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Effect of crop establishment methods on the yield of *boro* rice

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ABSTRACT

Yield and yield penalty as well as economic suitability of various high yielding varieties needed to be assessed by different crop establishment methods before promoting a sustainable crop establishment method in Bangladesh. Therefore, an experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during November 2017 to June 2018 to study the effect of crop establishment methods on the yield and economics of *boro* rice. The experiment comprised of two factors; factor A: methods of crop establishment viz. dry direct seeding, unpuddle transplanting, AWD (alternate wetting and drying) and puddle transplanting; factor B: rice cultivars viz. BRRI dhan28, BRRI dhan58, BRRI dhan74 and BRRI hybrid dhan3. The experiment was laid out in a split-plot design with three replications where method of crop establishment was assigned to the main plot and rice cultivar was assigned to the sub plots. The results showed that plant height, number of total tillers hill^{-1}, effective tillers hill^{-1}, number of grains panicle^{-1}, grain yield, straw yield and harvest index were significantly influenced by crop establishment methods. The highest grain yield (5.54 t ha^{-1}) was obtained in puddle transplanting method due to production of higher number of effective tiller hill^{-1} and higher number of grains panicle^{-1}. Among varieties, the highest grain yield (4.80 t ha^{-1}) was obtained in BRRI hybrid dhan3. The highest grain yield (6.21 t ha^{-1}) was found in puddle transplanting with BRRI dhan28, while the lowest grain yield (2.80 t ha^{-1}) was produced in dry direct seeding with BRRI dhan28. From the economic analysis it is observed that the highest BCR (benefit cost ratio) was observed in puddle transplanting with BBRI dhan28. Puddle transplanting with BRRI dhan28 might be recommended for obtaining higher grain yield and higher BCR of *boro* rice.

Introduction

Rice (*Oryza sativa* L.) production is very crucial to the economy of Bangladesh as it is the staple food of 164 million people of the country. Approximately 77% of the cropped area is devoted to rice production, with some 60-70% of the agricultural labour employed in rice production, marketing and distribution (Julfiquar, 2009). Production of rice contributes one half of the agricultural GDP and one sixth of the national income in Bangladesh (BBS, 2018). According to the provisional data by the Bangladesh Bureau of Statistics in FY 2016-17, the production of milled rice reached around 33.803 million tons (BBS, 2017) in Bangladesh. Among the total rice production, *boro* rice occupies 18.01 million tons in 2016-2017 and average yield was 4.03 t ha^{-1} (BBS, 2017). Though Bangladesh has excellent sub-tropical climate for *boro* rice cultivation but its productivity is low compared with other Asian countries like Indonesia, Malaysia etc. The increasing rate of population and decreasing rate of agricultural land limits the horizontal expansion of rice area. Therefore, to overcome this situation, increase in rice production per unit area is the only alternative to bring self sufficiency in food production. Production potential of rice cultivars yet to be achieved due to various reasons- rice establishment method is one of them. Rice is mainly grown as transplanted crop in puddled soil which reduces weed problems, increases the iron (Fe) availability and makes soil favourable for transplanting. At the same time, it requires large quantity of water starting from land preparation to grain filling (Pathak *et al*., 2011).

As recent estimates indicate that there would be acute water shortage in the coming decades, therefore there is need to develop and adopt water saving methods in rice cultivation so that production and productivity levels are elevated despite the looming water crisis. In this regards, water saving crop establishment methods like system of rice intensification (SRI), alternate wetting and drying (AWD) and dry direct-seeded rice (DSR) could be the options to reduce the water requirement in *boro* rice production. Because it has been reported that SRI, AWD, DSR methods require 40-46%, 16-36% and 35-57% less water than continuous flooding, respectively (Bouman *et al*., 2007; Belder *et al*., 2004; Singh *et al*., 2003).

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So, to get the maximum possible benefits from *boro* rice, it is essential to develop appropriate package of practices for successful cultivation and yield maximization. Among the various cultural practices, appropriate cultivars and methods of crop establishment might play an important role for yield maximization. In this study, attempts have been made to test the possibility of optimizing and improving the yield and estimate the economics of *boro* rice by exploring different methods of crop establishment and different *boro* rice cultivars.

Materials and Methods

The research work was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh. The experimental field belongs to the non-calcareous dark grey floodplain soil under the Agro-ecological Zone of the Old Brahmaputra Floodplain (AEZ-9) (FAO and UNDP, 1988) located at 24.75° N latitude and 90.50°E longitude at an elevation of 18 m above the sea level. The field was a medium high land with flat and well drained condition with the pH value of the soil ranged from 5.9-6.5. The experiment consists of two factors; factor A: methods of crop establishment viz. dry direct seeding, unpuddle transplanting, AWD (alternate wetting and drying) and puddle transplanting; Factor b: rice cultivars viz. BRRI dhan28, BRRI dhan58, BRRI dhan74 and BRRI hybrid dhan3.

The experiment was laid out in a split-plot design with three replications where method of crop establishment was assigned to the main plot and rice cultivar was assigned to the sub plots. Thus total number of plot was 48. Each plot size was 4 m × 2.5 m. The distance between block to block was 1.0 m, the distance between replication to replication was 1.5 m and that of plot to plot distance was 0.75 m. A piece of land was selected at Agronomy Field Laboratory, BAU, Mymensingh to raise seedlings. The sprouted seeds were sown in the nursery bed on 22 November 2017 for puddle transplanting, unpuddle transplanting and AWD methods. The main field was prepared by power tiller with four times ploughing and cross ploughing followed by laddering. After laying out the land was fertilized with urea, MoP, triple super phosphate, gypsum and zinc sulphate @ 300-100-120-60-10 kg ha^{-1}, respectively (FRG, 2012). The entire amounts of TSP, MoP, gypsum and zinc sulphate were applied at the time of final land preparation. Urea was applied in three equal installments at 15, 30 and 45 days after transplanting. The seedlings were uprooted and immediately transferred to the main field for puddle transplanting, unpuddle transplanting and AWD methods on 30 December 2017 and for dry direct seeding method sprouted seeds were sown in the main field manually on the same date. Seedlings were transplanted at the rate of two seedlings $hill^{-1}$, maintaining a spacing of 25 cm × 15 cm. Weed was removed when necessary. Irrigations were given in the plots as per treatment specification eg. dry direct seeding, alternate wetting drying, unpuddle transplanting as well as puddle transplanting required only 7, 10, 15 and 15 irrigations, respectively. When 80-90% of the panicles turned into golden yellow color, the crop was assessed to attain maturity. The crops of puddle transplanting, unpuddle transplanting and AWD plots were harvested on 1 May 2018 at 160 DAS and dry direct seeding plots on 30 May 2018 at 151 DAS. Five hills (excluding border hills) were selected randomly from each unit plot for recording data. An area of central 1m × 1m was selected from each plot to record the yield of grain and straw. The harvested crop of each unit area was separately bundled, properly tagged and then brought to the threshing floor of the Agronomy Field Laboratory. Grains were separated from the plants by thresher. Grains were then sun dried at 14% moisture level and cleaned. The straw was also sun dried properly. Finally, the yields of grain and straw $plot^{-1}$ were recorded and converted to t ha^{-1}.

Data were collected on plant height (cm), number of total tillers $plant^{-1}$, number of effective tillers $plant^{-1}$, panicle length (cm), number of grains $panicle^{-1}$, number of sterile spikelets $panicle^{-1}$, 1000-grain weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), harvest index (%). The collected data were compiled and tabulated in proper from and subjected to statistical analysis. Data were analyzed using the analysis of variance technique with the help of computer package program MSTAT-C and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984). The cost of individual head of expenditure was recorded and partial budget analysis was done.

Results and Discussion

Effect of establishment method on performance of rice

The plant height varied significantly due to different crop establishment methods (Table 1). The tallest plant (94.56 cm) was found in puddle transplanting method. The shortest plant (85.81 cm) was found in dry direct seeded. It might be due to puddle transplanted plant got the puddled condition which led to less crop weed competition and produced taller plants. Variation in the number of total and effective tillers $hill^{-1}$ might be due to the different establishment methods. The highest number of total and effective tillers $hill^{-1}$ (13.10 and 10.62, respectively) was observed in puddle transplanting method and the lowest (9.50 and 7.97, respectively) was observed in dry direct seeded method. This is because direct seeded rice suffered more from soil moisture stress than that of transplanted rice (Gupta *et al*., 1976). The highest number of grains $panicle^{-1}$ (99.95) was observed in puddle transplanting method and the lowest number (86.68) was found in dry direct seeding method. Similar research findings were also reported by Hossain *et al.* (2002), Liu *et al.* (2015) and Bhardwaj *et al.* (2018) who reported that transplanted puddled rice produced higher number of grain $panicle^{-1}$ than direct seeded one. There was no significant variation in panicle length, number of sterile spikelets panicle^{-1} and weight of 1000-grain due to different crop establishment methods. This result is in agreement with that of Bhardwaj *et al.* (2018). The highest grain yield and straw yield (5.54 t ha^{-1} and 6.43 t ha^{-1}, respectively) was obtained in puddle transplanting method and the lowest grain yield and straw yield (3.13 t ha^{-1} and 4.54 t ha^{-1}) was obtained in dry direct seeding method. During the growth period direct seeded rice suffered from inadequate moister so it produced lower grain and straw. Rice established through transplanting recorded significantly higher paddy yield because of the beneficial effects of puddling in transplanting and the ideal rhizosphere environment might have provide higher nutrient uptake which resulted in the greater source accumulation and efficient translocation of photosynthates into the sink as indicated by higher yield attributes (Bhardwaj *et al.*, 2018). These results are in agreement with that of Gupta *et al*. (1976) who reported that yield obtained from transplanted rice was higher than that of direct seeded rice. The highest harvest index (46.69%) was found in puddle transplanting method which was statistically identical to unpuddle transplanting as well as alternate wetting and drying and the lowest harvest index (40.56%) was found in dry direct seeded method.

Table 1. Effect of methods of crop establishment on crop character and yield component of *boro* rice

Methods of crop establishment	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Length of panicle (cm)	No. of sterile spikelets panicle^{-1}	Grains panicle^{-1} (no.)	1000-grain wt. (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)
Dry direct seeded	85.81c	9.50c	7.98b	21.18	16.98	86.68b	24.04	3.13c	4.54c	40.56b
Unpuddle transplanting	88.36bc	11.25b	9.44a	21.13	16.81	91.40b	23.74	4.39b	5.18bc	45.69a
AWD	91.54ab	12.02b	9.75a	21.03	17.55	92.85b	23.24	4.84ab	5.67ab	45.81a
Puddle transplanting	94.56a	13.10a	10.62a	21.69	18.04	99.95a	24.45	5.54a	6.43a	46.69a
Sig. level	0.05	0.01	0.05	NS	NS	0.05	NS	0.01	0.01	0.01
CV (%)	4.99	7.85	14.20	4.53	19.18	7.22	7.02	18.69	5.48	15.94
LSD	4.5	0.90	1.34	-	-	6.69	-	0.837	5.69	-
Standard Error	1.9	0.76	0.55	0.15	0.28	2.75	0.25	0.51	0.39	1.39

In a column figures having common letter(s) do not differ significantly as per DMRT.
NS= Not significant

Effect of variety method on performance of rice

Different yield and yield contributing characters of *boro* rice differed significantly due to varietal differences (Table 2). The tallest plant (94.85 cm) was found in BRRI Hybrid dhan3 and the shortest plant (87.13 cm) was found in BRRI dhan74. The highest number of total tillers hill^{-1} (13.90) was observed in BRRI dhan28 and the lowest (9.43) was observed in BRRI dhan58. Effect of variety on total tillers hill^{-1} was also reported by Hussain *et al.* (1989) who observed that number of total tillers hill^{-1} differed among the varieties which might be due to varietal character.

The highest number of effective tillers hill^{-1} (11.00) was recorded in BRRI dhan28 which was statistically identical to BRRI dhan74 and the lowest (7.92) was observed in BRRI dhan58. The longest panicle (22.51 cm) was observed in BRRI Hybrid dhan3 and the shortest panicle length (20.54 cm) was observed in BRRI dhan28 which was statistically identical to BRRI dhan74.

The highest number of grains panicle^{-1} (103.10) was recorded in BRRI Hybrid dhan3, while the lowest (86.58) was produced by BRRI dhan28. The highest weight of 1000-grain (26.65 g) was recorded in BRRI Hybrid dhan3 which was statistically identical to BRRI dhan74 and the lowest (21.43 g) was found in BRRI dhan28. It is due to 1000-grain weight is a varietal character and it varies from variety to variety.

Grain yield was not significantly influenced by different varieties. However, numerically the highest grain yield (4.80 t ha^{-1}) was produced by BRRI Hybrid dhan3, while the lowest grain yield (4.15 t ha^{-1}) was found in BRRI dhan58. This might be due to the fact that BRRI Hybrid dhan3 produced the highest number of grains panicle^{-1} and heaviest 1000-grain weight which ultimately contributed to highest grain yield. Straw yield was not significantly influenced by different varieties but numerically, the highest straw yield (5.82 t ha^{-1}) was observed in BRRI Hybrid dhan3 and the lowest (5.13 t ha^{-1}) was observed in BRRI dhan74. Harvest index was not significantly influenced by variety but numerically the highest harvest index (45.68%) was observed in BRRI dhan74 and the lowest (44.03%) was observed in BRRI dhan28.

Effect of interaction between establishment method and variety on performance of boro rice

Interaction of crop establishment method and variety had no significant effect on plant height, 1000-grain weight, grain yield, straw yield and harvest index (Table 3). There was significant variation in total tillers hill^{-1}, effective tillers hill^{-1}, panicle length, grains panicle^{-1} and sterile spikelets panicle^{-1} due to interaction between crop establishment method and variety. The highest number of total and effective tillers hill^{-1} (16.60 and 13.27, respectively) was found in puddle transplanting × BRRI dhan28 treatment, while the lowest number of total and effective tillers hill^{-1} (7.67 and 6.67, respectively) was observed in dry direct seeding × BRRI dhan58 treatment. The longest panicle (23.92 cm) was observed in puddle transplanting × BRRI hybrid dhan3 treatment and the shortest panicle (20.22 cm) was found in unpuddle transplanting × BRRI dhan74 treatment. The highest number of grains panicle^{-1} (126.20) was recorded in puddle transplanting × BRRI Hybrid dhan3 treatment, while the lowest (84.93) was found in unpuddle transplanting × BRRI dhan28 treatment. Numerically the highest grain yield (6.21 t ha^{-1}) was recorded in puddle transplanting × BRRI dhan28 treatment, while the lowest (2.80 t ha^{-1}) was found in dry direct seeding × BRRI dhan28 treatment. This result might be due to the varieties did not response well to dry direct seeding method.

Table 2. Effect of variety on crop character and yield component of *boro* rice

Variety	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Length of panicle (cm)	No. of sterile spikelets panicle^{-1}	Grains panicle^{-1} (no.)	1000-grain wt. (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
BRRI dhan28	89.38b	13.90a	11.00a	20.54c	16.79	86.58b	21.43b	4.61	5.69a	44.03
BRRI dhan58	88.81b	9.43c	7.92b	21.39b	17.76	92.96b	21.71b	4.15	5.18	44.08
BRRI dhan74	87.13b	12.58b	10.55a	20.58c	15.81	88.21b	25.69a	4.36	5.13	45.68
BRRI hybrid dhan-3	94.95a	9.95c	8.30b	22.51a	19.02	103.1a	26.65a	4.80	5.82	44.97
Sig. level	0.01	0.01	0.01	0.01	NS	0.01	0.01	NS	NS	NS
CV (%)	5.06	12.05	14.28	4.23	19.46	9.64	6.56	19.65	15.57	5.33
LSD	3.84	1.17	1.14	0.76	-	7.53	1.32	-	-	-
Standard error	1.7	1.06	0.78	0.46	.69	3.71	1.34	0.14	0.17	0.39

In a column figures having common letter(s) do not differ significantly as per DMRT; NS= Not significant

Table 3. Interaction effect of variety and methods of crop establishment on crop character and yield component of *boro* rice

Interaction (Methods of crop establishment and variety)	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Length of panicle (cm)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
M_1V_1	84.95	10.60def	8.60cde	20.93cd	85.72bc	19.40ab	21.27	2.80	4.77	36.89
M_1V_2	82.51	7.67g	6.67e	21.72bcd	89.07bc	16.12b	21.20	3.50	4.83	41.58
M_1V_3	89.67	9.33fg	7.93cde	21.14cd	86.16bc	18.06ab	26.80	3.28	4.08	44.54
M_1V_4	86.09	10.40ef	8.67cde	20.93cd	85.77bc	14.31b	26.89	2.97	4.46	39.24
M_2V_1	86.17	13.33bc	10.14bcd	20.36d	84.93c	14.80b	21.33	4.17	4.77	46.51
M_2V_2	89.31	9.13fg	7.73de	20.93cd	92.29bc	18.18ab	21.77	3.98	5.25	42.96
M_2V_3	83.71	13.00bcd	11.73ab	20.22d	85.53bc	15.09b	26.20	4.77	5.43	46.53
M_2V_4	94.27	9.53fg	8.13cde	23.00ab	102.9b	19.18ab	25.67	4.65	5.29	46.78
M_3V_1	91.82	15.07abc	12.00ab	20.54cd	87.99bc	18.29ab	20.67	5.27	6.13	46.09
M_3V_2	89.57	10.40ef	8.53cde	20.97cd	95.27bc	17.10ab	21.87	4.29	5.11	45.15
M_3V_3	85.53	12.67cde	10.40bc	20.39d	90.39bc	15.17b	23.40	4.10	4.96	45.14
M_3V_4	99.23	9.93fg	8.07cde	22.21bc	97.76bc	19.63ab	27.01	5.74	6.50	46.86
M_4V_1	94.57	16.60a	13.27a	20.33d	87.69bc	14.65b	22.45	6.21	7.10	46.63
M_4V_2	93.84	10.53def	8.73cde	21.94bcd	90.76bc	19.64ab	22.00	4.84	5.54	46.65
M_4V_3	89.61	15.33ab	12.13ab	20.57cd	95.20bc	14.91b	26.35	5.30	6.07	46.50
M_4V_4	100.21	9.93fg	8.33cde	23.92a	126.2a	22.95a	27.01	5.83	7.03	46.98
Sig. level	NS	0.05	0.05	0.05	0.05	0.05	NS	NS	NS	NS
CV (%)	5.06	12.05	14.28	4.23	9.64	19.46	6.56	19.65	15.57	5.33
LSD	-	2.33	2.27	1.52	15.06	5.69	-	-	-	-
Standard Error	0.91	0.39	0.31	0.18	1.79	0.52	0.41	0.18	0.13	0.76

In a column figures having common letter(s) do not differ significantly as per DMRT; NS= Non significant

M_1= Dry direct seeding, M_2= Unpuddle transplanting, M_3=AWD (Alternate wetting and drying), and M_4= Puddle transplanting, V_1= BRRI dhan28, V_2= BRRI dhan58, V_3=BRRI dhan74, V_4= BRRI hybrid dhan3

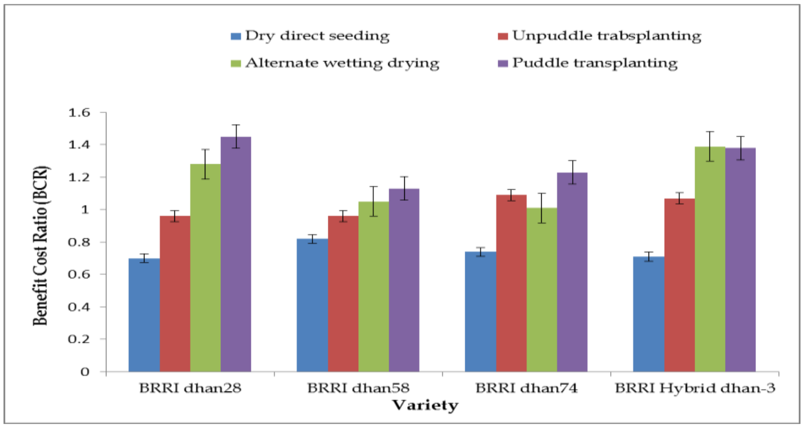

Fig. 1 Benefit cost ratio (BCR) of different crop establishment method in *boro* rice

Economics of different crop establishment method and variety

Considering BCR (benefit cost ratio), it is observed that highest BCR (1.45) was observed in puddle transplanting with BRRI dhan28 and the lowest BCR (0.70) was obtained in dry direct seeding method with BRRI dhan28 variety (Figure 1).

Conclusion

Therefore, in order to meet the projected rice demand of the nation in near future, considering the crop establishment methods, puddle transplanting with BRRI dhan28 could be a feasible not only to have a positive effect on rural economy by lowering the production cost but also contribute in increasing *boro* rice productivity.

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