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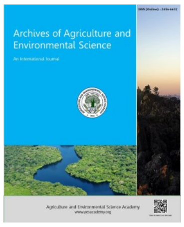

ORIGINAL RESEARCH ARTICLE

CrossMark

Effect of water and weed management in *Boro* rice (cv. BRRI dhan28) in Bangladesh

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ABSTRACT

The experiment was conducted at the Farm of Farm Management Division, Bangladesh Agricultural University, Mymensingh during December 2012 to June 2013 to find out the effect of water and weed management in *Boro* rice (cv. BRRI dhan28). The experiment consisted of three irrigation systems *viz.,* conventional flood irrigation, Alternate wetting and drying (AWD) and System of rice intensification (SRI) and four weed management practices *viz.,* No weeding, hand weeding thrice at 20, 35 and 50 days after sowing, blade weeding + hand weeding once at 20 DAS; and pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS. Crop characters, yield components and yield were significantly influenced by water and weed managements, and their interaction. The highest plant height (91.51 cm), total tillers hill^{-1} (15.49), grains panicle^{-1} (86.87) and grain yield (4.02 t ha^{-1}) were obtained in SRI method and corresponding lowest values were found in conventional flood irrigation while all parameters showed intermediate values in AWD. The highest plant height (93.45 cm), total tillers hill^{-1} (16.53), effective tillers hill^{-1} (12.88), grains panicle^{-1} (86.14), grain yield (5.47 t ha^{-1}) and straw yield were found in pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + one hand weeding at 20 DAS while all the parameters showed lowest values in weedy check. Weed infestation reduced 80.07% yield compared to application of pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + one hand weeding at 20 DAS. In case of interaction, the highest total tillers hill^{-1} (20.93), grains panicle^{-1} (102.3) and grain yield (5.86 t ha^{-1}) were found in SRI method with pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + one hand weeding at 20 DAT while the lowest total tillers hill^{-1} (10.97), grains panicle^{-1} (61.46) and grain yield (0.91 t ha^{-1}) were found in conventional flood irrigation having no weeding treatment. The above results concludes that SRI method with pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + one hand weeding at 20 DAS appeared as the promising technique for appreciable grain yield of *Boro* rice (cv. BRRI dhan28).

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INTRODUCTION

Food security is a burning issue of the world at present. Increased rice production can play a vital role to address this issue successfully. Rice (*Oryza sativa* L.) is the most important food crop and a primary food source for more than one -third of world's population (Singh and Singh, 2008; Sarkar *et al.,* 2017). It is consumed as the staple food in Bangladesh and has been given the highest priority in meeting the demands of its ever-increasing population. Rice contributes 95% of total food production in Bangladesh. About 77.07% of cropped area of Bangladesh is used for rice production, with annual production of 33.83 million tons from 11.41 million hectares of land which contributes about 19.60% of the country's GDP (BBS, 2013). Asia contributes more than 90% of the world's total rice production while using more than 90% of the total irrigation water (Khepar *et al*., 2011; Jahan *et al.,* 2017). It is estimated that by 2025, 15 million of Asia's 130 million hectares of irrigated rice area may experience physical water scarcity and approximately 22 million hectares of irrigated dry-season rice may suffer economic water scarcity (Tuong and Bouman, 2007). To fulfill the increased rice demand with shrinking resources, it will be necessary to increase yield in a unit area with less water. Water is a looming crisis due to competition among agricultural, industrial, environmental and domestic users. A growing scarcity of fresh water will pose problems for rice production in future years. The successful transition from traditional lowland cultivation to aerobic rice production should be invariably under conditions of effective water management, to keep the soil ''wet'' but not flooded or saturated. In practice, irrigation has to be applied to bring the soil water content up to field capacity once a lower threshold has been reached and hence for aerobic rice, the optimum threshold for re-irrigation still needs to be determined. Weeds are the greatest threat under upland or aerobic rice systems, resulting in yield losses between 30 and 98 percent (Ramana *et al.,* 2014). Weeds are the cause of serious yield reduction problems in rice production worldwide (Islam *et al.,* 2015). Losses caused by weeds vary from one country to another, depending on the predominant weed flora and on the control methods practiced by farmers. It is reported that in China, 10 million tonnes of rice are lost annually due to weed competition (Belder *et al.*, 2005); such a quantity of rice is sufficient to feed at least 56 million people for 1 year. In Sri Lanka, a country considered self-sufficient in rice, weeds are the major biotic stress in rice production and account for 30-40% of yield losses (Gowda *et al*., 2009). In Bangladesh, weed infestation reduces the grain yield by 70-80% in *Aus* rice, 30-40% for transplanted *Aman* rice and 22-36% for modern *Boro* rice cultivars (Mamun, 1990). The traditional method of weed control is hand weeding which is very much laborious and time consuming. The practice, however, is becoming less common due to labor scarcity. Mechanical weeding and herbicides are the alternative to hand weeding. Herbicides are effective in controlling weeds alone or in combination with hand weeding (Ahmed *et al.,* 2005). In recent years, chemical weed control has increased in Bangladesh (Ahmed *et al*., 2014). Herbicides in combination with hand weeding would help to obtain higher crop yield with less efforts and cost (Sathyamoorthy *et al.,* 2004; Parvez *et al*., 2013). Therefore, the present study was undertaken to find out the effect of weed and water management on yield of *Boro* rice (cv. BRRI dhan28), Bangladesh.

MATERIALS AND METHODS

The experiment was conducted at the Farm of Farm Management Division, Bangladesh Agricultural University, Mymensingh during December 2012 to June 2013 to find out the effect of water and weed management in *Boro* rice (cv. BRRI dhan28). The experimental plot is geographically situated at $24^0$75'N latitude and $90^0$50'E longitude at an altitude of 18 m above the mean sea level. The treatments consisted of three water management *viz.,* Conventional flood irrigation (I_1), AWD (Alternate wetting and drying (I_2), SRI (System of rice intensification) (I_3) and four weed management practices *viz.,* No weeding (W_0), hand weeding thrice at 20, 35 and 50 days after sowing (W_1), blade weeding + hand weeding once at 20 DAS (W_2) and pre-emergence herbicide (Panida 33 EC) @ 2.5 l h^{-1} + hand weeding once at 20 DAS. The experiment was laid out in randomized complete block design with three replications. The size of unit plot was 4.0 m × 2.5 m. The distances between blocks and plots were 1 m and 75 cm, respectively. Sprouted seeds of BRRI dhan28 were sown on puddled field having no standing water on 15 February 2013 with four seeds $hill^{-1}$ at 25 cm × 15 cm spacing. In case of SRI method, 12-day old seedlings were transplanted at 25 cm × 25 cm spacing on 27 February 2013 with one seedling $hill^{-1}$. The land was fertilized with 120-60-40-10-1.5 kg ha^{-1}N-P_2O_5-K_2O -S-Zn, through prilled urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate, respectively. Thinning and gap filling were done at 10 DAS to maintain the uniform plant stand in all the plots. Five hills (excluding border rows) from each plot were randomly selected, uprooted and properly tagged prior to harvest for recording data on crop characters and yield components. The harvested crop of central 2.5 m × 2.0 m harvest area was bundled plot-wise separately, tagged properly and brought to the clean threshing floor. The bundles were sun dried, threshed and then grains were cleaned and weighed. The grain yield was adjusted to 14% moisture content. Straws were also sun dried properly. Grain and straw yields were then converted to t ha^{-1}. The data recorded on various growth and yield were analyzed following analysis of variance (ANOVA) and mean differences were adjusted by Duncan's Multiple Range Test (Gomez and Gomez, 1984) using a statistical computer package program MSTAT-C (Michigan State University, USA).

RESULTS AND DISCUSSION

Crop characters and yield components: The highest plant height (91.51cm), total tillers $hill^{-1}$(15.49), panicle length (22.92 cm) and grains $panicle^{-1}$ (86.87) were recorded in SRI method of water management. The lowest plant height (86.96cm), total tillers $hill^{-1}$(13.75), panicle length (20.33 cm) and total number of grains $panicle^{-1}$ (73.25) were obtained from conventional flood irrigation system (Table 1). The highest effective tillers $hill^{-1}$ (11.58) was observed at conventional flood irrigation and the lowest one (10.77) in AWD. Irrigation system also significantly influenced sterile spikelets $panicle^{-1}$ where the highest value (12.69) was recorded in conventional flood irrigation which was at par with AWD (12.15) and the lowest one (11.44) was recorded in SRI system (Table 1). Zhao *et al*. (2009) found that water use efficiency (WUE) was found to be increased by 100% with SRI methods as single seedling was planted $hill^{-1}$ which consumes less water.

Within different weed management practices pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS produced the highest plant height (93.45 cm), total tillers $hill^{-1}$(16.53), effective tillers $hill^{-1}$(12.88), panicle length (24.56 cm), grains $panicle^{-1}$ (86.14) and 1000-grain weight (24.24 g) (Table 2) which were, however, in parity with blade weeding + hand weeding once at 20 DAS (W_2). Hand weeding thrice at 20, 35 and 50 days after sowing was comparable with blade weeding + hand weeding once at 20 DAS in respect of grain yield. The lowest values of these parameters were recorded with no weeding. Sarkar *et al*. (2016) reported that yield contributing characters showed higher values in pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS. This may be attributed to the effective weed management at critical stages of the crop weed competition. Similar results have been reported by Sharma (2014).

The number of total tillers, panicle length, number of grains $panicle^{-1}$, and 1000-grain weight were significantly influenced by the interaction between water and weed management practices. The highest number of total tillers $hill^{-1}$(20.93), panicle length (32.92 cm), number of grains $panicle^{-1}$(102.3) and 1000 -grain weight (24.20 g) were recorded at the combined effect of SRI with pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS whereas the corresponding lowest values were observed in the interaction between conventional flood irrigation with no weeding (Table 3).

Grain yield: A remarkable change of grain yield was observed due to irrigation and weed management treatment individually and their interaction. SRI system produced the highest grain yield (4.02 t ha^{-1}) followed by AWD (3.89 t ha^{-1}) whereas the lowest grain yield (3.85 t ha^{-1}) was obtained at conventional flood irrigation. However, grain yield of AWD and conventional flood irrigation was similar (Table 1). Grain yield of rice increased significantly with increase in irrigation schedule at SRI system. The impact of SRI management on grain yield enhancement was reported elsewhere (Kassam *et al.,* 2011; Jadhav *et al.,* 2013; Pascual and Wang, 2016). The improvement of yield in SRI was due to better availability of moisture, which in turn leads to efficient physiological activity. High level of dry matter production and efficient translocation of photosynthates from source to sink might be responsible for the production of increased level of yield structure. Rice plants when grown under saturated condition develop more plant stature, leaf area, root volume and productive tillers, resulting in higher yield.

Within different weed management practices tested, the maxi-

Table 1. Effect of water management on the crop characters, yield components and yield of *Boro* rice.

Water management	Plant height (cm)	Number of total tillers hill^{-1}	Number of effective tillers hill^{-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 (%)
I_1	86.96b	13.75c	11.58a	20.33c	73.25c	12.69a	22.28	3.85b	5.61a	40.69bc
I_2	89.17ab	14.69b	10.77c	20.74b	73.93b	12.15b	22.24	3.89b	5.45b	41.64b
I_3	91.51a	15.49a	10.94b	22.92a	86.87a	11.44c	22.30	4.02a	5.40b	42.67a
S$\bar{x}$	3.15	2.5	2.14	3.95	4.325	1.098	0.28	0.20	0.43	0.56
LSD	9.05	6.25	5.08	9.43	16.66	2.62	0.68	0.75	1.66	1.76
Level of significance	**	*	*	*	*	**	NS	**	**	**
CV (%)	6.13	16.16	19.58	22.01	9.60	15.73	2.04	10.35	13.18	14.22

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant; I_1: Conventional flood irrigation, I_2: AWD (Alternate wetting and drying, I_3: SRI (System of rice intensification).

Table 2. Effect of weed management on the crop characters, yield components and yield of *Boro* rice.

Weed management	Plant height (cm)	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}	Panicle length (cm)	Number of grains panicle^{-1}	Number of sterile spikelets panicle^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Grain yield loss (%)	Straw yield (t ha^{-1})	Harvest index (%)
W_0	86.00d	12.89d	10.18c	18.68d	64.64d	11.80	19.83d	1.09c	80.07	2.93d	27.11c
W_1	86.55c	16.21b	11.40b	18.75c	76.16c	11.96	22.01c	4.74b	13.34	6.28ab	43.0b
W_2	90.66b	12.96c	9.94d	23.49b	85.13b	11.98	22.87b	4.58b	16.27	6.03c	43.16ab
W_3	93.45a	16.53a	12.88a	24.56a	86.14a	12.62	24.24a	5.47a	0.00	6.73a	44.83a
S$\bar{x}$	4.39	1.367	1.25	0.95	4.32	1.098	0.26	0.2345	-	0.41	0.51
LSD	12.46	5.264	2.99	2.55	16.66	2.62	1.01	0.9034	-	1.61	1.34
Level of significance	*	*	*	*	**	NS	**	**	-	**	**
CV (%)	6.13	16.16	19.58	22.01	9.60	15.73	2.04	10.35	-	13.18	14.22

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant; W_0: No weeding, W_1: Hand weeding thrice at 20, 35 and 50 DAS, W_2: Blade weeding + hand weeding once at 20 DAS and W_3: pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + one hand weeding at 20 DAS.

Table 3. Effect of interaction between water and weed management on the crop characters, yield components and yield of *Boro* rice.

Interaction (Irrigation × Weed management)	Plant height (cm)	Number of total tillers hill^{-1}	Number of effective tillers hill^{-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 (%)
$I_1 \times W_0$	84.42	10.97d	9.16	17.91b	61.46g	10.08	19.76f	0.91g	3.37	21.26f
$I_1 \times W_1$	84.75	18.97ab	11.13	19.70b	75.18cdef	12.72	22.62 cd	4.41def	5.91	42.73cd
$I_1 \times W_2$	88.14	12.22cd	9.10	21.18b	77.29cde	12.93	22.44cde	4.55de	6.08	42.80c
$I_1 \times W_3$	90.53	13.57bcd	10.73	20.42b	79.09cde	15.03	24.01ab	5.27bc	6.35	45.35ab
$I_2 \times W_0$	85.11	12.93cd	11.27	18.54b	64.06fg	12.43	19.84f	1.20f	3.19	27.33ef
$I_2 \times W_1$	86.93	14.07bcd	11.10	18.49b	70.82defg	10.94	21.88e	4.78d	6.89	40.95cde
$I_2 \times W_2$	95.54	12.00cd	8.40	24.39ab	75.83cde	11.19	22.75c	4.29e	5.53	43.60bc
$I_2 \times W_3$	89.10	17.07abc	12.33	20.37b	85.0bc	11.19	24.52a	5.30b	6.83	43.69b
$I_3 \times W_0$	90.14	13.73bcd	10.10	19.61b	68.40efg	12.89	19.90 f	1.18fg	2.23	34.60
$I_3 \times W_1$	86.87	13.63bcd	10.20	18.06b	82.49cd	12.22	22.04 de	5.03c	6.04	45.43ab
$I_3 \times W_2$	92.34	15.63abcd	12.33	24.90ab	94.33ab	11.82	23.40b	4.31defg	6.49	39.90de
$I_3 \times W_3$	96.69	20.93a	17.33	32.92a	102.3a	11.63	24.20a	5.86a	7.03	45.46a
S$\bar{x}$	4.39	2.79	1.25	3.95	4.32	0.812	0.26	0.20	0.42	0.49
LSD	10.40	6.61	4.83	9.43	10.34	1.92	0.62	0.75	0.99	0.86
Level of significance	NS	*	NS	*	*	NS	*	*	NS	*
CV (%)	6.13	16.16	19.58	22.01	9.60	15.73	2.04	10.35	13.18	14.22

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant; I_1: Conventional flood irrigation, I_2: AWD (Alternate wetting and drying, I_3: SRI (System of rice intensification), W_0: No weeding, W_1: Hand weeding thrice at 20, 35 and 50 days after sowing, W_2: Blade weeding + hand weeding once at 20 DAS and W_3: Pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS.

mum yield (5.47 t ha^{-1}) was obtained in pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS and the lowest (1.09 t ha^{-1}) was obtained from weedy check (Table 2). This trend of grain yield was reported by Sarkar *et al*. (2016) who reported that weed control by (Panida 33 EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS increased grain yield. This might be due to the fact use of pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS in rice under aerobic culture reduced the weed competition and impaired growth and yield attributes resulting in higher grain yield. Yield obtained from blade weeding + hand weeding once at 20 DAS (4.58 t ha^{-1}) was at par (4.74 t ha^{-1}) with hand weeding thrice at 20, 35 and 50 DAS (Table 2). In control plots, weed reduced 80.07% grain yield in *Boro* rice (cv. BRRI dhan28) compared to application of pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1}+hand weeding once at 20 DAS. Weed reduced grain yield (28.16 %) in aromatic fine rice was reported by Zannat *et al*. (2014).

Grain yield was significantly changed due to the interaction between irrigation and weed management (Table 3). The highest grain yield (5.86 t ha^{-1}) was observed in the interaction between SRI and pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS and whereas the lowest grain yield (0.91 t ha^{-1}) was observed in the interaction between conventional flood irrigation and no weeding (Table 3).

Straw yield: Straw yield was significantly influenced by irrigation systems, weeding regime and their interaction. The highest straw yield was observed with conventional flood irrigation and the lowest one was found in AWD and SRI system. Conventional flood irrigation recorded the highest straw yield (5.61 t ha^{-1}) and SRI recorded the lowest straw yield (5.40 t ha^{-1}), which was at par (5.45 t ha^{-1}) with AWD (Table 1). Among the different weed management practices the maximum straw yield (6.73 t ha^{-1}) was obtained at pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS which was at par with hand weeding thrice at 20, 35 and 50 DAS (6.28 t ha^{-1}) and the lowest (2.93 t ha^{-1}) was obtained in weedy check (Table 2). Similar results were reported by Sarkar *et al.* (2016) who noticed that application of pre-emergence herbicide (Panida 33 EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS produced the highest straw yield compare to other treatments.

Effect on harvest index: Harvest index was significantly influenced by irrigation systems. The highest harvest index (42.6 %) was realized with the SRI system while the lowest (40.69 %) was recorded at conventional flood irrigation, which was at par with AWD (41.64 %) (Table 1). Pre-emergence herbicide (Panida 33EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS significantly recorded the highest value of harvest index (44.83 %) which was as good as blade weeding + hand weeding once at 20 DAS (43.16 %) while no weeding recorded the lowest (27.11 %) harvest index (Table 2). Similar trend of harvest index was reported by Sarkar *et al*. (2016). Who reported that pre-emergence herbicide (Panida 33EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS gave the highest harvest index compare to other treatments. Harvest index was significantly influenced by the interaction between irrigation and weed management. The highest harvest index (45.46 %) was observed in the interaction between SRI and pre-emergence herbicide (Panida 33 EC) @ 2.5 l/ha + hand weeding once at 20 DAS and the lowest harvest (21.26 %) was observed in the interaction between conventional flood irrigation and no weeding (Table 3).

Conclusions

From this study it can be concluded that among the water management practices SRI system was found as the best water management practice in *Boro* rice (cv. BRRI dhan28) in terms of productivity. For efficient weed management, pre-emergence herbicide (Panida 33EC) @ 2.5 l ha^{-1} + hand weeding once at 20 DAS was found to be the best weed management practice. Therefore, SRI method with pre-emergence herbicide (Panida 33 EC) + one hand weeding at 20 DAS appeared as the promising technique for appreciable grain yield in *Boro* rice (cv. BRRI dhan28) cultivation.

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