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Response of Boro rice under different irrigation practices

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Abstract

A field experiment was conducted at Bangladesh Agricultural University Farm, Mymensingh, during the Boro season 2006 to evaluate the response of transplanted Boro rice (BRRIdhan29) under different irrigation practices. Five irrigation treatments viz. 5 cm standing water was maintained throughout the growing season (T_1), 5 cm standing water was applied as soon as water disappeared from the field i.e. saturation was reached (T_2), 5 cm standing water was applied 3 days after disappearing of standing water (T_3), 5 cm standing water was applied 5 days after disappearing of standing water (T_4) and 5 cm standing water was applied 7 days after disappearing of standing water (T_5) were used. Each treatment was replicated thrice. Triple super phosphate (TSP) and muriate of potash (MP) fertilizers were applied before transplanting at the rate of 77 kg/ha and 59 kg/ha, respectively and urea fertilizer was applied thrice, namely, before transplanting, 20 days after transplanting (DAT) and 35 DAT equally in all treatment plots at the rate of 304 kg/ha. BRRIdhan29 was transplanted on 3 February and harvested on 27 May 2006. Irrigation treatments showed significant effects on the yield and yield contributing characters of Boro rice (BRRIdhan29). The results showed that the highest grain yield of 9.56 t/ha was obtained in treatment T_2 followed by T_1 (9.51 t/ha) and T_5 gave the lowest grain yield of 7.06 t/ha. It was also found that the reduction in grain yield in T_3 was 1.79% in comparison to treatment T_1, whereas, the water productivity was increased by 25% more than that of T_1. The application of irrigation water 3 days after disappearing of standing water (T_3) together with T_4 and T_5 will considerably save the water but reduced the grain yield significantly. Therefore, from the experimental findings, it may be inferred that 5 cm standing water applied 3 days after disappearing of standing water (T_3) produced the satisfactory yield for BRRIdhan29.

Keywords: Boro rice, Irrigation practices, Grain yield, Water use, Water productivity

Introduction

In Bangladesh, rice dominates over all other crops and covers 75% of total cropped area and 92% peasants grow rice (Rekabdar, 2004) and has no more room for horizontal expansion. So, the vertical means is the only way to increase the rice production. Vertical expansion includes the use of modern production technologies, such as use of quality seeds, high yielding varieties, seedling raising technique, optimum age of seedlings, optimum time of transplanting, adopting plant protection measures, water management practices and so on. Rice is the major consumer of irrigation water in Bangladesh.

The conventional method of rice cultivation practice requires continuous ponded water in the field, which is possible where irrigation water is abundant and cheap. However, rice can be grown under alternate wet and dry conditions without sacrificing yields and adoption of such a practice may allow savings of costly water. Since shallow standing water to saturation and irrigation after 3 days of disappearing standing water also give same level of yield, so the water saving techniques like shallow application of water and irrigation after 3 days of disappearing standing water, if adopted properly will lead to efficient utilization of water through minimizing excessive losses of seepage and percolation and maximize the yield (Rashid and Khan, 2001). Currently in Bangladesh, about 26.74 million tons of rice per annum were produced from10.83 million hectares of land of which Boro rice contributes about 36.43% of total rice production (BBS, 2004).

BRRIdhan29 is a well established inbred modern variety grown in Boro season and is the most acceptable and popular rice to the farmers due to its quality and highest yield performance (BRRI, 1995). The basic feature of water saving irrigation is that no water should be present above the soil surface for the desired period (days) during the growing season of rice. Water saving irrigation technique not only saves water and increases the rice yields but also reduces soil and water pollution, improves soil aeration, improves field's microclimatic condition, reduces rice diseases and insect pests, and improves the regional water balance (Alam and Mondal, 2003). The experiment reported, herein, is designed to develop feasible techniques for studying tolerable water stresses in the Boro rice field with a view to making efficient utilization of irrigation water and maximizing the yield for rice cultivation by reducing excessive loss through water saving.

Materials and Methods

The experiment was conducted at Bangladesh Agricultural University Farm, Mymensingh during the Boro season of 2006. The study area includes mainly the Old Brahmputra Floodplain soil. The experimental soil was silty loam. The colour of the soil seemed to be grey, whereas, P^H, bulk density, field capacity and wilting point of the soil were 5.48 to 6.36, 1.40 gm/cm^3, 27.63% and 14.06%, respectively. The seasonal precipitation was 56.18 cm and the average daily air temperature of the experimental area was 25.85^{0}C.

The experimental field was prepared by using tractor drawn plough, puddler and ladder (wooden plank or leveler). The experiment was laid out in a randomized complete block design (RCBD) with three replications. Each plot was provided with a calibrated scale to measure the water level depth each day. The size of unit plot was 4 m × 3m. Around each unit plot having levee of 25 cm width and 20 cm height was constructed. Each plot was separated by 1 m buffer zone between the rows and 1.5 m wide buffer zone between the plots along rows to prevent seepage between the adjoining plots.

Triple super phosphate and muriate of potash fertilizers were applied at the final preparation of land at the rate of 77 kg/ha and 59 kg/ha, respectively and urea fertilizer was applied thrice, namely, at the final land preparation, 20 days after transplanting (DAT) and 35 DAT equally in all plots at the rate of 304 kg/ha. The study consisted of the following treatments- 5 cm standing water was maintained throughout the growing season (T_1), 5 cm standing water was applied as soon as water disappeared from the field (T_2) i.e. saturation was reached, 5 cm standing water was applied 3 days after disappearing of standing water (T_3), 5 cm standing water was applied 5 days after disappearing of standing water (T_4) and 5 cm standing water was applied 7 days after disappearing of standing water (T_5).

BRRIdhan29 variety selected for the study was an inbred modern variety, developed by the Bangladesh Rice Research Institute in 1995. On an average the growth duration of BRRIdhan29 is about 168 days (BRRI, 1995). The seedlings of the variety were collected from the BAU farm on 2 February, 2006. The seedlings were 10 to 17 cm in height and they were 40 days of age.

Transplanting was done on 3 February using 25 cm × 15 cm spacing with 2 seedlings/hill.

Amount of water needed for land preparation varies with soil type, degree of prior drying out and cracks of the soil profile, and the time taken for the clay fraction to swell. For this study, the amount was assumed to be 240 mm for each treatment. Seepage and percolation losses were computed by applying water balance technique. These losses were determined using the formula:

$$S\ \&\ P = WD_{t-1} - WD - ET \qquad (1)$$

and $$ET = b + a\,(EVt) \qquad (2)$$

where, S & P = Seepage and percolation loss (cm/day), "t" refers to the day of measurement, WD= Water depth measured in cm, on the meter stick, ET= Daily rate (cm) of evapotranspiration, EV= Daily rate (cm) of evaporation, a= Pan factor, and b = An empirical constant = 0.5

In this study seepage and percolation rate was considered to be 2 mm/day for 100 days and thus accounts the total seasonal loss of 20 cm.

The simple equation used to estimate the water requirements for growing a rice crop is given by Walker (1994) as-

$$Q = W+R+C+E+F \qquad (3)$$

where, Q = Total water requirements (cm), W = Wetting up and land preparation (cm), R= Surface runoff (cm), C= Conveyance loss (cm), E = Evapotranspiration from water and plants (cm), and F= Seepage and percolation (cm)

This version of the equation assumes for simplicity that there is no net subsurface inflow or outflow, and disregards any effects due to the underlying water table.

The water used by the crop is generally described in terms of water productivity, which is the ratio of crop yield to the total amount of water used by the crop (Michael, 1978). Thus, it was calculated as $WUE = \frac{Y}{WR}$ .... (4)

where, WUE = Total water use efficiency (water productivity) (ton/ha/cm), Y= Crop yield (ton/ha), and WR= Total amount of water used by the crop (cm).

The matured rice pants were harvested on 27 May 2006. From each plot, 10 sample hills were selected randomly and harvested separately. The rest of the plots were harvested, threshed and weighed in line with 10 sample hills. From each 15 samples, an average weight of 20 to 25 grams of rice grain was taken in the pre-weighted empty basin and weighted again with the samples. The basin with grains was kept in the oven for 24 hours at 105^0C and weighed again. Moisture content was then calculated.

The threshed grains were well dried to bring the grain moisture content at 14% (wet basis) and then weight was taken. Similarly, straw yield was calculated by taking the weight of straw after making dried enough as the usual practice of the farmers.

The yield and yield contributing characters namely, plant height (cm), number of effective tillers per hill, length of panicle (cm), no. of spiklets per panicle, no. of grains per panicle, no. of unfilled spikelets per panicle were taken before threshing the grains from the sample plants and 1000-grain weight (gm), grain yield (t/ha), straw yield (t/ha) and harvest index (%) were determined after threshing the grains from the sample plants.

Results and Discussion

The stage, number and amount of irrigation water applied at different stages from irrigation treatments are presented in Table 1. It is evident that irrigation water was applied at five different growth stages of modern variety Boro (BRRIdhan29) rice with different amounts. Total numbers of irrigations given in treatments were 13, 11, 8, 6 and 5, respectively. Water used in crop establishment plus water used from the rainfall and water lost due to drainage were altogether estimated to be 55.14 cm in all the treatments.

Table 1. Stages, number and amount of irrigation water at different growth stages of Boro rice BRRIdhan29

Treatment	Amount of irrigation water (cm) with stage and time (Days)					No. of irrigation	Water required {(Crop establishment) + (R.F.) + (Drainage)}, cm	Total amount of water used by plant (cm)
	Tillering (21 DAT)	Internodes elongation (57 DAT)	Booting (72 DAT)	Flowering (88 DAT)	Grain Filling to Ripening (95 DAT)			
T_1	5	25	15	15	5	13	55.14	120.14
T_2	5	25	10	10	5	11	55.14	110.14
T_3	5	20	5	5	5	8	55.14	95.14
T_4	5	15	0	5	5	6	55.14	85.14
T_5	5	10	5	0	5	5	55.14	80.14

It was found that the maximum irrigation water (120.14 cm) was applied in treatment T_1. The second maximum irrigation water (110.14 cm) was applied in treatment T_2 followed by treatments T_3 (95.14 cm) and T_4 (85.14 cm), respectively. Minimum irrigation water (80.14 cm) was applied in treatment T_5. Similar results were also reported by Rashid and Khan (2001). They found that the irrigation water applied was maximum in continuously standing water condition (T_1) followed by treatments T_2, T_3, T_4 and T_5, respectively.

The mean effects of different irrigation practices on the yield and yield contributing characters of Boro rice Cv. BRRIdhan29 are given in Table 2. The results obtained for yield and yield contributing characters are statistically analyzed.

The results showed that the mean plant height in treatment T_1 produced the tallest (70.48 cm) plant, which was statistically identical with treatment T_2 (68.30 cm), whereas, treatment T_5 produced the shortest (63.05 cm) one. Similarly, the highest number of effective tillers per hill (13.77) was found in treatment T_3 followed by treatment T_2 (13.13) and treatment T_1 (13.00) and treatment T_4 (11.17), respectively but treatment T_5 (10.90) produced the lowest number of effective tillers per hill. The results indicated that length of panicle was significantly affected by irrigation practices. Length of panicle in treatments T_1 and T_2 as well as in T_3, T_4 and T_5 were not significantly different but they were significantly different to each other. Highest length of panicle was found in treatment T_2 (26.15 cm) and the lowest in T_5 (23.45 cm). Numbers of spikelets/panicle were significantly different between the treatments. The highest number of spikelets/panicle was observed in treatment T_3 (179.27) and the lowest in treatment T_2 (171.13), respectively.

Table 2. Mean effect of irrigation treatments on yield and yield contributing characters of BRRIdhan29

Treatment	Plant height (cm)	Number of effective tillers/ hill	Length of panicle (cm)	No. of spikelets/ panicle	No. of grains per panicle	Unfilled spikelets per panicle	1000-grain weight (gm)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
T_1	70.48^a	13.00^a	26.13^a	173.30^b	158.7^a	14.60^c	21.55^a	9.510^a	9.730^a	49.43
T_2	68.30^a	13.13^a	26.15^a	171.13^b	156.0^a	15.13^c	21.46^a	9.560^a	9.770^a	49.46
T_3	64.02^b	13.77^a	24.20^b	179.27^a	153.9^a	25.37^b	21.13^a	9.340^a	9.500^a	49.58
T_4	63.98^b	11.17^b	23.98^b	174.37^b	136.3^b	38.07^a	20.34^b	7.550^b	7.703^b	49.50
T_5	63.05^b	10.90^b	23.45^b	178.07^a	136.0^b	42.07^a	20.46^b	7.060^b	7.220^b	49.44
Level of Significant	**	**	**	**	*	**	**	*	**	NS

Common letter(s) within the same column do not differ significantly at either 1% or 5% level of significance analyzed by DMRT using MSTAT

** Statistically significant at 1% level of probability

* Statistically significant at 5% level of probability

NS = Non-significant

Significant differences in number of grains per panicle were observed between treatments T_1, T_2 and T_3 and T_4 and T_5 treatments, respectively. The highest number of grains per panicle was found in treatment T_1 (158.7) and the lowest in treatment T_5 (136.0). The results showed that the highest number of unfilled spikelets per panicle was observed in treatment T_5 (42.07) followed by treatment T_4 (38.07) with no significant difference between them. However, the lowest number of unfilled spikelets per panicle was obtained in treatment T_1 (14.60) which was insignificant with treatment T_2 (15.13) but varied significantly with treatments T_4 and T_5, respectively. Treatment T_3 (25.37) also produced significant number of unfilled spikelets per panicle compared to the other treatments.

Thousand-grain weight also called the test weight is one of the most important agronomical parameters that contribute in grain yield. The maximum 1000-grain weight (21.55 g) was obtained in treatment T_1 followed by treatments T_2 (21.46 g) and T_3 (21.13 g). But the lowest grain weight (20.34 g) was found in treatment T_4. It was found that treatments T_1, T_2 and T_3 produced statistically insignificant variation in 1000-grain weight among themselves but these treatments were significantly different with treatments T_4 and T_5, which were subjected to longer water stress. Thus, it is clear that water stress reduced 1000-grain weight.

It can be seen that grain yield was significantly influenced by different irrigation practices (Table 2). The results clearly showed that the productivity decreased significantly when the rice field was kept under stressed condition for long period. Treatments T_1, T_2 and T_3 were statistically insignificant among themselves for grain yield at 5% level of probability. Treatment T_2 produced the highest grain yield (9.560 t/ha) followed by T_1 (9.510 t/ha), T_3 (9.340 t/ha), T_4 (7.550 t/ha) and T_5 (7.060), respectively. The lowest grain yield (7.060 t/ha) was obtained in treatment T_5 (having the water stress for longer duration). The present findings are in conformity with Alam and Mondal (2003). They observed that application of irrigation water 3 days after disappearing of stranding water produced optimum yield of rice. The percent reduction in grain yield over the treatments producing maximum and minimum yield varied from (0.52 to 21.03 %). The decrease in grain yield under treatment T_5 was 21.03 % from the maximum. This helped to conclude that the lowest yield in treatment T_5 was due to the fact that this treatment was subjected to severe water stress, which resulted to produce the lowest number of effective tillers, shorter length of panicle and less number of grains per panicle which finally produced less yield per unit area. Straw yield also followed similar trend as observed in grain yield. The highest straw yield (9.770 t/ha) was found in treatment T_1 and the lowest (7.220 t/ha) in treatment T_5.

Table 2 also shows the effect of irrigation practices on harvest index. The harvest index was the highest in treatment T_3 (49.58 %) followed by T_4 (49.50%), T_2 (49.46%) and T_5 (49.44%) and the minimum in treatment T_1 (49.43%).

Water use and water productivity under different irrigation treatments are shown in Table 3. It was found that in treatment T_1 irrigation was applied each day to maintain the water level of 5 cm which required the maximum number of irrigations and is equivalent to the application of 5 cm of water 13 times, thus standing to a total amount of 65 cm as irrigation water.

Table 3. Water use and water productivity under different irrigation treatments

Treat-ment	No of irrigation	Irrigation frequency (DAS)	Water used for crop establishment (cm)	Irrigation water applied (cm)	Rainfall (cm)	Drainage* (cm)	Total water use (cm)	Grain yield (t/ha)	Water productivity (t ha^{-1}cm^{-1})
T_1	Continuous flooding with 5 cm	Almost every day	5	65	30.14	20	120.14	9.51	0.079
T_2	11	19, 25, 31, 37, 44, 50, 57, 71, 81, 88, 95	5	55	30.14	20	110.14	9.56	0.087
T_3	8	19, 27, 35, 44, 53, 66, 77, 91	5	40	30.14	20	95.14	9.34	0.098
T_4	6	19, 30, 41, 57, 73, 94	5	30	30.14	20	85.14	7.55	0.089
T_5	5	19, 35, 52, 68, 95	5	25	30.14	20	80.14	7.06	0.088

*Standard value for drainage (seepage & percolation) as 2 mm/day was considered for 100 days

On the contrary, 5 cm of standing water was applied for each irrigation and then next irrigation was applied after disappearing of standing water from the field for 1 day, 3 days, 5 days and 7 days in treatments T_2, T_3, T_4 and T_5, respectively. In this way, numbers of irrigation water applied in these treatments were 11, 8, 6 and 5 times, respectively. It can be seen that the total water use was maximum for treatment T_1 (120.14 cm) followed by treatments T_2 (110.14 cm), T_3 (95.14 cm), T_4 (85.14 cm) and minimum in treatment T_5 (80.14 cm). Hence, it was observed that total water use increased with the increase of irrigation frequency. Alternately, irrigation frequency decreased with the increase of the water stress imposed to different treatments. Similarly, water productivity was the highest (0.098 t/ha/cm) in treatment T_3 followed by treatments T_4 (0.089 t/ha/cm), T_5 (0.088 t/ha/cm) and T_2 (0.087 t/ha/cm), respectively and was found to be minimum (0.079 t/ha/cm) in treatment T_1. From these results, it can be seen that the water productivity decreased with the increase of irrigation water. These results are in agreement with the findings of Rashid and Khan (2001).

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