanting (DAT).

Treatments	Plant density m^{-2} (no.)			Plant dry matter (g)			Plant height (cm)		
	Days after transplanting (DAT)								
	20	40	60	20	40	60	20	40	60
T_1	26.79c	98.16c	132.00b	1.02b	6.43c	20.96b	22.04c	42.79b	65.95c
T_2	40.87b	109.70b	114.50c	1.12b	10.78b	35.94a	24.927b	47.91a	70.44b
T_3	71.79a	123.87a	143.16a	2.75a	11.93a	36.40a	29.095a	48.76a	73.48a
% variance	5.41	4.35	4.23	3.97	11.27	9.60	4.11	4.74	4.93
Level of significance	**	**	**	**	**	**	**	**	**

Notes: $T_{1:}$ direct wet seeding by drum seeder, $T_{2:}$ hand broadcasting, $T_{3:}$ transplanting. There is no significant difference between results followed by the same letter or results that are not followed by a letter. However, results followed by dissimilar letters are significantly different as per Duncan's Multiple Range Test (DMRT). **Significant at P <0.01 level.

Table 2: Effect of crop establishment method on yield and yield attributes of T. *aman* rice at harvest.

Treatments	Plant height (cm)	Tiller number ($hill^{-1}$)	Panicle number ($hill^{-1}$)	Filled grains number ($panicle^{-1}$)	1000-grain weight(g)	Grain yield (t ha^{-1})	Straw yield(t ha^{-1})
T_1	114.85a	8.31c	69.50c	89.89b	26.9b	3.30c	3.96c
T_2	106.52b	9.72b	74.58b	97.30a	27.4ab	4.95b	5.94b
T_3	117.18a	10.60a	86.16a	96.88a	28.7a	5.05a	6.06a
% variance	3.34	9.06	6.21	12.44	11.47	9.40	10.95
Level of significance	**	**	**	**	**	**	**

Notes: $T_{1:}$ direct wet seeding by drum seeder, $T_{2:}$ hand broadcasting, $T_{3:}$ transplanting. There is no significant difference between results followed by the same letter or results that are not followed by a letter. However, results followed by dissimilar letters are significantly different as per Duncan's Multiple Range Test (DMRT). **Significant at P < 0.01 level.

Table 3: Production cost of T. *aman* rice under different crop establishment methods in presence of N fertilizer.

Crop establishment methods	Different operational cost in $							Total Variable cost ($ ha^{-1})
	Land preparation ($ ha^{-1})	Seed ($ ha^{-1})	Irrigation($ ha^{-1})	Fertilizer ($ ha^{-1})	Labor ($$ha^{-1}$)	Herbicide($ ha^{-1})	Insecticide($ ha^{-1})	
T_1	53.51	22.93	19.11	77.58	387.28	7.64	11.47	579.52
T_2	53.51	22.93	19.11	77.58	363.07	7.64	11.47	555.31
T_3	68.79	25.48	22.93	77.58	456.07	7.64	11.47	669.97

Notes: T_1: direct wet seeding by drum seeder, T_2: hand broadcasting, T_3: transplanting. Seed: 40 kg ha^{-1} at 0.55 US dollar ($) kg^{-1}, Urea: 130 kg ha^{-1} at 0.25 $ kg^{-1}, TSP: 50 kg ha^{-1} at 0.27 $ kg^{-1}, MP: 80 kg ha^{-1} at 0.19 $ kg^{-1}, Gypsum: 60 kg ha^{-1} at0.15 $ kg^{-1}, Zinc sulphate: 7 kg ha^{-1} at 1 $ kg^{-1}, Irrigation: 19.11 $ $season^{-1}$ ha^{-1}, Wage rate: 3.18 $ man^{-1} day^{-1}.

Plant density and dry matter production in all DAT was the highest in treatment N_2 (¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at panicle initial stage (PI), followed by treatment N_1 (⅓ at 15 DAT + ⅓ at 30 DAT + ⅓ at PI) (Table 5). The results reveal that nitrogen management options made no remarkable difference in plant heights at 20, 40, and 60 DAT. Nitrogen split applications of ⅓ at 15 DAT + ⅓ at 30 DAT + ⅓ at PI (N_1) stage gave higher plant height (115.79 cm) (Table 6). By using nitrogen split at ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI (N_2) gave the highest number of tillers per hill (10.6), panicles per hill (8.23), and filled grains per panicle (110.83). This result confirmed the findings of Ali (2005). The 1000–grain weight of grain did not significantly differ from other nitrogen management practices. The lowest grain yield (3.50 t ha^{-1}) was observed with the no-nitrogen treatment while the highest grain yield (4.97 t ha^{-1}) was found when applying nitrogen in four splits of ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI (N_2). Nitrogen enhances the vegetative growth of plants but the yield of rice only increases up to a certain level with the increase in nitrogen rate (Patnaiki, 1991). The higher straw yield (5.96 t ha^{-1}) was found in the split application of ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI (N_2), followed by the use of ⅓ at 15 DAT + ⅓ at 30 DAT + ⅓ at panicle initiation stage (N_1) (5.72 t ha^{-1}).

A budget along with total cultivation cost according to different nitrogen management practices in *aman* season is provided in Table 7. The variable cost of production varied from $ 469.96 (N_4: no nitrogen) to $ 661.05 (N_2: ¼ at basal + ¼ at 15 DAT, + ¼ at 30 DAT + ¼ at PI). When means of grain and straw yields were considered, it was noticed that the highest gross and net return ($ 1,1304.26 and $ 643.21) were found in 4 split application of N (N_2: ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI) along with the highest BCR 1.97 (Table 7). The same observation was also obtained in the findings of De Datta (1988).

Table 4: Gross return, net return and benefit cost ratio (BCR) of T. *aman* rice as affected by different crop establishment methods in presence of N fertilizer.

Treatments	Total variable cost ($ ha^{-1})	Gross return ($ ha^{-1})			Net return ($ ha^{-1})	BCR
		Grain*	Straw*	Total		
T_1	a579.52	840.80	25.22	b 866.03	(b-a) 286.51	(b ÷ a) 1.49
T_2	555.31	1261.20	37.84	1299.04	743.73	2.33
T_3	669.97	1286.68	38.60	1325.28	655.32	1.97

Notes: T_1: direct wet seeding by drum seeder, T_2: hand broadcasting, T_3: transplanting, price of paddy: 0.25 $ kg^{-1}, price of straw: 0.01 $ kg^{-1}, BCR: benefit cost ratio.

Table 5: Effect of application time and level of N on plant density, plant dry matter, and plant height of T. *aman* rice at different days after transplanting (DAT).

Treatments	Plant density m^{-2} (no.)			Plant dry matter (g)			Plant height (cm)		
	Days after transplanting (DAT)								
	20	40	60	20	40	60	20	40	60
N_1	50.72a	116.77b	129.22a	1.72a	10.29ab	33.12a	25.63a	47.79a	72.11a
N_2	54.83a	124.77a	134.11a	1.95a	10.89a	34.78a	25.97b	47.25a	73.09a
N_3	41.00b	106.22c	133.50a	1.49c	9.09b	30.08b	25.23a	47.77a	70.98a
N_4	39.39b	94.55d	122.72b	1.35c	8.58c	26.42c	24.58b	43.14b	63.65b
% variance	5.41	4.35	4.23	3.97	11.27	9.60	4.11	4.74	4.93
Level of significance	**	**	**	**	**	**	**	**	**

Notes: N_1: ⅓ at 15 DAT+ ⅓ at 30 DAT +⅓ at PI, N_2: ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI, N_3: leaf color chat (LCC) based N application, N_4: no nitrogen. There is no significant difference between results followed by the same letter or results that are not followed by a letter. However, results followed by dissimilar letters are significantly different as per Duncan's Multiple Range Test (DMRT). **Significant at $P < 0.01$ level.

Table 6: Effect of application time and level of N on yield and yield attributes of T. *aman* rice at harvest.

Treatments	Cost of production (US \$ ha^{-1})			Yield ($t\ ha^{-1}$)		Gross return (\$ ha^{-1})			Net return (\$ ha^{-1})	BCR
	Fixed cost	N–application cost	Total \$	Gain	Straw	Grain	Straw	Total		
N_1	601.17	40.77	641.94	4.77	5.72	1215.34	36.43	1251.78	609.84	1.95
N_2	620.28	40.77	661.05	4.97	5.96	1266.30	37.96	1304.26	643.21	1.97
N_3	587.29	36.94	624.23	4.50	5.4	1146.55	34.40	1180.94	556.71	1.89
N_4	469.96	0	469.96	3.50	4.2	891.76	26.75	918.51	448.55	1.95

Notes: $N_{1:}$ ⅓ at 15 DAT+ ⅓ at 30 DAT +⅓ at PI, $N_{2:}$ ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI, $N_{3:}$ leaf color chat (LCC) based N application, $N_{4:}$ no nitrogen. There is no significant difference between results followed by the same letter or results that are not followed by a letter. However, results followed by dissimilar letters are significantly different as per Duncan's Multiple Range Test (DMRT). **Significant at P < 0.01 level.

Table 7: Economic performance with benefit cost ratio of different N–management treatments during T. *aman* season

Treatments	Plant height (cm)	Tiller number ($hill^{-1}$)	Panicle number ($hill^{-1}$)	Filled grains number ($panicle^{-1}$)	1000-grain weight (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
N_1	115.79a	10.0a	7.86ab	94.66b	27.6b	4.77ab	5.72ab
N_2	114.39a	10.6a	8.23a	110.83a	31.7a	4.97a	5.96a
N_3	115.04a	9.0b	7.49bc	89.72b	25.9b	4.50bc	5.40bc
N_4	106.18b	8.6b	7.12c	83.54b	25.7b	3.50c	4.20c
% variance	3.34	9.06	6.21	12.44	11.47	9.94	10.95
Level of significance	**	**	**	**	**	**	**

Notes: $N_{1:}$ ⅓ at 15 DAT+ ⅓ at 30 DAT +⅓ at PI, $N_{2:}$ ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI, $N_{3:}$ leaf color chat (LCC) based N application, $N_{4:}$ no nitrogen, price of un–husked rice: 0.25 \$ kg^{-1}, price of straw: 0.01 \$ kg^{-1}, BCR: benefit cost ratio

Interaction effect between establishment methods and time and dose of N application was highly significant in respect to plant population (Table 8). Plant density of rice varied from 25.50 in T_1N_4 to 89.50 in T_3N_2 at 20 DAT, 85.83 in T_1N_4 to 141.00 in T_3N_2 at 40 DAT and 99.00 in T_2N_4 to 152.00 in T_3N_2 at 60 DAT (Table 8). As a result, the highest weights of plant dry matter (3.56 and 42.81 g) were obtained from the transplanting system along with the application of ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI (T_3N_2) followed by T_3N_1 (2.68 and 39.58 g) at 20 and 60 DAT, respectively (Table 8). Transplanting methods with the application of ⅓ at basal (15 DAT) + ⅓ at 30 DAT + ⅓ at PI (T_3N_1) had highly significant effects on development of plants than other interaction treatments. The result revealed that the interaction of transplanting methods with nitrogen application of ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at panicle initiation stage (T_3N_2) produced the tallest plant (121.46 cm) (Table 9). Hand broadcasting method with nitrogen application of ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at panicle initiation stage (T_2N_2) obtained the highest straw yield (6.76 t ha^{-1}). The rest of the observation parameters such as number of tillers, number of panicles, grain yield, filled grains $panicles^{-1}$ and 1000–grain weight did not vary significantly due to interaction effect of crop establishment methods and various application option of N (Table 9).

Table 8: Interaction effect between crop establishment methods and application timing and level of N on plant density, plant dry matter, and plant height of T. *aman* rice at different days after transplanting (DAT).

Treatments	Plant density m^{-2} (no.)			Plant dry matter (g)			Plant height (cm)		
	Days after transplanting (DAT)								
	20	40	60	20	40	60	20	40	60
T_1N_1	27.16de	101.50	118.66d	1.18de	6.68	20.88e	22.22	43.62cd	67.62
T_1N_2	27.83de	115.66	135.00c	1.26d	8.31	22.56e	22.39	42.46d	68.38
T_1N_3	26.66e	89.66	138.16bc	0.88ef	5.73	20.43e	22.07	44.22cd	65.55
T_1N_4	25.50e	85.83	136.16c	0.75f	5.00	19.96e	21.50	40.87d	62.26
T_2N_1	41.83c	110.33	121.00d	1.31d	11.66	38.90ab	25.67	48.82ab	72.68
T_2N_2	47.16c	117.66	115.00d	1.01def	11.85	38.98ab	25.70	51.85a	74.64
T_2N_3	37.13c	109.00	123.00d	1.13de	10.20	35.10bc	24.80	48.95ab	72.54
T_2N_4	37.16cd	101.83	99.00e	1.01def	9.43	30.80cd	23.53	42.02d	61.91
T_3N_1	83.16a	138.50	148.00ab	2.68b	12.53	39.58ab	28.99	50.92ab	76.02
T_3N_2	89.50a	141.00	152.33a	3.56a	12.51	42.81a	29.84	47.44bc	76.26
T_3N_3	59.00b	120.00	139.33bc	2.46bc	11.35	34.71bc	28.82	50.15ab	74.85
T_3N_4	55.50b	96.00	133.00c	2.28c	11.33	28.50d	28.72	46.54bc	66.79
% variance	5.41	4.35	4.23	3.97	11.27	9.60	4.11	4.74	4.93
Level of significance	**	ns	**	**	ns	**	ns	**	ns

Notes: T_1: direct wet seeding by drum seeder, T_2: hand broadcasting, T_3: transplanting, N_1: ⅓ at 15 DAT+ ⅓ at 30 DAT +⅓ at PI, N_2: ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI, N_3: leaf color chat (LCC) based N application, N_4: no nitrogen. There is no significant difference between results followed by the same letter or results that are not followed by a letter. However, results followed by dissimilar letters are significantly different as per Duncan's Multiple Range Test (DMRT); **Significant at P < 0.01; ns: not significant.

Table 9: Interaction effect between crop establishment method and application timing and level of N on yield and yield attributes of T. *aman* rice at harvest

Treatments	Plant height (cm)	Tiller number ($hill^{-1}$)	Panicle number($hill^{-1}$)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Filled grains Number ($panicle^{-1}$)	1000-grain weight (g)
T_1N_1	119.47ab	8.83	7.41de	3.85	4.62 e	90.1	26.8
T_1N_2	113.84c	8.97	7.56de	4.00	4.80 e	100.3	29.5
T_1N_3	120.78ab	7.90	6.68g	3.25	3.90 f	86.4	26.1
T_1N_4	105.31f	7.55	6.13h	2.08	2.50 g	82.7	25.5
T_2N_1	107.91e	9.68	7.56de	5.22	6.26 b	96.5	28.6
T_2N_2	107.86e	10.58	7.85d	5.63	6.76 a	117.3	29.6
T_2N_3	108.34e	9.30	7.38e	4.93	5.92 c	87.6	25.8
T_2N_4	101.98g	9.35	7.03f	4.02	4.82 e	87.7	25.6
T_3N_1	120.00ab	11.53	8.58b	5.22	6.26 b	97.4	27.3
T_3N_2	121.46a	12.28	9.26a	5.27	6.32 b	114.9	35.9
T_3N_3	116.00b	9.80	8.41b	5.30	6.36 b	95.1	26.0
T_3N_4	111.26d	8.93	8.20c	4.38	5.26 d	80.1	25.9
% variance	3.34	9.06	6.21	9.40	10.95	12.44	11.47
Level of significance	**	ns	**	ns	**	ns	ns

Notes: T_1: direct wet seeding by drum seeder, T_2: hand broadcasting, T_3: transplanting, N_1: ⅓ at 15 DAT+ ⅓ at 30 DAT +⅓ at PI, N_2: ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI, N_3: leaf color chat (LCC) based N application,

N_4: no nitrogen. There is no significant difference between results followed by the same letter or results that are not followed by a letter. However, results followed by dissimilar letters are significantly different as per Duncan's Multiple Range Test (DMRT); **Significant at P <0.01; ns: Not significant

CONCLUSION

It can be concluded from the results that variety BRRI dhan44 performed better when grown using the transplanting method and split N fertilization ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI, singly (T_3 or N_2) or together, because of an interaction effect (T_3N_2). Therefore, the cultivation of BRRI dhan44 with a transplanting method and N at ¼ at basal + ¼ at 15 DAT + ¼ at 30 DAT + ¼ at PI, singly (T_3 and N_2) or their together (T_3N_2), would be the most productive application treatment during *aman* season. Further study is needed to conclude the most effective method of cultivation for BRRI dhan44 with other nutrient management practices.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest".

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AUTHOR CONTRIBUTIONS

The research has been successfully done with helping from others. Bir designed and performleed the experiments and also wrote the manuscript. MA, HR, SK, and IDJ performed experimental treatments, weeding, interculture operation, data collection, and data analysis. AH, MHR, RI, JW and KW designed experiments and reviewed the manuscript. All authors read and approved the final version.

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