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YIELD PERFORMANCE AND COST-EFFECTIVENESS OF DRY DIRECT SEEDED *BORO* RICE IN RESPONSE TO SOWING DATE AND IRRIGATION REGIME

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Abstract

Dry direct seeding is a new technology to address the water scarcity problem faced in rice culture in *boro* season. An experiment was run at Bangladesh Agricultural University in Mymensingh, to determine the impact of the sowing date and irrigation schedule on the yield potential and cost effectiveness of *boro* rice grown under a dry direct seeding system. The experiment was laid out in a split-plot design and consisted of two sowing dates viz. 10 February and 02 March; and five irrigation regimes viz., no irrigation, one irrigation at 25% field capacity (FC), two irrigations (at 25% FC and at 1 week after 25% FC), three irrigations (at 25% FC, at 1 and at 2 weeks after 25% FC) and four irrigations (at 25% FC, 1, 2 and 3 weeks after 25% FC) replicated thrice assigning sowing date in main plots and irrigation in sub-plots. The result showed that BRRI dhan58 sown on 10 February with four irrigations (at 25% FC, 1, 2 and 3 weeks after 25% FC) produced the highest grain yield and economic return which was statistically comparable to those for two (at 25% FC and at 1 week after 25% FC), and three irrigations (at 25% FC, at 1 and at 2 weeks after 25% FC). The present study concludes that rice variety BRRI dhan58 can be cultivated successfully to achieve maximum yield and economic return by sowing the seed during 10 February to 02 March and applying 2 - 3 irrigations at the vegetative phase in dry direct seeding system.

Keywords: Sowing date, Field capacity, Water saving, Grain yield, Economic return

Introduction

The main rice establishment method is the seedling transplanting into puddle land. This puddle transplanted (PTR) system is labour intensive and requires huge amount of irrigation water. The shortage of labour, increased labour costs and water scarcity threatens the sustainability of rice production in *boro* season under this system (Rahman, 2019). In Bangladesh, the *boro* season rice cultivation fully depends on irrigation due to highly scarce rainfall during this season. Surface and subterranean water resources are depleting, and water has become a limiting element in rice production. In Bangladesh, the water table is dropping day by day as more irrigation water is pumped up during *boro* season. Moreover, the profit margins from PTR rice in *boro* season have been slashed because of high water inputs, labour costs, and labour requirements (Pandey and Velasco, 1999). In the coming days, the water scarcity will be looming in the country. Moreover, irrigation for *boro* rice is causing pressure on the electricity and diesel. The sustainability of conventional transplanted rice cultivation in *boro* season has been threatened and therefore, an alternative rice system is required to cope up with the situation.

Dry direct seeding (DDS) system has been established as a viable alternative to the PTR system (Rahman, 2019). DDS system produces higher or similar rice grain yields compared to the PTR system (Rahman and Masood, 2014). Rice seed is directly sown on dry cultivated lands and no standing water is kept during the period of sowing to panicle initiation stage (PI) while standing water (3-5cm) is maintained from PI to blooming or milking stage as in PTR system. Thus, 50-60% irrigation water saving in the DDS system is primarily achieved by avoiding puddling, seed bed preparation, and maintaining aerobic soil conditions from sowing to PI stage compared to PTR system of rice cultivation (Cabangon et al., 2002). The DDS system is not only a great water-saving rice technology but also lowers production costs, arsenic contamination and greenhouse gas emission (Rahman, 2019).

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There are 316 cropping patterns in Bangladesh of which T. *aman* rice - Fallow - *Boro* rice is the most dominant one (Nasim et al., 2018). The transplanting system for rice cultivation can be easily replaced by DDS system as it is more economic and environment friendly. Moreover, a *rabi* crop can be grown during the fallow period in between *aman* rice and *boro* rice. Thus, T. *aman* rice – *Rabi* crop – DDS *boro* rice pattern can be adopted to increase cropping intensity, diversity and farm productivity. Farmers generally prefer short duration *rabi* crops so that *boro* rice planting does not go too late. In general, *boro* rice is transplanted during mid December to mid January while the optimum date for sowing of *boro* rice under DDS system ranges between15 January to 15 February (Uddin, 2019). The sowing date of *boro* rice may be even delayed under T. *aman* rice – *Rabi* crop – DDS *boro* rice pattern depending on the type of *rabi* crops used. Therefore, it is necessary to examine the effect of sowing date on yield performance of *boro* rice under dry direct seeded system.

Dry direct seeded system saves 50-60% irrigation water and the water saving mainly comes from cutback of irrigation during vegetative stage (Rahman, 2019). Both in the PTR and DDS system, standing water or wet condition is maintained from one week before panicle initiation and continued to the heading or grain filling stage. Under late sown condition the rainfall is often sufficient to maintain wet condition during reproductive phase of rice crop. In general, during the vegetative phase, the allowable soil moisture depletion for dry direct seeded *boro* rice may be set at about 25% of field capacity (FC). In other words, irrigation should be delayed up to 25% FC and this point could be regarded as 25% of management allowable depletion (MAD) of soil water. In practice, 4 - 6 irrigations are required for DDS rice in boro season depending on the soil and environment. Therefore, it is necessary to investigate whether further irrigation water saving could be achieved by reducing the frequency of irrigation during the vegetative phase without affecting yield performance of the crop.

In view of the above statement, it is necessary to examine the effect of sowing date and irrigation cutback on yield performance and economics of dry direct *boro* rice for maximizing grain yield and economic return with minimum water input.

Materials and Method

Site and Soil

The Agronomy Field Laboratory of Bangladesh agriculture university, Mymensingh was the site where the experiment was done during February to June 2020 to examine the effect of sowing date and irrigation regime on growth and yield of late sown dry direct seeded *boro* rice variety BRRI dhan58. The experimental field was situated 18 meters above sea level at 24°25' N latitude and 90°50' E longitude. The experimental field is made up of non-calcareous dark grey floodplain soil under the Sonatala series, which is part of the Old Brahmaputra Floodplain's Agroecological Zone (AEZ-9). It was a medium high land having silty loam soil with moderate drainage condition. The experimental soil had pH 6.50, 1.29% organic matter, 1.0% total N, 16.72 ppm available P, 0.12 ppm exchangeable K and 14.2 ppm available sulphur. The bulk density, particle density and porosity of the soil were 2.60 g cc^{-1}, 1.35 g cc^{-1} and 46.67%, respectively. The area has a subtropical climate, which is typified by high temperatures and frequent showers during the *kharif* season (April to September) and sparse rainfall and somewhat low temperatures during the *rabi* season (October to March). The daily average maximum, minimum and mean air temperature, total rainfall, sunshine hours and evaporation during the experimental period (January to June, 2020) have been presented in Figure 1.

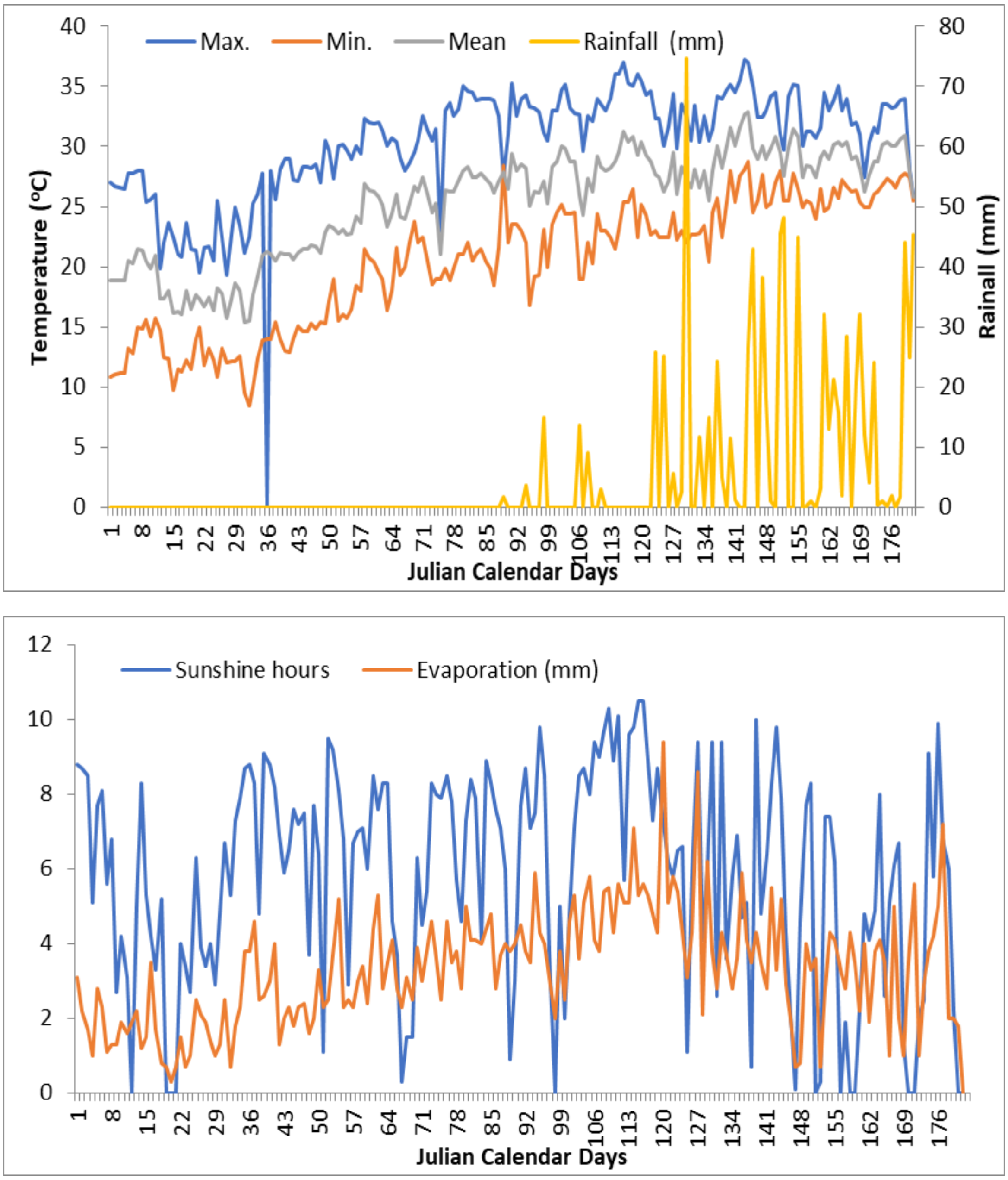

Figure 1. Daily average temperature, rainfall, sunshine hours and evaporation of the experimental site during 01 January to 30 June 2020

Experimental treatment, design and layout

The experiment included two factors; (a) date of sowing viz. 10 February and 2 March and (b) five irrigation regimes viz. no irrigation, one irrigation at 25% field capacity (25%FC), two irrigations (at 25% FC and at 1 week after 25% FC), three irrigations (at 25% FC, at 1 and at 2 weeks after 25% FC) and four irrigations (at 25% FC, 1, 2 and 3 weeks after 25% FC) using a spilt-plot design and replicated thrice. Sowing dates were allocated into the main plots and irrigation regime into the sub plots. The unit plot size was 10 m² (4m ×2.5m).

Crop husbandry

Rice seeds of the BRRI dhan58 variety were hydro-primed by soaking in water for 24 hours at room temperature, followed by 30 hours of incubation at 35 ^{0}C. Then those seeds were directly sown on to the dry cultivated land in two different sowing dates as per experimental specification at 25cm × 15cm in 3-5cm depth allocating 4 seeds hill^{-1}. The field was fertilized at the rate of 325, 100, 130, 115, 4 kg ha^{-1} of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate (monohydrate), respectively as per recommendation of FRG (2012). The whole amounts of all fertilizers were applied as basal dose at the time of final land preparation while urea was top dressed in three equal installments at 15, 30 and 45 days after sowing (DAS). Panida (Pendimethalin), a pre-emergence herbicide was applied at 3 DAS and weeding was done thrice at 15, 30 and 45 DAS. Fana (Carbofuran) 5G @ 4 kg ha^{-1} and Licar (Abamectin) 1.8 EC @ 1.0 L ha^{-1} were applied to control the insect infestation.

Sampling, harvesting and processing

At full maturity, when 90% of the grains turned into golden yellow, the crop was harvested. Prior to harvest, five randomly chosen hills (excluding border hills) from each unit plot were uprooted to collect data on yield metrics. The crop was harvested from central 3.0 m^{-2} area (2.0 m × 1.5 m) to register grain and straw yield. The harvested crops of individual plot were bundled, properly tagged and then taken to threshing floor. After drying the grains and straws in the sun the grain yield was recorded at 14% moisture basis and converted to t ha^{-1}.

Data recording

Field capacity and soil moisture content: The amount of water reserved in the soil after all the extra water at saturation has been exhausted out. It was measured by taking soil samples from the field after 2 days of saturation and the soil sample was oven dried at 105 ^{o}C for 48 hours. The moisture content of soil (P_w) was calculated by oven-dry weight basis using formula below.

$$Pw = \frac{W1 - W2}{W2} \times 100$$

Where,
W1 = weight of wet soil sample
W2 = weight of dry soil sample

The soil moisture content at field capacity was 35%. The management allowable depletion (MAD) of soil moisture at which irrigation to be applied was scheduled to be at 25% of field capacity and that condition of field was reached at 26% soil moisture content. The soil moisture content of the field was monitored at 7 days interval by collecting soil samples from three randomly selected spots of the field. The soil moisture content at different day after sowing was noted and presented in Figure 2.

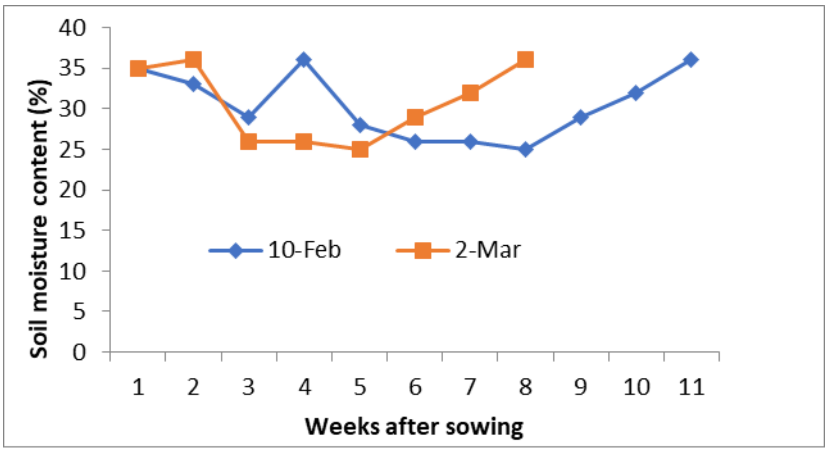

Figure 2. Soil moisture content at different weeks after sowing of dry direct seeded rice in 2020

Crop related parameters
Plant height, number of total, effective and non-effective tillers hill^{-1}, panicle length, numbers of filled grains panicle^{-1}, numbers of unfilled spikelets panicle^{-1}, thousand grain weight, grain yield and straw yield were recorded at harvest. Different phonological events of the crop i.e. the date of panicle initiation, flowering and harvesting were recorded. The crop sown on 10 February and 02 March reached their PI stage on 30 April and 20 May, flowering on 25 May and 4 June and harvesting on 29 June and 02 July 2020, respectively.

Economic Analysis
Costs for all heads of expenditure were recorded for studying the economic performance of the *boro* rice under sowing date and irrigation regime. The non-material input cost, material input costs and overhead costs were recorded to estimate gross return, net return and benefit cost ratios (BCR). The formula below as used to calculate the benefit Cost Ratio:

Benefit Cost Ratio $(\mathrm{BCR}) = \frac{\textbf{Gross Retun}}{\textbf{Total cost of production}}$

Statistical Analysis
The gathered data was properly organized, tallied, and statistically analyzed. The analysis of variance (ANOVA) technique used in data analysis with the help of computer package program STATISTIX-10 and LSD Test was used for mean comparison.

Results
Effect of sowing date
Sowing date exerted significant influence on number of effective tillers hill^{-1} and grain yield but not on plant height, number of total tillers hill^{-1}, number of non-effective tillers hill^{-1}, panicle length, number of filled grains panicle^{-1}, numbers of unfilled spikelets panicle^{-1}, thousand grain weight and straw yield (Table 1). The number of effective tiller was higher for the crop sown on 10 February (11.46 tillers hill^{-1}) than the 02March sown crop (10.90 tillers hill^{-1}). Table 1 showed that the crop sown on 10 February produced significantly higher grain yield (4.74 t ha^{-1}) than that sown on 02 March (4.38 t ha^{-1}). The crop sown on 10 February produced 7.59% more yield than 02 March crop. This greater grain yield in 10 February crop was accredited to the higher number of effective tillers hill^{-1} although other yield attributes remained similar. The lower number of effective tiller in case of 02 March crop might be due to moisture stress faced by the crop at the early stage due to rapid depletion of moisture compared to the 10 February sown crop (Fig. 2).

Effect of irrigation regime
Irrigation regime exerted significant effect on number of total tillers hill^{-1}, number of effective tillers hill^{-1}, panicle length, number of filled grains panicle^{-1}, number of unfilled spikelets panicle^{-1}, grain yield and straw yield but not noteworthy for plant height, number of effective tillers hill^{-1} and thousand grain weight (Table 3). The plots receiving 4 irrigations created the highest grain yield (4.99 t ha^{-1}) that was statistically at par with 2 and 3 irrigation plots. The lowest grain yield was found with no irrigation plot, which was similar with 1 irrigation plot. It was found that two irrigations produced the highest number of total tillers hill^{-1} (15.17) which was statistically similar with those for 1, 3 and 4 irrigation plots. It was further revealed that the irrigated plots produced significantly higher grain yield than the plots receiving no irrigation. Notably, irrigated plots produced significantly higher number of effective tillers than no irrigated plots. The plots having 4 irrigations had the longest panicle (21.56 cm) which was statically similar with 3 and 2 irrigations. The no irrigation plots produced the shortest panicle (20.28 cm). The plots receiving 4 irrigations produced the highest number of filled grain (90.16) which was at par with 3 irrigation plots. The lowest numbers of filled grains (79.33) was noted in no irrigated plot. The highest numbers of unfilled spikelets panicle^{-1} (50.67) were also obtained with 4 irrigations which were statistically similar with those for 3 and 2 irrigation plots while the lowest numbers of unfilled spikelets were found in no irrigation plot. The straw yield was also highest with the plots receiving 4 irrigations, likewise 2 and 3 irrigation receiving plots also gave similar yields (Table 4).

Interaction effect of sowing date and irrigation regime

The interaction of sowing date and irrigation regime was significant for numbers of total tillers hill^{-1}, effective tillers hill^{-1}, non-effective tillers hill^{-1}, grains panicle^{-1}, thousand grain weight, grain yield and straw yield but not significant for plant height, panicle length, and number of unfilled spikelets panicle^{-1}(Table 5 and 6) The crop sown on 10 February and applied with 4 irrigations ($SD_1 \times I_4$) produced the highest grain yield (5.14 t ha^{-1}) and the lowest grain yield (3.60 t ha^{-1}) was noted with the crop sown on 02 March with no irrigation ($SD_2 \times I_0$). In both the sowing dates the lowest grain yield was found with no irrigation plots which were statistically comparable with those produced from crops receiving one irrigation. It was further observed that in case of 10 February crops receiving two and three irrigations and for 02 March sowing the crop receiving three and four irrigations gave statistically similar yields to that of the crop sown on 10 February with four irrigations.

Economic Analysis

Economic analysis revealed that the crop sown on10 February sowing and applied with three irrigations exhibited the maximum gross return (175100 Tk ha^{-1}), gross margin (91175 Tk ha^{-1}) and benefit cost ratio (2.09). These values were very close to those obtained from the crop sown on 10 February and applied with two irrigations (Table 7). The next highest gross return and gross margin values were observed with the crop sown on the same date and grown with four irrigations. In case of the crop sown on 02 March, the highest gross return was obtained from four irrigations but the BCR was similar for the crops receiving 2, 3 and 4 irrigations.

Table 1. Effect of sowing date on plant height, tiller production and panicle length of dry direct seeded boro rice var. BRRI dhan58

Sowing date	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)
10 February 2020	102.53	14.26	11.46a	2.80	21.10
02 March 2020	102.58	14.35	10.90b	3.45	21.23
Level of significance	NS	NS	**	NS	NS
SEM (±)	0.60	0.31	0.08	0.25	0.147
CV%	1.36	6.82	6.27	31.87	1.95

*In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per LSD test ($p < 0.05$); NS = Not significant; ** = Significant at 1% level of probability.*

Table 2. Effect of sowing date on yield contributing characters and yield of dry direct seeded boro rice var. BRRI dhan58

Sowing date	No. of grain panicle^{-1}	No. of unfilled spikelet panicle^{-1}	1000 grain weight(g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
10 February 2020	85.66	49.93	21.29	4.74a	5.11
02 March 2020	84.06	48.77	21.06	4.38b	4.84
Level of significance	NS	NS	NS	**	NS
SEM (±)	0.41	1.41	0.12	0.18	0.07
CV%	3.17	3.33	2.22	6.16	7.28

*In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per LSD test ($p < 0.05$); NS = Not significant; ** = Significant at 1% level of probability.*

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Table 3. Effect of irrigation schedule on plant height, tiller production and panicle length of dry direct seeded boro rice var. BRRI dhan58

Irrigation regime	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)
I_0	102.11	13.56b	10.26b	3.30	20.28c
I_1	102.83	14.17ab	10.83ab	3.33	21.03b
I_2	103.00	15.17a	11.50a	3.66	21.45ab
I_3	103.00	14.50ab	11.67a	2.83	21.50ab
I_4	101.83	14.17ab	11.67a	2.50	21.56a
Level of significance	NS	**	**	NS	**
SEM (±)	0.80	0.56	0.40	0.58	0.24
CV%	1.36	6.82	6.27	31.87	1.95

*In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per LSD test ($p < 0.05$); NS = Not significant; ** = Significant at 1% level of probability; I_0 = No irrigation; I_1 = One irrigation at 25% Field Capacity (FC); I_2 = Two irrigations at 25% FC and 1 week after (WA) 25%FC; I_3 = Three irrigations at 25% FC, 1 WA 25% FC and 2 WA 25% FC; I_4 = Four irrigations at 25% FC, 1 WA 25% FC, 2 WA 25% FC and 3WA25% FC*

Table 4. Effect of irrigation schedule on yield contributing characters and yield of dry direct seeded boro rice var. BRRI dhan58

Irrigation regime	No. of grain panicle^{-1}	No. of unfilled spikelet panicle^{-1}	1000 grain weight(g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
I_0	79.33c	48.09c	21.34	3.95b	4.60c
I_1	81.00c	48.33bc	21.20	4.21b	4.70bc
I_2	85.67b	49.33abc	21.40	4.77a	5.16a
I_3	88.16ab	50.33ab	20.94	4.87a	5.09ab
I_4	90.16a	50.67a	20.99	4.99a	5.35a
Level of significance	**	**	NS	**	**
SEM (±)	1.56	0.95	0.27	0.16	0.21
CV%	3.17	3.33	2.22	6.16	7.28

*In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per LSD test ($p < 0.05$); NS = Not significant; ** = Significant at 1% level of probability; I_0 = No irrigation; I_1 = One irrigation at 25% Field Capacity (FC); I_2 = Two irrigations at 25% FC and 1 week after (WA) 25%FC; I_3 = Three irrigations at 25% FC, 1 WA 25% FC and 2 WA 25% FC; I_4 = Four irrigations at 25% FC, 1 WA 25% FC, 2 WA 25% FC and 3WA25% FC*

Table 5. Effect of interaction between sowing date and irrigation schedule on plant height, tiller production and panicle length of of dry direct seeded boro rice var. BRRI dhan58

Sowing date x Irrigation regime	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)
$SD_1 \times I_0$	101.6	13.6b	10.66bcd	3.00ab	20.23
$SD_1 \times I_1$	103	14.3ab	11.33abc	3.00ab	21.03
$SD_1 \times I_2$	103.6	14.6ab	11.66ab	3.00ab	21.26
$SD_1 \times I_3$	103	14.3ab	11.67ab	2.66ab	21.46
$SD_1 \times I_4$	101.3	15.6a	12.00a	2.33b	21.50
$SD_2 \times I_0$	102.5	13.4b	9.85d	3.60ab	20.34
$SD_2 \times I_1$	102.6	14.00ab	10.33cd	3.66ab	21.03
$SD_2 \times I_2$	102.3	14.3ab	11.33abc	4.33a	21.63
$SD_2 \times I_3$	103	14.6ab	11.66ab	3.00ab	21.53
$SD_2 \times I_4$	102.3	14.0ab	11.33abc	2.66ab	21.63
Level of significance	NS	**	**	**	NS
SEM (±)	1.14	0.80	0.57	0.81	0.34
CV%	1.59	5.90	1.99	21.89	1.89

*In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per LSD test ($p < 0.05$); NS = Not significant ; ** = Significant at 1% level of probability; D_1 = 10 February D_2 = 02 March;; I_0 = No irrigation; I_1 = One irrigation at 25% Field Capacity*

(FC); I_2 = Two irrigations at 25% FC and 1 week after (WA) 25%FC; I_3 = Three irrigations at 25% FC, 1 WA 25% FC and 2 WA 25% FC; I_4 = Four irrigations at 25% FC, 1 WA 25% FC, 2 WA 25% FC and 3WA25% FC

Table 6. Effect of interaction between sowing date and irrigation schedule on yield contributing characters and yield of dry direct seeded boro rice var. BRRI dhan58

Sowing date x Irrigation regime	No. of grain panicle^{-1}	No. of unfilled Spikelet panicle^{-1}	1000 grain weight(g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
$SD_1 \times I_0$	82.67cde	51.67	21.45ab	4.29df	4.74bc
$SD_1 \times I_1$	81.67de	48.33	21.16ab	4.44cd	4.93bc
$SD_1 \times I_2$	85.00bcd	47.00	21.67a	4.87ab	5.07abc
$SD_1 \times I_3$	89.00a	51.33	21.14ab	4.97ab	5.20ab
$SD_1 \times I_4$	90.00a	51.33	21.05ab	5.14a	5.64a
$SD_2 \times I_0$	75.99f	44.52	21.24ab	3.60f	4.47c
$SD_2 \times I_1$	80.33ef	48.33	21.23ab	3.99ef	4.7c
$SD_2 \times I_2$	86.33abc	51.67	21.14ab	4.68bcd	5.25ab
$SD_2 \times I_3$	87.33ab	49.33	20.74b	4.78abc	4.98bc
$SD_2 \times I_4$	90.33a	50.00	20.93ab	4.84abc	5.06abc
Level of significance	**	NS	**	**	**
SEM (±)	2.20	1.34	0.38	0.23	0.30
CV%	1.31	7.77	0.84	1.00	4.09

*In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per LSD test ($p < 0.05$); NS = Not significant ; ** = Significant at 1% level of probability; D_1 = 10 February D_2 = 02 March;; I_0 = No irrigation; I_1 = One irrigation at 25% Field Capacity (FC); I_2 = Two irrigations at 25% FC and 1 week after (WA) 25%FC; I_3 = Three irrigations at 25% FC, 1 WA 25% FC and 2 WA 25% FC; I_4 = Four irrigations at 25% FC, 1 WA 25% FC, 2 WA 25% FC and 3WA25% FC*

Table 7. Economic performance of dry direct seeded boro rice var. BRRI dhan58 in response to sowing dates and irrigation schedule

Treatment combination	Input cost (Tk ha^{-1})	Cost of Irrigation (Tk ha^{-1})	Total Input cost (Tk ha^{-1})	Gross Return (Tk ha^{-1})	Gross Margin (Tk ha^{-1})	Benefit Cost Ratio (BCR)
$SD_1 \times I_0$	79,425	0	79425	152400	72975	1.92
$SD_1 \times I_1$	79,425	1500	80925	157850	76925	1.95
$SD_1 \times I_2$	79,425	3000	82425	171450	89025	2.08
$SD_1 \times I_3$	79,425	4500	83925	175100	91175	2.09
$SD_1 \times I_4$	79,425	6000	85425	170500	85075	2.00
$SD_2 \times I_0$	79425	0	79425	130350	51425	1.64
$SD_2 \times I_1$	79425	1500	80925	143200	62275	1.77
$SD_2 \times I_2$	79425	3000	82425	166650	84225	2.02
$SD_2 \times I_3$	79425	4500	83925	168300	84375	2.01
$SD_2 \times I_4$	79425	6000	85425	170450	85025	2.00

*Total cost includes all variable cost and fixed cost (ploughing and land preparation = 8400 Tk, Fertilizer application = 800 Tk, Seed sowing = (40*400=16000 Tk), Per irrigation = 1500 Tk, Weeding = 16000 Tk, Harvesting = 12000 Tk, post-harvest operation = 4000 Tk, Seed = 3000 Tk @5000 Tk t^{-1}), SD_1 = 10 February, SD_2 = 02 March;; I_0 = No irrigation; I_1 = One irrigation at 25% Field Capacity (FC); I_2 = Two irrigations at 25% FC and 1 week after (WA) 25%FC; I_3 = Three irrigations at 25% FC, 1 WA 25% FC and 2 WA 25% FC; I_4 = Four irrigations at 25% FC, 1 WA 25% FC, 2 WA 25% FC and 3WA25% FC.*

Discussion

Dry direct seeding (DDS) system has been established as a viable alternative to the PTR system. It saves 50-60% irrigation water by avoiding puddling, seed bed preparation, and maintaining aerobic soil conditions from sowing to PI stage compared to PTR system of rice cultivation (Rahman, 2019). In general, *boro* rice is transplanted during mid-December to mid-January while the optimum dates for sowing under DDS system is between mid -January to mid-February (Uddin, 2019). However, the planting of *boro* rice may be delayed due to late harvesting of *rabi* crops cultivated in T. *aman* rice – *Rabi* crop – DDS *boro* rice pattern. The present study discovered that the yield of *boro* rice cv. BRRI dhan58 decreased significantly for sowing on 3 March compared to 10 February. However, the reduction was only 7.5% but such a small reduction can be tolerated as the *rabi* crop can give higher return (Rahman, 2021). Short duration *rabi* crops are grown in the T. *aman* rice – *Rabi* crop – T. *boro* rice pattern. The present study exposed that planting of *boro* rice can be late up to first week of March without remarkable yield penalty (Rahman, 2021).

During the vegetative phase, irrigation was delayed up to 25% FC and this point was considered as 25% of management allowable depletion (MAD) of soil water. During the vegetative phase, 4 - 6 irrigations are usually required for dry direct seeded rice in *boro* season depending on the soil and environment (Rahman, 2019). The present study showed that the crop sown on 10 February and applied with 4 irrigations ($SD_1 \times I_4$) produced the highest grain yield (5.14 t h^{-1}). It was also observed that in case of 10 February crops receiving two and three irrigations and for 02 March sowing the crop receiving three and four irrigations gave statistically similar yields to that of the crop sown on 10 February with four irrigations. Thus, the present study exhibited that the crop required at least three irrigations to obtain a satisfactory yield from dry direct seeded *boro* rice sown during 10 February and 02 March. The yield improvement was attributed to the increased number of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$ and grain weight due to application of two or more irrigations.

Economic analysis revealed that the crop sown on10 February sowing and applied with three irrigations exhibited the highest gross return, gross margin and benefit cost ratio. These values were very close to those obtained from the crop sown on 10 February and applied with two irrigations. The next highest gross return and gross margin values were found with the crop sown on the same date and grown with four irrigations. In case of the crop sown on 02 March, the highest gross return was obtained from four irrigations but the BCR was similar for the crops receiving 2, 3 and 4 irrigations. Therefore, on the basis of the economic analysis, it can be concluded that 2 - 3 irrigations could be considered for obtaining the highest return from rice cultivation in *boro* season by sowing the crop during 10 February to 02 March.

Conclusion

The result of the present study discovered that the crop sown on 10 February produced higher grain yield than that sown on 02 March. The plots receiving 2 to 4 irrigations produced the higher yield than those received no and one irrigation. The interaction between sowing date and irrigation regime exposed that the plots sown on 10 February with 4 irrigations gave highest yield and economic return although the crop receiving 2 and 3 irrigations gave similar results. The crop sown on 02 March and applied with 3 to 4 irrigations gave similar yield and economic return. Thus, it can be concluded that the rice variety BRRI dhan58 can be grown by sowing the seed during 10 February to 02 March and using 2 - 3 irrigations during the vegetative phase to produce a reasonable yield and maximum economic return under dry direct seeding system.

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Conflict of Interest

None of the authors present any conflict of interest.

References

Cabangon, R. J., Tuong, T. P. & Abdullah, N. B. (2002). Comparing Water Input and Water Productivity of Transplanted and Direct-Seeded Rice Production Systems. *Agriculture Water Management*, 57**,** 11-31.

FRG. (2012). Fertilizer Recommendation Guide (FRG), Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka 1215. 274p

Nasim, M., Shahidullah, S. M., Saha, A., Muttaleb, M. A., Aditya, T. L., Ali, M. A., Kabir, M. S., (2018). Distribution of crops and cropping patterns in Bangladesh. *Bangladesh Rice Journal*, 21, 1–55. doi: 10.3329/brj.v21i2.38195.

Pandey, S., & Velasco, L. (1999). Economics of direct seeding in Asia: Patterns of adoption and research priorities, International Rice Research Institute, Los Banos, Philippines, 24, 6-11.

Rahman, M. M., & Masood, M. M. (2014). Sustaining productivity in *boro* (winter) season using minimal water through dry direct seeding of rice.*Journal of Crop and Weed Science*. 10, 24-30.

Rahman, M. M. (2019). Potential benefits of dry direct seeded rice culture: A review. *Fundamental and Applied Agriculture*, 4(2), 744-758.

Rahman, M. M. (2021). Agro-economic productivity of rice - rabi crop - rice systems in northwestern drought-prone areas of Bangladesh. *SAARC Journal of Agriculture*, 19(2), 85-94. DOI: *https:*//doi.org/10.3329/sja.v19i2.57673.

Uddin, J. (2019). Development of Transplant aman rice – Mustard – Dry direct seeded boro rice cropping pattern. An unpublished Ph. D. Dissertation, Department of Agronomy, Bangladesh Agricultural Unviersity, Mymensingh, Bangladesh. 233p.