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Research Article

Effect of Crop Establishment and Weed Control Method on Productivity of Transplanted *aman* Rice

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Abstract

This experiment was conducted to find the most suitable crop establishment method and weed management practices for transplanted aman rice in Bangladesh. Rice variety Bangladesh Rice Research Institute (BRRI) dhan44 was used as planting materials where three crop establishment methods (T_1: direct wet seeding by drum seeder; T_2: hand broadcasting; T_3: transplanting) and four weeding options (W_1: Hand weeding (HW); W_2: BRRI weeder+HW; W_3: Herbicide+HW; and W_4: no weeding) were tested. Among the crop establishment methods, the highest grain yield (5.12 t ha^{-1}) was obtained with the T_3, while the highest benefit cost ratio (BCR) of 2.08 was found in T_2. In case of the weed management method, W_1 showed superior results on the plant density/m^2 (139.66) at 60 days after transplanting (DAT), grain yield (4.97 t ha^{-1}), and BCR (2.03). On the other hand, the highest plant dry matter (36.20 g) at 60 DAT and the highest yield (6.10 t ha^{-1}) were obtained in a T_3W_1 combination. The results of this study show that the productivity of rice during *aman* season could be most significantly increased with the use of transplanting (T_3) alone, hand weeding (W_1) alone, or a combination of the two methods (T_3W_1).

Keywords: Crop establishment method, Transplanted *aman* rice, Weed control method, Yield

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INTRODUCTION

Bangladesh is one of the largest producer and consumer of rice in the world with an annual production of 33.88 tons occupying 77.15% of the total cropped area of the country (BBS, 2013). But in the future, maintaining an increased production of rice will be a challenge especially in the context of decreasing cultivable rice land and scarcity of irrigated water of the country. Transplanted *aman* currently takes the greatest percentage of arable land, which is about 49.63% of total rice cultivated area, and contributes 40.57% of the total rice production (BBS, 2012).

Transplanting is the most popular crop establishment method in Asia's irrigated rice growing areas (paddy fields). Traditional manual transplanting is one of the most time consuming, water-demanding, and laborious operations in rice cultivation, and thus direct seeding is becoming an attractive alternative to transplanting. Rice is directly seeded essentially by two methods (dry and wet seeding) based on physical conditions of the field and seed (sprouting or dry).

Direct seeding, using a drum seeder, is one of these methods of crop establishment. In order to achieve desired performance from direct wet-seeded rice, seeding has to be done much earlier than when most farmers would transplant, which could lead to crop maturity much before possible flash floods. In this method, the sprouted rice seeds are sown on well puddled soil in rows.

Weeds are one of the major biotic constraints to rice production (Yeasmin et al., 2008), and weed management has been a huge challenge for rice farmers and researchers as well (Anwar et al., 2011). In Bangladesh, weed infestation reduces grain yield by 70-80% in aus rice (early summer rice), 30-40% in transplant aman rice (autumn rice), 22-36% in boro rice (winter rice), and 40% in transplanted aman rice (BRRI, 2008; Haque et al., 2011). To reduce the cost of rice production, the adoption of alternative methods of weed control have been urgently needed, which includes mechanical weed control, biological weed control, and chemical weed control in combination with manual weeding. Moreover, integrated weed management systems utilizing cultural control technique can be developed for effective weed management (Hwang et al., 2017).

Mechanical weeding and herbicides are the alternatives to hand weeding. However, herbicides are now gaining popularity among farmers. Currently, numerous pre-emergence herbicides are effective in controlling weeds when used together with hand weeding (Ahmed et al., 2003). A technique developed for environmentally-friendly weed management, the combined applications of rice bran with pine leaves in rice fields, has increased yields of rice and has provided higher yields than hand weeding (Lee et al., 2015). Thus, more effective weed management systems are needed to optimize the aman rice yield.

The present study was undertaken to evaluate alternative crop establishment methods and weed control options for aman rice with the following objectives: (i) to evaluate the performance of different crop establishment methods on the productivity of aman rice and (ii) to compare the different weed control methods in transplanted aman rice.

MATERIALS AND METHODS

The field experiment was carried out on the experimental field of the Bangladesh Rice Research Institute (BRRI) at Shyampur Regional Station, Rajshahi, 2012. The experimental field was located in the High Gangetic River Floodplain and its soil belongs to Agro-ecological zone (AEZ)-26 **(**BARC, 2005**)**. Bangladesh has a tropical monsoon climate. There are three major cropping season in Bangladesh: Rabi, Kharif-I, and Kharif-II. A popular transplanted *aman* rice variety developed by Bangladesh Rice Research Institute, BRRI dhan44, was used as planting material in the experiment for the growing season of Kharif-II (July to middle of October) in 2012. The following three crop establishment methods were chosen as 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 weeding options were studied: Hand weeding (30 DAT and 45 DAT) (W_1), BRRI weeder+HW (hand weeding) (W_2), Herbicide (Pretilachlor 500 EC 1 L ha^{-1})+HW (W_3), and no weeding (W_4). The experiment was laid out in a split-plot design with crop establishment

methods as the whole-plot factor and combination of weed management as the subplot factor. The treatments were replicated thrice. The unit plot size was 3 m×2 m. Two to three 30-day old seedlings were transplanted per hill with planting spacing of 20 cm×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. All the fertilizers except urea were applied at final land preparation in full amount. Urea was applied in three splits: 30% at 7-10 days after transplanting (DAT), 30% at 20-30 DAT, and the last 40% at panicle initiation stage. Pretilachlor was applied at the early period of crop growth (30 DAT and 45 DAT). Maturity of rice occurred at different times irrespective of crop establishment methods and weed management practice. The crop was harvested at different dates at maturity.

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

$$BCR = \frac{Gross\ \ return}{Total\ \ Variable\ \mathrm{cost}}$$

Statistical analysis

The recorded data were compiled and tabulated for statistical analysis. Analysis of variance was conducted with the help of a computer package, MSTAT-C. The mean differences among the treatments were adjudged by Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

The highest rice plant density was observed with the T_3 as compared to T_1 and T_2 methods, respectively (Table 1). Similarly, the greatest dry matter weight and plant height were exhibited using the T_3 method. This was similar to the results of Chowdhury et al. (1995). Among three crop establishment methods, the tallest plant was observed with the T_3 method (120.38 cm) followed by T_2 (111.75 cm) (Table 2). This is similar to the results of Chowdhury et al. (1995),

Table 1. Effect of crop establishment method on plant density, plant dry matter, and plant height of transplanted *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	27.41c	103.29b	110.00c	0.96b	7.26c	22.57b	22.78c	42.80c	69.05b
T_2	36.37b	111.08a	128.00b	1.06b	9.39b	30.69a	25.00b	47.84b	73.01a
T_3	79.95a	147.91	142.91a	2.38a	12.47a	32.79a	28.26a	51.08a	74.077a
CV (%)	4.97	7.43	4.47	11.91	5.87	5.46	5.62	4.36	3.18
Level of significance	**	**	**	**	**	**	**	**	**

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 transplanted *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	108.98c	8.76c	6.32c	87.1c	24.87c	3.45c	4.14c
T_2	111.75b	9.58b	7.80b	88.3b	26.30b	4.40b	5.28b
T_3	120.38a	12.31a	8.74a	92.8a	27.95a	5.12a	6.14a
CV (%)	3.25	5.63	5.32	6.68	5.87	7.86	6.60
Level of significance	**	**	**	**	**	**	**

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.

which indicated that plant height significantly increased with concerning all crop establishment methods as evidenced from the present study. Transplanted rice had a significantly higher number of tillers (12.31) than rice planted by hand broadcasting (9.58) or direct wet seeding using drum seeder (8.76). The highest number of panicles (8.74) and filled grains $panicles^{-1}$ (92.8) were established with a T_3 method whereas the lowest number of panicles (6.32) and filled grains $panicles^{-1}$ (87.1) were found with direct wet seeding by drum seeder. The above result of the present study shows similarity with the research reports of Prasad et al. (1999) and Ali (2005). Weight of 1000-grains was the highest (27.95 g) using T_3 method followed by T_2. The highest grain and straw yields were found in T_3 (5.12 t ha^{-1}) and (6.14 t ha^{-1}). The results indicated that the highest yield obtained with a transplanting method might be due to the tallest plant; higher numbers of tillers and panicles. The maximum filled grains were recorded under this method, which ultimately resulted in the higher yield. This was similar to the results of Moody (1991). A partial budget showing cost of cultivation among T_1, T_2, and T_3 methods in *aman* growing season according to the various weed management practices are presented in Table 3. Among three planting techniques, the highest ($ 644.71) and the lowest ($ 276.37) marginal returns were found in the crop establishment method of T_3 and T_1, respectively (Table 4).

In *aman* season, T_2 gave the highest BCR of 2.03 where for T_1 and T_3 showed the BCR of 1.53 and 1.96, respectively (Table 4).

Table 3. Production cost of transplanted *aman* rice under different crop establishment methods in presence of weed management practices.

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	77.20	387.28	7.64	11.47	579.14
T_2	53.51	22.93	19.11	77.20	363.07	7.64	11.47	554.93
T_3	68.79	25.48	22.93	77.20	456.07	7.64	11.47	669.59

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} at 0.15 $ kg^{-1}, Zinc sulphate: 7 kg ha^{-1} at 1 $ kg^{-1}, Irrigation: 19.11 $ season^{-1} ha^{-1}, Labor wage: 3.18 $ day^{-1}.
T_1, direct wet seeding by drum seeder; T_2, hand broadcasting; T_3, transplanting.

Table 4. Gross return, net return, and benefit cost ratio (BCR) of transplanted *aman* rice as affected by different crop establishment methods in presence of weed management practices.

Treatments	Total variable cost ($ ha^{-1})(a)	Gross return ($ ha^{-1})			Net return ($ ha^{-1})(b-a)	BCR (b÷a)
		Grain*	Straw*	Total (b)		
T_1	579.52	860.08	25.80	885.89	276.37	1.53
T_2	555.31	1096.92	32.91	1129.82	574.41	2.03
T_3	669.97	1276.41	38.27	1314.68	644.71	1.96

Mean yield of 3 replications, price of paddy: 0.25 $ kg^{-1}, price of straw: 0.01 $ kg^{-1}.
T_1, direct wet seeding by drum seeder; T_2, hand broadcasting; T_3, transplanting; BCR, benefit cost ratio.

Among the weed management treatments, rice plant densities were statistically similar at 60 DAT when the highest density was found with W_1 and the lowest was with W_4 (Table 5). It was found that the W_1 produced the highest dry matter weight (1.54, 11.66, and 31.66 g) at 20, 40, and 60 DAT, respectively. The results also revealed that hand weeding had a remarkable effect on plant height as the heights were 26.28, 49.16, and 74.43 cm at 20, 40, and 60 DAT, respectively. It is evident from the Table 6 that there were no significant differences in plant height between the weed management practices of hand weeding (W_1) and herbicide application combined with hand weeding techniques (W_3) (115.98 and 115.11 cm, respectively) at harvest. This might be due to the fact that the presence of weeds will lead to a reduction in the average yield of the crop and individual plant height. A most tillers were found in W_1 (11.20) than in W_3 (10.69) and W_2 (9.94) while W4 treatment registered the fewest tillers in this study (Table 6). This might be due to the careful removal of weeds by hand which reduced crop damage and yielded an increased number of plants m^{-2}. It was found that the number of panicle ranged from 6.65 (W_4) to 8.52 (W_1). This might be attributed to better root development in transplanted seedling which produced healthy panicles with a higher number of grains. Weed management treatment of W_1 produced a significantly higher number of filled grains (105.3) whereas W_4 showed the fewest filled grains per panicle (72.2) (Table 6). The W_1 treatment produced the highest grain and straw yields (4.97 t ha^{-1}) and (5.96 t ha^{-1}), respectively, while they were respectively the lowest (3.45 t ha^{-1} and 4.14 t ha^{-1}) in the W_4

Table 5. Effect of weed management practices on plant density, plant dry matter, and plant height of transplanted *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
W_1	53.88a	128.55a	139.66	1.54a	11.66a	31.66a	26.28a	49.15a	74.43a
W_2	46.16c	120.00a	126.94	1.45ab	8.80c	28.48b	24.85b	46.53b	72.16a
W_3	48.55b	125.44a	132.94	1.53a	10.70b	30.40a	26.43a	48.03a	72.92a
W_4	43.05d	109.05b	108.33	1.34b	7.67d	24.19c	23.83b	45.24c	68.68b
CV (%)	4.97	7.43	4.47	11.91	5.87	5.46	5.62	4.36	3.18
Level of significance	**	**	ns	**	**	**	**	**	**

W_1, hand weeding (HW); W_2, BRRI (Bangladesh Rice Research Institute) weeder+HW; W_3, herbicide+HW; W_4, no weeding.
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, ns: not significant.

Table 6. Effect of weed management practices on yield and yield attributes of transplanted *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 ($t\ ha^{-1}$)
W_1	115.98a	11.20a	8.52a	105.3a	28.92a	4.97a	5.96
W_2	112.95ab	9.94c	7.45c	85.9c	26.16b	4.33c	5.20
W_3	115.11a	10.69b	8.11b	94.0b	26.16b	4.53b	5.44
W_4	110.78b	9.04d	6.65d	72.2d	24.57b	3.45d	4.14
CV (%)	3.25	5.63	5.32	6.68	5.87	7.86	6.60
Level of significance	**	**	**	**	**	**	ns

W_1, hand weeding (HW); W_2, BRRI (Bangladesh Rice Research Institute) weeder+HW; W_3, herbicide+HW; W_4, no weeding.
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, ns: not significant.

treatment. Treatment W_1 involved the maximum cost of production ($ 503.58) along with the highest BCR of 1.53 where the lowest cost of production ($ 365.22) was involved in W_4 (Table 7). The net return from rice cultivation was found to be the maximum ($ 772.58) with the weed control practices in W_1 followed by W_3 ($ 723.22). The economic return when there was no weeding throughout the growing season due to lower grain and straw yield having the lowest net return of $ 520 along with lower BCR value of 1.42 than W_2 (1.51). The results correlated with the findings of Ahmed et al. (2005).The results correlated with the findings of Ahmed et al. (2005).

A significant variation was found due to the interaction effect of establishment methods and various types of weed management at 20 DAT where the maximum plant density (94.66) was noted from the interactions between T_3W_1 (Table 8). The rice plant density at 40 and 60 DAT were not statistically different due to whole interaction treatments due to its non-significant variation. However, plant dry matter was significantly affected by crop establishment along with various weed management methods at 40 and 60 DAT although it did not significantly differ at 20 DAT (Table 8).

Table 7. Economic performance with BCR of different weed management methods.

Treatments	Cost of production (US $ ha^{-1})			Yield (t ha^{-1})		Gross return ($ ha^{-1})			Net return ($ ha^{-1}) (b-a)	BCR (b÷a)
	Fixed cost	Weed management cost	Total $ (a)	Gain	Straw	Grain	Straw	Total (b)		
W_1	483.64	19.94	503.58	4.97	5.96	1239.02	37.15	1276.16	772.58	1.53
W_2	421.32	19.94	441.26	4.33	5.2	1079.47	32.41	1111.88	670.62	1.51
W_3	390.15	49.86	440.01	4.53	5.44	1129.33	33.90	1163.23	723.22	1.64
W_4	365.22	0.00	365.22	3.45	4.14	860.08	25.80	885.89	520	1.42

Price of un-husked rice: $ 0.25 kg^{-1} and price of straw: $ 0.01 kg^{-1}.
W_1, hand weeding (HW); W_2, BRRI (Bangladesh Rice Research Institute) weeder+HW; W_3, herbicide+HW; W_4, no weeding; BCR, benefit cost ratio.

Table 8. Interaction effect between crop establishment methods and weed management practices on plant density, plant dry matter and plant height of transplanted *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_1W_1	28.33g	115.66	124.66	1.08	8.70ef	24.45bd	24.78	44.71	72.29
T_1W_2	27.66g	98.16	110.16	1.85	7.10g	22.51d	21.66	41.68	68.97
T_1W_3	28.16g	110.50	116.16	1.00	7.68fg	23.70d	24.10	43.85	70.33
T_1W_4	25.50g	88.83	89.00	0.91	5.58h	19.62e	20.58	40.95	64.63
T_2W_1	38.66e	115.83	140.00	0.93	11.05cd	35.80a	25.72	49.90	74.52
T_2W_2	35.66ef	110.66	129.00	1.11	7.50g	26.75b	24.78	47.19	74.41
T_2W_3	37.50ef	112.66	132.50	1.20	10.31d	33.46a	25.40	48.95	73.21
T_2W_4	33.66f	105.16	110.50	1.00	8.70ef	26.75b	24.10	45.34	69.91
T_3W_1	94.66a	154.16	154.33	2.61	15.23a	36.20a	28.33	52.84	76.47
T_3W_2	75.16c	151.16	141.66	2.38	11.80c	34.73a	28.12	50.71	73.10
T_3W_3	80.00b	153.16	150.16	2.41	14.10b	34.05a	29.79	51.30	75.24
T_3W_4	70.00d	133.16	125.50	2.11	8.75e	26.20b	26.82	49.45	71.49
CV (%)	4.97	7.43	4.47	11.91	5.87	5.46	5.62	4.36	3.18
Level of significance	**	ns	ns	ns	**	**	ns	ns	ns

T_1, direct wet seeding by drum seeder; T_2, hand broadcasting; T_3, transplanting; W_1, hand weeding; W_2, BRRI (Bangladesh Rice Research Institute) weeder+HW (hand weeding); W_3, herbicide+HW; W_4, no weeding.
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, ns: not significant.

Plant height varied from 20.58 to 28.33 cm at 20 DAT, 40.95 to 52.84 cm at 40 DAT and, 64.63 to 76.47 cm at 60 DAT. The data on number of panicles per hill significantly varied from 5.90 to 9.82. These data were obtained from the treatment combinations of T_1W_4 and T_3W_1, respectively, at harvest (Table 9). Prasad et al. (2001) also found significant variation due to crop establishment methods which supports the present findings. They reported that transplanting technique increased all the growth and yield attributes of rice significantly over seeding and puddle sowing of sprouted seeds. The maximum number of filled grains (108.50) was observed in T_3W_1 while the treatment

combinations of T_2W_1 obtained the statistically similar maximum filled grains (107.00) followed by T_1W_1 and T_2W_3 (100.50 and 97.60, respectively). Among the treatment combinations, grain yield was the highest (6.10 t ha^{-1}) in T_3W_1 followed by T_3W_3 (5.17 t ha^{-1}). Among other yield and yield contributing characters, plant height, the number of tillers per hill, and straw yield were significantly identical due to all interaction treatments between crop establishment methods and various application option of weed management.

Table 6. Effect of weed management practices on yield and yield attributes of transplanted *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_1W_1	111.08	9.73	6.92e	100.5ab	29.30a	3.92d	4.70
T_1W_2	108.04	8.45	5.90f	88.1c	25.00bc	3.63de	4.36
T_1W_3	110.90	8.80	6.53ef	89.4bc	23.00c	3.72de	4.46
T_1W_4	105.92	8.05	5.92f	70.4d	22.20c	2.55f	3.06
T_2W_1	114.01	10.78	8.83cd	107.0a	28.60a	4.92bc	5.90
T_2W_2	110.00	9.13	7.93d	75.3d	25.03bc	4.63c	5.56
T_2W_3	113.23	10.37	8.32cd	97.6bc	26.93ab	4.72bc	5.66
T_2W_4	109.78	8.05	68.83e	73.3d	24.66bc	3.33e	4.00
T_3W_1	122.86	13.10	9.82a	108.5a	28.86a	6.10a	7.32
T_3W_2	120.80	12.23	8.51cd	94.5bc	27.53ab	4.75bc	5.70
T_3W_3	121.20	12.92	9.48ab	95.1bc	28.56a	5.17b	6.20
T_3W_4	116.66	11.03	7.15e	73.0d	26.86ab	4.50c	5.40
CV (%)	3.25	5.63	5.32	6.68	5.87	7.86	6.60
Level of significance	ns	ns	**	**	**	**	ns

T_1, direct wet seeding by drum seeder; T_2, hand broadcasting; T_3, transplanting; W_1, hand weeding; W_2, BRRI (Bangladesh Rice Research Institute) weeder+HW (hand weeding); W_3, herbicide+HW; W_4, no weeding.
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, ns: not significant.

Economic analyses

T_3 recorded higher gross return ($1314.68 ha^{-1}) and net returns ($ 644.71 ha^{-1}) than T_1 and T_2 (Table 4). Significant improvement in grain and straw yield could have contributed to the higher gross and net return. The BCR ratio was for T_1 (1.53), T_2 (2.03), and T_3 (1.96) respectively. The W_1 treatment recorded higher gross return ($ 1276.58 ha^{-1}) and net return ($ 772.75 ha^{-1}) than other treatments due to significant improvement of grain yield (Table 7). The BCR ratio was almost same for W_2 (1.51) and W_1 (1.53). The higher BCR ratio (1.64) was recorded in W_3 because of less treatment cost, higher gross, and net returns. No weeding (W_4) recorded lower net return of $ 520 ha^{-1} attributable to severe yield reduction. W_4 showed lower BCR (1.42) might be due to less net return and higher cost of production than that of others (Table 7). It may therefore be concluded that the hand weeding approach whenever necessary was the best treatment than others. As the similarity with W_1, it may be mentioned that the use of herbicide is an alternative in controlling weeds by hand weeding.

CONCLUSION

It can be concluded from the results that variety BRRI dhan44 performed better when grown using a transplanting method (T_3) alone, hand weeding (W_1) alone, or with their combination (T_3 W_1). Therefore, the cultivation of BRRI dhan44 with T_3 alone, and W_1 management alone, or with their combination (T_3 W_1) method is recommended for better yield during *aman* season. Further study is required to conclude the most effective method of cultivation for BRRI dhan44 with other agronomical management practices.

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