Bangladesh Agron. J. 2019, 22 (1): 57-69

EFFECT OF WATER, NUTRIENT AND WEED MANAGEMENT ON THE YIELD AND QUALITY OF AROMATIC *BORO* RICE (cv. BRRI dhan50)

S.K. Paul*, M.C. Ray, M.A.R. Sarkar and S.K. Sarkar

Department of Agronomy, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh
*Corresponding E-mail: skpaul@bau.edu.bd

(**Received:** 25 April 2019, **Accepted:** 30 July 2019)

Keywords: Yield, grain protein, aromatic *Boro*rice

Abstract

An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during January to June 2016 to observe the effect of water, nutrient and weed management practices on the yield and quality of aromatic *Boro* rice (cv. BRRI dhan50). The experiment consisted of three water managements viz. conventional flood irrigation, AWD (Alternate Wetting and Drying) and SRI (System of Rice Intensification); two nutrient managements *viz.* recommended dose of inorganic fertilizers (Urea, TSP, MoP, Gypsum, $ZnSO_4$ @ 250, 120, 120, 100, 10 Kg ha^{-1}, respectively) and 25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1}; and three weed managements *viz.* weedy check (control), two hand weeding at 20 and 40 DAT, and pre-emergence herbicide (Rifit 33EC) followed by post emergence herbicide (Fast klin 10WP) application. The highest number of effective tillers $hill^{-1}$, grains $panicle^{-1}$,grain yield and protein (%) in grain were obtained in SRI water management which was followed by AWD and conventional flood irrigation. Between the two nutrient management practices, application of 25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1} produced higher number of effective tillers $hill^{-1}$,grains $panicle^{-1}$,1000-grain weight, grain yield and protein (%) in grain than in organic fertilizer. Among the weed management practices, application of pre-emergence herbicide (Rifit 33EC) followed by post-emergence herbicide (Fast Klin 10WP) produced the highest number of effective tillers $hill^{-1}$,grains $panicle^{-1}$,1000-grain weight, grain yield and protein (%) in grain followed by two weedings at 20 and 40 DAT while the lowest grain yield was obtained in weedy check. The highest number of effective tillers $hill^{-1}$,grains $panicle^{-1}$, grain yield and protein (%) in grain was found in SRI water management combined with 25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1} and application of pre-emergence herbicide followed by post-emergence herbicide. So, it may be concluded that, to get the highest grain yield in aromatic *Boro* rice, SRI method along with application of 25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1} and applying pre-emergence herbicide (Rifit 33EC) followed by post emergence herbicide (Fast Klin 10WP) could be recommended.

Introduction

Rice (*Oryza sativa*) is the most extensively cultivated cereal crop in Bangladesh. Aromatic rice contributes a small portion (10%) but an important subgroup of rice production. In recent years, aromatic rice has been introduced to the global market because of its taste, deliciousness and high price (Adhikari *et al.*, 2018). The yield of fine rice is lower than that of coarse and

medium rice varieties. To overcome this situation increment of aromatic rice production unit^{-1} area is the only alternative to bring self-sufficiency in aromatic rice through intensive care, management and adoption of new technologies. IRRI has developed AWD (Alternate Wetting and Drying) technology. This system can save 30% irrigation water, save energy and fuel consumption. AWD requires irrigation when the water level goes down to 15 cm below the soil surface. SRI (System of rice intensification) is another water saving technology (Stool *et al.*, 2002) where minimum water input with intermittent or saturated soil requires 20-50% less water (Lek and Yongyod, 1989) than continuous flooding.

In recent years there has been serious concern about long-term adverse effect of continuous and indiscriminate use of inorganic fertilizers on deterioration of soil structure, soil health and environmental pollution (Ghosh and Bhat, 1998). Combined application of manure with inorganic fertilizers increased grain yield and protein content of aromatic rice (Sarkar *et al.*, 2014, Roy *et al.*, 2015; Pal *et al.*, 2016; Biswas *et al.*, 2016 and Marzia *et al.*, 2016). High competitive ability of weeds exerts a serious negative effect on crop production causing significant losses in crop yield. Yield losses due to weed infestation are greater than the combined losses of insect pests and diseases. In Bangladesh, weed infestation reduces the grain yield 70-80% in *Aus* rice, 30-40% for transplanted *Aman* rice and 22-36% for modern *Boro* rice cultivars (Mamun, 1990). In case of aromatic rice grain yield was reduced by 28.16% in Binadhan-9 in Aman season (Zannat *et al.,* 2014) whereas by 59.82% in BRRI dhan50 at *Boro* season (Sinha *et al.*, 2018) due to weed infestation. Herbicides are effective in controlling weeds alone or in combination with hand weeding (Ahmed *et al.,* 2005). Herbicides in combination with hand weeding would help to obtain higher crop yield with less efforts and cost (Prasad and Rafy, 1995; Sathyamoorthy *et al.,* 2004). So, the present study was undertaken to find out the effect of water, nutrient and weed management on the growth, yield and quality of aromatic *Boro*rice (cv. BRRI dhan50).

Materials and Methods

The experiment was carried out at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh during January to June 2016 to study the effect of water, nutrient and weed management practices on the performance of aromatic *Boro* rice. The experimental field was located at 24°°75'N latitude and 90°°50'E longitude at an elevation of 18m above the mean sea level. The experimental area belongs to non-calcareous dark grey floodplain soil under the Sonatola soil series of Old Brahmaputra Floodplain in Agro Ecological Zone (AEZ- 9) (UNDP and FAO, 1988). The experimental field was medium high, fairly leveled with well drained soils. The soils of this series are pre-dominantly silty loam, dark grey in color having pH 6.5 and low in organic matter.

The experiment comprised three water management viz. Conventional flood irrigation - (I_1), AWD (Alternate wetting and drying) - (I_2) and SRI (System of rice intensification) - (I_3); two levels of nutrient management viz. Recommended dose of inorganic fertilizer (Urea, TSP, MoP, Gypsum, $ZnSO_4$ @ 250, 120, 120, 100, 10 kg ha^{-1} respectively) - (F_1) and 25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1} - (F_2), and there levels of weed management viz. weedy check (control) - (W_0),two hand weedings at 20 and 40 (Days after transplanting) DAT - (W_1) and application of Pre-emergence herbicide (Rifit 33EC) followed by post emergence herbicide (Fast Klin 10WP) (W_2). The experiment was laid out in a randomized complete block design with three replications. Eachunit plot size was 4.0 m Ч 2.5m. The rice var. BRRI

dhan50 of aromatic *Boro* rice was used as the test crop. Sprouted seeds were sown in the nursery bed on 13 December 2015 for AWD and continuous flooding practices. In SRI method seeds were sown in 11 January 2016. The experimental plots were fertilized with as per experimental treatments. The entire amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate and poultry manure were applied at final land preparation. Urea was applied in three equal installments at 15, 30 and 45 DAT. The seedlings were uprooted on 26 January 2016 without causing much mechanical injury to the roots and they were immediately transplanted in the well puddled main fieldat the rate of two seedlings $hill^{-1}$, maintaining row and hill distance of 25 cm and 15 cm in AWD and Conventional flooding systems. In case of SRI, single seedling $hill^{-1}$ was used12-day old seedlings whereas conventional and AWD systems 30-day old seedlings were used. AWD is monitored the depth of irrigated water on the field using a 'field water tube' or magic pipe. It involves installation of a perforated pipe in the rice field to allow observation of water level. In this experiment, magic pipe was installed at 10 DAT. After irrigation, the depth of irrigation water will gradually decrease. When the irrigation water has dropped to 15 cm below the surface of the soil, irrigation was applied with 5 cm depth water. From one week before to one week after flowering, irrigation water was kept at 5 cm depth. After flowering, the water level was dropped again to 15 cm below the surface before irrigation. Water management was the most complicated variable in SRI method where rice crops are kept unflooded during vegetative growth with partial amount of water was applied to keep the soil moist.It was even allowed to dry out for 2 to 4 days during tillering to keep the soil well aerated and to allow better root growth. From panicle initiation (PI) to hard dough stage, a thin layer of water (2-3 cm) was kept on the plots. Again water was drained out from the plots during ripening stage.

Data on weed population were recorded from each plot at 65 DAT by using 1 m^2 quadrate as per method described by Cruz *et al.* (1986). The weeds inside each quadrate were uprooted and cleaned, separated species-wise and dried first in the sun and then in an electrical oven for 72 hours at a temperature of 80 °C followed by weed dry weight of each plot was recorded by an electrical balance. The crop was harvested on 25 May, 30 May and 06 June 2016, respectively for conventional, AWD and SRI. The grains were cleaned and finally the weight was adjusted to a moisture content of 14%. The straw was sun dried and the yields of grain and straw $plot^{-1}$ were recorded and converted to t ha^{-1}. Harvest index indicates the ratio of economic yield (grain yield) to biological yield (grain yield + straw yield) and was calculated by the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain Yield (t ha}^{o})}{\text{Biological Yield (t ha}^{o})} \text{ Чx } 100.$$

Estimation of protein in grains was done by following Micro-Kjeldahl Method. Oven dried rice kernels were then put in polythene bags and kept in desiccators for subsequent chemical analysis for estimation of protein. Protein content (%) was estimated by Micro-Kjeldahl method (AOAC, 1984) at the Agri-Varsity Humboldt Soil Testing Laboratory of Soil Science Department, Bangladesh Agricultural University, Mymensingh. The recorded data were compiled and tabulated for statistical analysis. Analysis of variance was done with the help of computer package, MSTAT. The mean differences among the treatments were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

Weed dry weight

There was significant effect on total weed dry weight (g m^{-2}) due to water management (Table 1). The highest total weed dry weight (38.71 g m^{-2}) was found in I_1 (Conventional flood irrigation) followed by AWD (Alternate Wetting and Drying), while the lowest total weed dry weight (33.35 g m^{-2}) was found in I_3 (SRI) water management (Table 1).There was significant effect on total weed dry weight due to nutrient management (Table 1). Maximum weed dry weight (37.75 g m^{-2}) was found in F_1 (Recommended dose of inorganic fertilizer) and minimum one (33.56 g m^{-2}) was found in F_2 (25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1}) nutrient management (Table 1). There was significant effect on total weed dry weight due to weed management (Table 1). At 65 DAT, the maximum total weed dry weight (75.03 g m^{-2}) was found in W_0 (No weeding) followed by two hand weedings at 20 and 40 DAT while the lowest total weed dry weight (8.91 g m^{-2}) in W_2 (Pre-emergence herbicide Rifit 33EC followed by post emergence herbicide Fast Klin 10WP) weed management (Table 1).Non-significant variation was found on total weed dry weight due to interaction effect of water and nutrient management at 65 DAT (Table 2). However, numerically, the highest weed dry weight (41.43 g m^{-2}) was found in $I_1ЧF_1$ (Conventional flood irrigation Ч Recommended dose of inorganic fertilizer) and the lowest (31.35 g m^{-2}) one was found in $I_3ЧF_2$ (SRI Ч 25% less than recommended dose of inorganic fertilizer + poultry manure) treatment (Table 2). Significant variation was found on total weed dry weight due to interaction effect of water and weed management at 65 DAT (Table 3). The highest weed dry weight (80.48 g m^{-2}) was found in $I_1ЧW_0$ (Conventional flood irrigation Ч No weeding) followed by I_2 Ч W_0 (AWD Ч No weeding) and I_3 Ч W_0 (SRI Ч No weeding) and the lowest (7.66 g m^{-2}) one was found on $I_3ЧW_2$ (SRI Ч Pre-emergence herbicide Rifit 33EC followed by post emergence herbicide Fast Klin 10WP) treatment (Table 3).Significant variation was found on total weed dry weight due to interaction effect of nutrient and weed management practices at 65 DAT (Table 4). The highest total weed dry weight (77.74 g m^{-2}) was found in $F_1ЧW_0$ (Recommended dose of inorganic fertilizer Ч No Weeding) and the lowest (8.692 g m^{-2}) one was found in $F_1ЧW_2$ (Recommended dose of inorganic fertilizerЧ pre-emergence herbicide Rifit 33EC followed by post-emergence herbicide Fast Klin 10WP) treatment (Table 4). Non-significant variation was found on total weed dry weight due to interaction effect of water, nutrient and weed management practices at 65 DAT (Table 5).

Yield and yield components

Crop characters, yield contributing characters, yield and grain protein content were significantly influenced by water management except panicle length and 1000-grain weight (Table 1). The tallest plant (82.56 cm), number of total tillers $hill^{-1}$ (12.25), effective tillers $hill^{-1}$ (11.07) and grains $panicle^{-1}$ (119.99) were found in I_3 (SRI method) followed by I_2 (AWD) and all parameters showed the lowest values in I_1 (conventional flood irrigation) (Table 1). While the highest number of non-effective tillers $hill^{-1}$(1.44) was recorded in AWD (Alternate wetting and drying) and sterile spikelets $panicle^{-1}$ (16.12) were recorded in I_1 (conventional flood irrigation) and the lowest values were found in I_3 (SRI). The highest grain yield (5.41 t ha^{-1}) was obtained in I_3 (SRI) water management followed by I_2 (AWD) and the lowest grain yield (4.80 t ha^{-1}) in I_1 (Conventional flood irrigation). The increased yield might be due to the highest number of grains $panicle^{-1}$ and number of effective tillers $hill^{-1}$. Straw yield also showed similar trend as that of grain yield. The highest grain protein content (8.54%) was found in I_3

(SRI) followed by I_2 (AWD) and the lowest grain protein content (7.96%) in I_1 (conventional flood irrigation).

Table 1. Effect of water management on crop characters, yield components and yield of aromatic *Boro* rice (cv. BRRI dhan50)

Treatments	Dry matter of weed (g m^{-2})	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Non-effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Grains $panicle^{-1}$ (no.)	No. of sterile spikelets $panicle^{-1}$	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Grain protein content (%)
Water management													
I_1	38.71a	76.96b	10.49b	9.08b	1.41a	21.36	116.11c	16.12a	18.30	4.80c	5.20c	48.00	7.957b
I_2	34.90b	82.49a	10.92b	9.48b	1.44a	21.64	117.03b	14.11b	18.64	4.99b	5.46b	47.75	8.093b
I_3	33.35c	82.56a	12.25a	11.07a	1.18b	21.89	119.99a	13.75c	19.32	5.41a	6.05a	47.20	8.536a
CV (%)	6.44	3.62	7.62	5.17	11.84	4.37	8.19	14.46	4.94	3.86	4.00	3.48	4.18
Nutrient management													
F_1	37.75a	80.69	10.81b	9.40b	1.41a	21.52	114.40b	15.10a	18.41b	4.72b	5.37b	46.78	8.00b
F_2	33.56b	80.66	11.63a	10.36a	1.28b	21.74	117.68a	14.22b	19.15a	5.03a	5.77a	46.57	8.26a
CV (%)	6.44	3.62	7.62	5.17	11.84	4.37	8.19	14.46	4.94	3.86	4.00	3.48	4.18
Weed management													
W_0	75.03a	78.81b	9.13c	8.17c	0.96c	21.22 b	116.53	16.50a	18.12b	2.91c	3.80c	43.36c	7.92b
W_1	23.03b	81.46a	11.62b	9.97b	1.65a	21.57ab	118.05	14.03b	18.50b	5.10b	6.19b	45.17b	8.12b
W_2	8.91c	81.75a	12.91a	11.50a	1.41b	22.10a	120.55	13.46c	19.64a	5.75a	6.73a	46.07a	8.54a
CV (%)	6.44	3.62	7.62	5.17	11.84	4.37	8.19	14.46	4.94	3.86	4.00	3.48	4.18

In a column, figures with same letter or without letter do not differ significantly (as per DMRT).

I_1 = Conventional flood irrigation, I_2 = AWD (Alternate Wetting and Drying), I_3 = SRI (System of Rice Intensification), F_1 = Recommended dose of inorganic fertilizer, F_2 = 25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1}, W_0 = Weed check (control), W_1 = Two hand weeding at 20 and 40 DAT, W_2 = Pre-emergence herbicide (Rifit 33EC) followed by post emergence herbicide (Fast Klin 10WP)

All yield contributing characters, yield and grain protein content were significantly influenced by nutrient management except plant height and panicle length (Table 1). The highest number of total tillers hill^{-1} (11.63), effective tillers hill^{-1} (10.36), grains panicle^{-1} (117.68) and 1000-grain weight (19.15 g) were found in all the parameters showed lower values in F_1.The highest number of non-effective tillers hill^{-1} (1.41) and sterile spikelets panicle^{-1} (15.10) were produced in F_1 nutrient management, while the lowest number of sterile spikelets panicle^{-1} (14.22) in F_2 (25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1}). Higher grain yield (5.03 t ha^{-1}) and straw yield (5.77 t ha^{-1}) were obtained in F_2 (25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1}) nutrient management than that of F_1.The increased yield might be due to higher number of grains panicle^{-1}, higher 1000-grain weight and higher number of effective tillers hill^{-1}. Application of inorganic fertilizer along with manure greatly influence the grain yield of rice were reported (Islam *et al.*, 2015; Roy *et al.*, 2015; Pal *et al.*, 2016; Biswas *et al.*, 2016 and Sarkar *et al.*, 2016). Table 1 indicates that higher grain protein content (8.26%) was found in F_2 compared to F_1. Integration of poultry manure with chemical fertilizer increased grain protein content was also reported (Sarkar *et al.*, 2014; Biswas *et al.*, 2016 and Pal *et al.*, 2016)

Crop characters, yield contributing characters, yield and grain protein content were significantly influenced by water management except grains panicle^{-1} (Table 1). The tallest plant (81.75 cm) was found in W_2 (pre-emergence herbicide Rifit 33EC followed by post emergence herbicide Fast Klin 10WP) which was at par with W_1(two hand weeding at 20 and 40 DAT) while the shortest plant (78.81 cm) was found in W_0 (No weeding). The highest number of total tillers hill^{-1} (12.91), effective tillers hill^{-1} (11.50), longest panicle (22.10 cm) and the highest weight of 1000-grain (19.64 g) were obtained in W_2 whileall the parameters showed intermediate values in $W_1$and the corresponding lowest values in W_0. The highest number of non-effective tillers hill^{-1} (1.65) was produced in W_1 while the lowest number of non-effective tillers hill^{-1} (0.96) in W_0. The highest number of sterile spikelets panicle^{-1} (16.50) was produced in W_0 weed management, while the lowest number of sterile spikelets panicle^{-1} (13.46) in W_2. Number of grains panicle^{-1} was not significantly influenced by different weed management. Table 1 indicates that numerically the highest number of grains panicle^{-1} (120.55) was produced in W_2 while the lowest number of grains panicle^{-1} (116.53) by W_0. The highest grain yield (5.75 t ha^{-1}), straw yield (6.73 t ha^{-1}) and harvest index (46.07%) were produced in W_2 followed by W_1 while the corresponding lowest values were obtained in W_0. Weed infestation reduced 49.39% grain yield over W_2. Similar trend was reported by Sinha *et al.* (2018) that weed reduced grain yield by 59.83% in aromatic *Boro* rice cv. BRRI dhan50. The highest grain protein content (8.54%) was found in W_2 and the lowest grain protein content (7.92%) in W_0which was at par with W_1.

Table 2 indicates that the highest number of total tillers hill^{-1}(12.78), effective tillers hill-$^{-1}$ (11.67), and grain yield (5.19 t ha^{-1} t ha^{-1}) were obtained in I_3 Ч F_2 (SRI Ч 25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1}t). Grain yield produced in I_3 Ч F_1 (SRI Ч recommended dose of inorganic fertilizer) was at parinI_3 Ч F_2 (SRI-25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1} t) while the corresponding lowest values in I_1 F_1 (conventional flood irrigation Ч recommended dose of inorganic fertilizer).

Table 2. Interaction effect of water and nutrient management on crop characters, yield components and yield aromatic *Boro* rice (cv. BRRI dhan50)

Interaction (Water Ч nutrient management)	Dry matter of weed (g m^{-2})	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Non-effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Grains $panicle^{-1}$ (no.)	No. of sterile spikelets $panicle^{-1}$	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Grain protein content (%)
I_1 Ч F_1	41.43	82.59	10.15c	8.64d	1.52	21.22	113.40	16.89	18.07	4.76c	5.01	48.72	7.58
I_1 Ч F_2	35.98	82.54	10.82bc	9.52bc	1.29	21.50	114.82	15.35	18.54	4.92b	5.44	47.49	7.93
I_2 Ч F_1	36.43	82.14	10.51bc	9.09c	1.42	21.66	115.10	14.31	18.27	4.80bc	5.28	47.61	7.94
I_2 Ч F_2	33.36	82.84	11.32b	9.87bc	1.45	21.63	116.96	13.92	19.00	4.95b	5.65	46.69	8.24
I_3 Ч F_1	35.35	77.35	11.74ab	10.47b	1.27	21.67	115.71	14.12	18.87	4.98ab	5.86	45.94	8.48
I_3 Ч F_2	31.35	76.58	12.78a	11.67a	1.09	22.10	118.26	13.38	19.77	5.19a	6.24	45.40	8.59
CV (%)	6.44	3.62	7.62	5.17	11.84	4.37	8.19	14.46	4.94	3.86	4.00	3.48	4.18

In a column, figures with same letter or without letter do not differ significantly (as per DMRT).
I_1 = Conventional flood irrigation, I_2 = AWD (Alternate Wetting and Drying), I_3 = SRI (System of Rice Intensification)
F_1 = Recommended dose of inorganic fertilizer, F_2 = 25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha

Table 3 indicates that the highest number of grains $panicle^{-1}$(119.0) was produced in I_3 Ч W_2 (SRI Ч pre-emergence herbicide Rifit 33EC followed by post-emergence herbicide Fast Klin 10WP) which was at par to I_2 W_2 (AWD pre-emergence herbicide Rifit 33EC followed by post emergence herbicide Fast Klin 10WP). The highest grain yield (6.14 t ha^{-1}) was produced in I_3 W_2 followed by I_3 W_2 (SRI two hand weeding at 20 and 40 DAT) (6.14 t ha^{-1}) and the lowest grain yield (2.70 t ha^{-1}) in I_1 ЧW_0 (conventional flood irrigation Ч no weeding). The highest number of effective tillers $hill^{-1}$(11.96) was obtained in F_2 Ч W_2 (25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1} Ч pre-emergence herbicide Rifit 33EC followed by post-emergence herbicide Fast Klin 10WP) followed by F_1ЧW_2 (recommended dose of inorganic fertilizer pre-emergence herbicide Rifit 33EC followed by post emergence herbicide Fast Klin 10WP) and lowest one (7.79) in F_1ЧW_0 (recommended dose of inorganic fertilizer no weeding)

Table 3. Interaction effect of water and weed management on crop characters, yield components and yield of aromatic *Boro* rice (cv. BRRI dhan50)

Interaction (Water Ч weed management)	Dry matter of weed (g m^{-2})	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Non-effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Grains $panicle^{-1}$ (no.)	No. of sterile spikelets $panicle^{-1}$	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Grain protein content (%)
I_1 Ч W_0	80.48a	81.47	8.39	7.40	0.99d	20.87	116.40de	20.10a	17.71	2.70e	3.45	43.90	7.35
I_1 Ч W_1	25.80c	83.65	10.88	9.14	1.74ab	21.32	117.00cd	14.53bc	18.12	5.07c	5.81	46.59	7.82
I_1 Ч W_2	9.832e	82.57	12.20	10.70	1.50b	21.90	117.93b	13.73cd	19.08	5.43bc	6.35	46.09	8.11
I_2 Ч W_0	73.46b	81.15	8.71	7.79	0.91e	21.25	116.58d	14.85b	17.92	2.83de	3.73	43.14	7.83
I_2 Ч W_1	22.00d	83.08	11.47	9.54	1.93a	21.60	116.86d	13.96bd	18.40	5.41bc	6.19	46.63	7.99
I_2 Ч W_2	9.236e	83.24	12.57	11.11	1.47b	22.08	118.63ab	13.53cd	19.60	5.69b	6.48	46.75	8.46
I_3 Ч W_0	71.10b	73.81	10.30	9.31	0.99d	21.55	117.61bc	14.56bc	18.74	3.21d	4.20	43.34	8.28
I_3 Ч W_1	21.28d	78.51	12.50	11.23	1.28c	21.80	117.28c	13.59cd	19.00	5.69b	6.58	46.37	8.46
I_3 Ч W_2	7.662e	78.57	13.95	12.68	1.27c	22.31	119.0a	13.11d	20.24	6.14a	7.36	45.48	8.87
CV (%)	6.44	3.62	7.62	5.17	11.84	4.37	8.19	14.46	4.94	3.86	4.00	3.48	4.18

In a column, figures with same letter or without letter do not differ significantly (as per DMRT).
I_1 = Conventional flood irrigation, I_2 = AWD (Alternate Wetting and Drying), I_3 = SRI (System of Rice Intensification), W_0 = Weed check (control),
W_1 = Two hand weeding at 20 and 40 DAT, W_2 = Pre-emergence herbicide (Rifit 33EC) followed by post emergence herbicide (Fast Klin 10WP)

Table 4. Interaction effect of nutrient and weed management on crop characters, yield components and yield of aromatic *Boro* rice (cv. BRRI dhan50)

Nutrient Ч weed management	Dry matter of weed (g m^{-2})	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Non-effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Grains $panicle^{-1}$ (no.)	No. of sterile spikelets $panicle^{-1}$	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Grain protein content (%)
F_1 Ч W_0	77.74a	78.87	8.74	7.79ef	0.95c	21.19	107.53	17.12	17.77	2.78	3.58	43.71	7.71
F_1 Ч W_1	26.34c	81.85	11.18	9.37d	1.81a	21.44	109.36	14.39	18.16	5.22	5.98	46.60	7.93
F_1 Ч W_2	9.128e	81.35	12.49	11.03b	1.46b	21.93	111.31	13.80	19.29	5.60	6.55	46.09	8.36
F_2 Ч W_0	72.28b	78.74	9.52	8.54e	0.98c	21.26	111.52	15.87	18.48	3.05	4.02	43.14	7.93
F_2 Ч W_1	19.71d	81.65	12.06	10.57c	1.49b	21.71	112.73	13.67	18.84	5.56	6.40	46.48	8.24
F_2 Ч W_2	8.692e	81.57	13.32	11.96a	1.37b	22.26	113.78	13.11	19.99	5.90	6.90	46.09	8.59
CV (%)	6.44	3.62	7.62	5.17	11.84	4.37	8.19	14.46	4.94	3.86	4.00	3.48	4.18

In a column, figures with same letter or without letter do not differ significantly (as per DMRT).
F_1 = Recommended dose of inorganic fertilizer, F_2 = 25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1}
W_0 = Weed check (control), W_1 = Two hand weeding at 20 and 40 DAT, W_2 = Pre-emergence herbicide (Rifit 33EC) followed by post emergence herbicide (Fast Klin 10WP)

Table 5 indicates that the highest number of total tillers $hill^{-1}$ (14.58), effective tillers $hill^{-1}$ (13.40) and grains $panicle^{-1}$ (118.65) were obtained in I_3ЧF_2ЧW_2 (SRI 25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1} pre-emergence herbicide Rifit 33EC followed by post emergence herbicide Fast Klin 10WP) treatment while the corresponding lowest values in I_1F_1ЧW_0 (conventional flood irrigation Ч recommended dose of inorganic fertilizer Чno weeding) treatment.

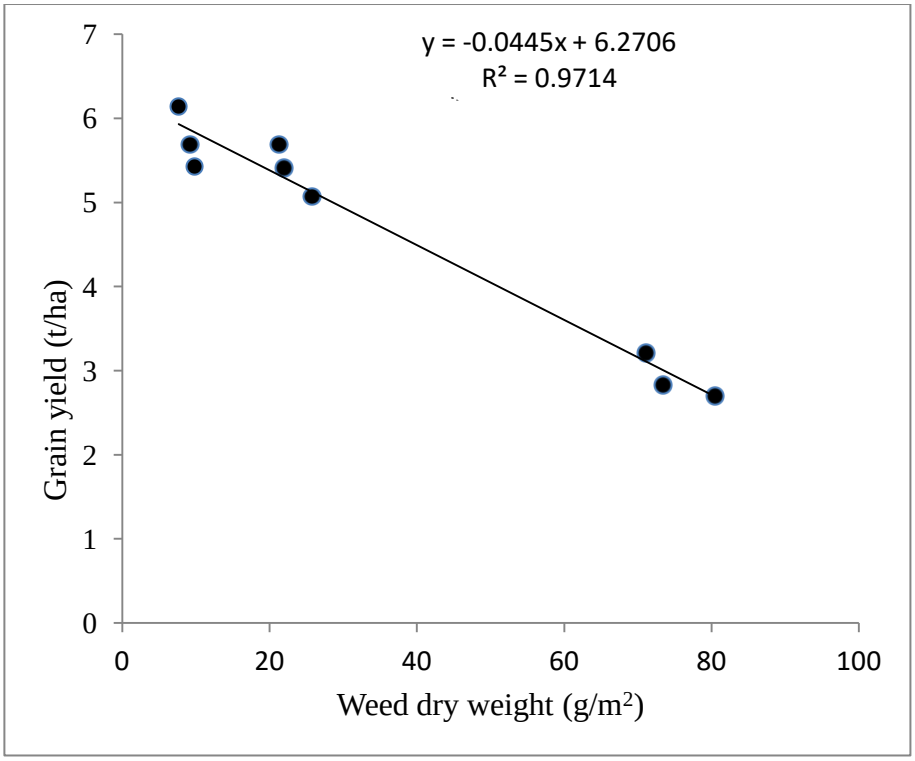
Table 5. Interaction effect of water, nutrient and weed management on crop characters, yield components and yield of aromatic *Boro* rice (cv. BRRI dhan50)

Interaction (Water Ч nutrient Ч weed management)	Dry matter of weed (g m^{-2})	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Non-effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Grains $panicle^{-1}$ (no.)	No. of sterile spikelets $panicle^{-1}$	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Grain protein content (%)
I_1 Ч F_1 Ч W_0	83.30	81.61	8.11f	7.10i	1.01	20.56	114.17fg	21.43	17.49	2.55h	3.25	43.96	7.23
I_1 Ч F_1 Ч W_1	31.04	83.21	10.4d	8.49fg	1.91	21.21	117.17bcde	15.19	17.98	4.78e	5.43	46.81	7.58
I_1 Ч F_1 Ч W_2	9.960	82.94	11.98c	10.33cde	1.65	21.89	117.93ab	14.05	18.74	5.25de	6.23	45.73	7.93
I_1 Ч F_2 Ч W_0	77.67	81.33	8.67ef	7.70g	0.97	21.18	117.70b	18.76	17.93	2.89g	3.66	44.12	7.47
I_1 Ч F_2 Ч W_1	20.56	84.09	11.37cd	9.80de	1.57	21.42	117.83abc	13.87	18.25	5.36cde	6.19	46.40	8.05
I_1 Ч F_2 Ч W_2	9.703	82.20	12.42b	11.07bcde	1.35	21.90	117.93ab	13.41	19.42	5.62bc	6.47	46.48	8.28
I_2 Ч F_1 Ч W_0	75.52	82.13	8.34efg	7.42gh	0.93	21.59	115.10f	15.02	17.50	2.72gh	3.43	44.22	7.60
I_2 Ч F_1 Ч W_1	24.03	82.28	11.01cde	9.03defg	1.98	21.48	115.63def	14.18	18.00	5.29d	6.07	46.56	7.82
I_2 Ч F_1 Ч W_2	9.733	82.00	12.18bc	10.82c	1.37	21.92	116.50cde	13.71	19.31	5.49cd	6.35	46.36	8.40
I_2 Ч F_2 Ч W_0	71.39	80.16	9.07e	8.17fgh	0.90	20.91	116.00de	14.67	18.34	3.00fgh	4.04	42.61	8.05
I_2 Ч F_2 Ч W_1	19.96	83.88	11.93c	10.05d	1.88	21.73	117.00c	13.74	18.79	5.52c	6.30	46.70	8.17
I_2 Ч F_2 Ч W_2	8.740	84.48	12.96abc	11.40bcd	1.56	22.24	117.77abd	13.35	19.88	5.88b	6.60	47.12	8.52
I_3 Ч F_1 Ч W_0	74.40	72.88	9.77de	8.85f	0.92	21.42	116.33d	14.92	18.31	3.15fg	4.06	43.68	8.28
I_3 Ч F_1 Ч W_1	23.95	80.05	12.13bc	10.60cd	1.53	21.63	117.30bcd	13.79	18.50	5.59bc	6.43	46.50	8.40
I_3 Ч F_1 Ч W_2	7.690	79.10	13.32ab	11.95b	1.36	21.98	117.50bc	13.64	19.81	6.07ab	7.08	46.15	8.75
I_3 Ч F_2 Ч W_0	67.79	74.74	10.83cdef	9.77def	1.07	21.68	116.87cd	14.19	19.16	3.27f	4.35	42.91	8.28
I_3 Ч F_2 Ч W_1	18.62	76.97	12.87abcd	11.85bc	1.02	21.98	117.87ab	13.39	19.49	5.80b	6.72	46.32	8.52
I_3 Ч F_2 Ч W_2	7.634	78.04	14.58a	13.40a	1.18	22.64	118.65a	12.57	20.67	6.20a	7.64	44.79	8.98
CV (%)	6.44	3.62	7.62	5.17	11.84	4.37	8.19	14.46	4.94	3.86	4.00	3.48	4.18

In a column, figures with same letter or without letter do not differ significantly (as per DMRT).
I_1 = Conventional flood irrigation, I_2 = AWD (Alternate Wetting and Drying), I_3 = SRI (System of Rice Intensification)
F_1 = Recommended dose of inorganic fertilizer, F_2 = 25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1}
W_0 = Weed check (control), W_1 = Two hand weeding at 20 and 40 DAT, W_2 = Pre-emergence herbicide (Rifit 33EC) followed by post emergence herbicide (Fast Klin 10WP)

The highest grain yield (6.20 t ha^{-1}) was obtained in $I_3ЧF_2ЧW_2$ followed by $I_3ЧF_2ЧW_1$ while the lowest grain yield (2.55 t ha^{-1}) was found in $I_1ЧF_1ЧW_0$. Grain protein content was not statistically significant (Table 5).

A functional relationship was observed between dry matter weight of weeds (at 65 DAT) and grain yield of aromatic *Boro* rice (cv. BRRI dhan50). A negative linear relationship between weed dry weight (at 65 DAT) and grain yield of aromatic *Boro* rice was observed, indicating that higher the weed dry matter value lower the grain yield (Figure 1). The functional relationship adequately described by regression equation Y = -0.0445x + 6.2706 (R^2 = 0.9714). The functional relationship indicates that 97% of the variation in grain yield could be explained from the variation in weed dry matter production at 65 DAT. This finding is in agreement with that of Sinha *et al.* (2018) who reported that 89% of *Boro* rice (cv. BRRI dhan50) yield could be explained by the functional relationship of weed dry matter production at 65 DAT while Islam *et al.* (2015) reported that 80% of the variation in grain yield could be explained from the variation in weed dry matter production at 60 DAT in BRRI dhan49.



Conclusion

The highest number of effective tillers $hill^{-1}$,grains $panicle^{-1}$, grain yield and protein (%) in grain was found in SRI water management along with 25% less than recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1} and application of pre-emergence herbicide followed by post emergence herbicide. Therefore, it could be concluded that SRI method along with application of 25% less than recommended dose of inorganic fertilizer + poultry @ 2.5 tha^{-1} and pre-emergence herbicide (Rifit 33EC) followed by post-emergence herbicide

(Fast Klin 10WP) may be recommended for higher grain yield and quality in terms of grain protein content in aromatic *Boro* rice cv. BRRI dhan50.

Acknowledgement

The financial assistance of Ministry of Science and Technology, Govt. of the People's Republic of Bangladesh, to conduct the research project is thankfully acknowledged.

References

Adhikari, A., M.A.R. Sarkar, S.K. Paul and K.K. Saha. 2018. Impact of nutrient management on the yield performance of some aromatic fine rice (*Oryza sativa* L.) varieties in *Boro* season. Arch. Agr. Environ. Sci. 3(3): 245-251.

Ahmed, G.J.U., M.K.A. Bhuiyan, C.R. Riches, M. Mortimer and D. Jhonson. 2005. Farmer's participatory studies of integrated weed management system for intensified lowland. Proceeding of the 8th Biennial Agronomy Convention, Bangladesh Agron. J. 31-32.

AOAC. 1984. Official Methods of Analysis. Association of Official Agricultural Chemists. Washington, D. C. pp. 121-135.

Biswas, T., S.K. Paul, M.A.R. Sarkar and S.K. Sarkar. 2016. Integrated use of poultry manure with prilled urea and urea super granules for improving yield and protein content of aromatic rice (cv. BRRI dhan50). Prog. Agric. 27(2): 86-93.

Cruz, E.D., K. Moody and M.B.D. Ramos. 1986. Reducingvriability in sampling weeds in upland rice (*Oryza sativa*). Philipp. J. Weed Sci. 13: 56-59.

Ghosh, B.C. and R. Bhat. 1998. Environment hazards of nitrogen loading in wetland rice fields. Environ. Pollut. 102: 123-126.

Gomez, K.A. and A.A. Gomez. 1984. Statistical Procedure for Agricultural Research. Intl. Rice Res. Inst., Philippines, John Wiley and Sons. New York, Chichester, Brisbane, Toronto, Singapore.680p.

Islam, S.M.M., S. K. Paul and M.A.R. Sarkar. 2015. Effect of weeding regime and integrated nutrient management on yield contributing characters and yield of BRRI dhan49. J. Crop Weed. 11 (Special Issue): 193-197.

Lek, P. and S. Yongyod. 1989. Water management for wet and dry season rice growing in irrigated area. Irrigation station 2-10. Paper for 1999 Pathunthani. Rice Research Center Annual Seminar.

Mamun, A.A. 1990. Weeds and their control: A review of weed research in Bangladesh. Agricultural and rural development in Bangladesh.Japan Intl. Co- operation Agency, Dhaka, Bangladesh. JSARD. 19: 45-72.

Marzia, R., M.A.R. Sarkar and S.K. Paul. 2016. Effect of row management and integrated nutrient management on the yield of aromatic fine rice (cv. BRRI dhan34).Int. J. Plant Soil Sci. 13(5): 1-8.

Pal, S., S.K Paul, M.A.R. Sarkar and D.R. Gupta. 2016. Response on yield and protein content of fine aromatic rice varieties to integrated use of cowdung and inorganic fertilizers. J. Crop Weed. 12(1): 01-06.

Prasad, K. and A. Raffy. 1995. Effect of integrated weed management on weed growth nutrient uptake, economics and energetics in rainfed upland rice *(Oryza sativa).* Indian J. Agril. Sci. 65(4): 260-264.

Roy, B., M.A.R. Sarkar and S.K. Paul. 2015. Effect of integrated nutrient management in *Boro* rice cultivation. SAARC J. Agri. 13(2): 131-140.

Sarkar, M.A.R., S.K. Paul and U. Paul. 2016. Effect of plant nutrient and weed management in direct wet seeded *Boro* rice. Prog. Agric. 27(4): 466-472.

Sarkar, S.K., M.A.R. Sarkar, N. Islam and S.K. Paul. 2014. Yield and quality of aromatic fine rice as affected by variety and nutrient management. J. Bangladesh Agril. Univ. 12(2): 279-284.

Sathyamoorthy, N.K., S. Mahendran, R. Babu and T. Ragavan. 2004. Effect of intgrated weed management practices on total weed dry weight, nutrient removal of weeds in rice-rice wet seedbed system. J. Agron. 3(4): 263-267.

Sinha, T., S.K. Paul. and M.A.R. Sarkar. 2018. Effect of age of seedlings at staggered transplanting and weed management on the growth and yield of aromatic *Boro* rice (cv. BRRI dhan50). J. Bangladesh Agril. Univ. 16(1): 5-11.

Stool, W.A., N. Uphoff and A. Kassam. 2002. A review of agricultural research issues raised by the System of Rice Intensification (SRI) from Madagascar: Opportunities for improving farming systems for resource-poor farmers. Agril. Sys. 71(3): 249-274.

UNDP and FAO. 1988. Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2. Agroecological Regions of Bangladesh. Bangladesh Agril. Res. Coun., Dhaka-1207. pp.212-221.

Zannat, S.T., S.K. Paul and M.A. Salam. 2014. Effect of weeding regime and nitrogen management on the performance of transplant aromatic *Aman* rice (cv. Binadhan-9). Bangladesh J. Seed Sci. Tech. 18(1 & 2): 29-34.