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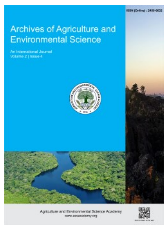

ORIGINAL RESEARCH ARTICLE

CrossMark

Influence of weeding regime on the performance of aromatic *Boro* rice (*Oryza sativa* L.)

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ABSTRACT

An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, from December 2013 to May 2014 to investigate the influence of weeding regime on the performance of aromatic *Boro* rice (cv. BRRI dhan50). The experiment comprised nine treatments *viz*., un-weeded, one hand weeding at 20 DAT + pre-emergence herbicide after hand weeding, two hand weeding at 20 and 40 DAT, pre-emergence herbicide followed by one hand weeding at 20 DAT, pre-emergence herbicide followed by one hand weeding at 40 DAT, post-emergence herbicide + one hand weeding at 40 DAT, pre-emergence herbicide + post-emergence herbicide, pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT and weed free throughout the growth period. Panida (pendimethalin) @ 2.5 L ha^{-1} as pre-emergence herbicide and granite (penoxsulam) @ 93.70 ml ha^{-1} as post-emergence were used for weed control. The experiment was laid out in a randomized complete block design with four replications. Thirteen weed species belonging to seven families were observed in the experimental field. The highest weed density and dry weight were observed in no weeding condition compared to other treatments. The tallest plant, the highest number of total tillers hill^{-1}, number of effective tillers hill^{-1}, total spikelets panicle^{-1}, grains panicle^{-1}, 1000-grain weight, grain yield, straw yield, biological yield and harvest index were obtained from weed free treatment. The highest grain yield (5.92 t ha^{-1}) was obtained from weed free throughout the growth period. Grain yield was reduced by 56.42% due to weed infestation in unweeded condition. The highest benefit-cost ratio (2.28) was obtained from application of pre-emergence herbicide followed by post-emergence herbicide + one hand weeding at 40 DAT. Therefore, weeding treatment pre-emergence herbicide followed by post-emergence herbicide + one hand weeding at 40 DAT may consider for cultivation of aromatic *Boro* rice (cv. BRRI dhan50).

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INTRODUCTION

Rice (*Oryza sativa* L) is the staple food for the people of Bangladesh. Aromatic rice is special group that covers 2% of the national rice acreage of Bangladesh and 12.5% of the total transplant *Aman* rice cultivation (Roy *et al*., 2018). Most of the aromatic rice varieties are traditional photo-period sensitive type and grown during *Aman season* in Bangladesh (Kabir *et al*., 2004). The average yield of rice in Bangladesh is 3.04 t ha^{-1} and which is very much lower than world average (Sinha *et al*., 2018). Islam *et al*. (1996) noticed that the yield of aromatic rice was lower (1.5-2.0 t ha^{-1}) but its higher price and low cost of cultivation generated higher profit margins compared to other varieties grown in the area. Bangladesh Rice Research Institute (BRRI) developed a modern aromatic rice BRRI dhan50 (Banglamoti) with high yield ability which is suitable for *Boro* season.

Severe weed infestation reduces the grain yield in *Aus*, *Aman* and *Boro* season in 70.80%, 30–40% and 22–36% in Bangladesh (Sarkar *et al*., 2017). In case of aromatic rice grain yield reduced by 59.82% for BRRI dhan50 in *Boro* season (Sinha *et al*., 2018) and 28.16% for Binadhan-9 in *Aman* season (Zannat *et al*., 2014). The traditional method of weed control is hand weeding which is very much laborious and time consuming. 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). Herbicides in combination with hand weeding would help to obtain higher crop yield with less efforts and cost (Sathyamoorthy *et al*., 2004). Weed competition at early growth stage can be eliminated through pre-emergence herbicides like Panida, Ronstar 25 EC and Rifit 50 EC and post emergence herbicides Granaite and 2, 4-D amine. This type of herbicides can be used in Bangladesh against mono and dicotyledonous weeds in rice fields. Replacement of traditional weeding in *Boro* rice by pre-emergence and post-emergence herbicides or herbicides in combination with hand weeding would help obtain higher rice yield. Therefore, the present study was undertaken to determine the effective weed control option for maximizing yield of BRRI dhan50.

MATERIALS AND METHODS

Experimental design

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during the period from December 2013 to May 2014. The experimental site is located at 24.75° N latitude and 90.50°E longitude at an elevation of 18 m above the sea level. The site belongs to the non-calcareous dark grey floodplain soil under the Agro-ecological Zone of the Old Brahmaputra Floodplain (AEZ-9) (UNDP and FAO, 1988). The soil of the experimental field belongs to the Sonatala soil series which is slightly acidic in reaction with 1.29 % organic matter content. The experimental field was a medium high having pH 6.5. The experiment consisted of nine treatments viz. Unweeded (T_1), One hand weeding at 20 days after transplanting (DAT) + pre-emergence herbicide after hand weeding (T_2), Two hand weeding at 20 and 40 DAT (T_3), Pre-emergence herbicide followed by one hand weeding at 20 DAT (T_4), Pre-emergence herbicide followed by one hand weeding at 40 DAT (T_5), Post-emergence herbicide + one hand weeding at 40 DAT (T_6), Pre-emergence herbicide + post-emergence herbicide (T_7), Pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT (T_8) and Weed free throughout the growth period (T_9). The experiment was laid out in a one factor randomized complete block design with four replications. The size of a unit plot was 4.0 m × 2.5 m (10 m^2). The spacing between the unit plots was 50 cm and that between the blocks was 1.0 m.

Description of herbicides

A short description of herbicides that were used in the experiment is given in the Table 1.

Healthy seeds were selected by specific gravity method. Seeds were then immersed in water in bucket for 24 hours. Then seeds were taken out of water and kept thickly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours on 1 December, 2013 with proper care. The land was first opened with a tractor drawn disc plough on 29 December, 2013. The land was then puddled thoroughly by repeated ploughing and cross ploughing with a country plough and subsequently leveled by laddering. The field layout was made on 8 January, 2014 according to experimental specification immediately after final land preparation. Weeds and stubbles were cleared off from individual plots and finally plots were leveled properly by wooden plank so that no water pocket could remain in the field. The land was fertilized with urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate @ 250 kg, 120 kg, 120 kg, 100 kg, 10 kg ha^{-1}, respectively. The whole amount of triple super phosphate, muriate of potash, gypsum, zinc sulphate were applied at the time of final land preparation. Urea was applied in 3 equal split at 10, 30 and 45 DAT. Seedlings were transplanted on 9 January, 2014 using two seedlings $hill^{-1}$ with 25 cm × 15 cm spacing between the rows and hills, respectively. The gaps were filled up with the seedlings from the same source. Weeding was done as per experimental specification. Flood irrigation was given to maintain a level of standing water up to 2-4 cm till maximum tillering stage and after that, a water level of 7-10 cm was maintained up to grain filling stage and then drained out after milk stage to enhance maturity. The crop was attacked by yellow rice stem borer (*Scirpopaga incertulas*) at the panicle initiation stage which was successfully controlled with Sumithion @ 1.5 L ha^{-1}. Four hills were randomly selected from each plot (excluding boarder rows and central 1 m^2) and uprooted to record data on crop characters and yield components. After sampling, the whole plot was harvested on 7 May, 2014 when 90% of the seeds became golden yellow in colour. At maturity, one square meter area from each plot was selected from the central portion and was cut manually from the ground level to take grain and straw yields. The harvested crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. The harvested crops were threshed manually. The grain was cleaned and dried to a moisture content of 14 %. Straws were sun dried properly. Final grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}. Harvest index was calculated using the following formula.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Table 1. Short description of herbicides that were used in the experiment.

Trade name	Common name	Mode of action	Selectivity	Time of application
Panida 33 EC	Pendimethalin	Systematic	Selective for potato and rice	Pre-emergence (3 DAT)
Granite 240 SC	Penoxulam	Systematic	Selective for rice	Post-emergence (12 DAT)

Weed parameter

The 1st data on weed infestation was taken from the plots where T_2, T_3 and T_4 treatments were applied at 20 DAT of rice plant. The 2nd data on weed infestation was taken from the plots where T_3, T_5, T_6 and T_8 treatments were applied at 40 DAT of rice plant. The 3rd data on weed infestation was taken from each of the unit plot as per treatments at dough stage of rice plant. The data were taken by 0.25 m^2 quadrate from two places of each plot at random.

The weeds infested in each plot were identified species-wise and their density per square meter was counted. The density of weed was determined using a quadrate of 0.25 m^2 in two places at random in each plot. The average number of two samples was converted to no. m^{-2}. The weeds inside each quadrate for density count were uprooted, cleaned and separated. The collected weeds were dried in an electrical oven for 72 hours maintaining a constant temperature of 80°C. After drying, weight of dried weeds were taken and converted to g m^{-2}. The plants at dough stage inside quadrate (0.25 m^2) were uprooted. The roots of each plant were removed. Then the plants were washed with tap water and the plant samples were packed in labeled brown paper bags and dried in the oven at 85±5°C for 72 hours until constant weight was reached. The dried samples were weighed carefully and converted to t ha^{-1}.

Statistical analysis

The recorded data were compiled and subjected to statistical analysis. Analysis of variance was done following randomized complete block design with the of computer package MSTAT. The mean differences among the weed control treatments were adjudged by Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Infested weed species in the experimental field

Thirteen weed species infested the experimental field which belongs to seven families. Among these species 5 belonged to Gramineae, 3 Cyperaceae, 2 Pontederiaceae and 1 from Oxalidaceae, Araceae. The most important weed in the experimental plots were *Scirpus juncoides*, *Echinochloa crusgalli* and *Monochoria hastata*. Weeds grown in the experimental plot were grass, broad-leaved, sedge type. The particulars of weeds common name, english name, scientific name, family name and life cycle have been presented in Table 2.

Effect of weed control treatments on weed density

Weed density was influenced by different weed control treatments as recorded at 20 DAT, 40 DAT and at harvest of the rice plot (Table 3 and 4). The highest weed density was observed in the unweeded treatment and the lowest weed density was observed at weed free treatment. This result is agreement with the findings of Rekha *et al.* (2002). The weed population at harvest was higher than that of the population at 20 DAT and 40 DAT. *Scirpus juncoides*, *Echinochloa crusgalli* and *Monochoria hastate* were the most important weeds in experimental plot. Among these *Echinochloa crusgalli*, *Monochoria hastate* were significantly controlled by pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT. But the infestation of *Scirpus juncoides* was so high that no control measures were effective to control this weed species.

Effect of weed control treatment on weed dry weight

Weed dry weight was influenced by weed control treatment (Table 5). The highest weed dry weight (183.14 g m^{-2}) was observed in the unweeded treatment and the zero dry weight of weed was observed at weed free treatment. This result is agreement with the findings of Jena *et al.* (2002). It was also found-that the pre-emergence herbicide and post-emergence herbicides when supplemented with one hand weeding at 40 DAT gave lower dry weight (34.76 g m^{-2}) of weed and pre-emergence herbicide when supplemented with one hand weeding at 40 DAT gave lower dry weight (35.71 g m^{-2}) of weed were more effective than other weed control treatments. The weed population at harvest was higher than that of the population at 20 DAT and 40 DAT.

Table 2. List of weed species in the experimental field.

Common Name	English name	Scientific name	Family name	Life cycle
Panikachu	Pickerel weed	*Monochoria vaginalis* (Burm. f.) Presl.	Pontederiaceae	Perennial
Holde mutha	Yellow nutsedge	*Cyperus esculentus* L.	Cyperraceae	Perennial
Angta	Torpedo grass	*Panicum repens* L.	Gramineae	Perennial
Bara Shama	Barnyard grass	*Echinochloa crusgalli* L. Beauv.	Gramineae	Annual
Arail	Swamp rice grass	*Leersia hexandra* Sw.	Gramineae	Perennial
Joina	Globe fringerush	*Fimbristylis milliaceae* L. Vahl	Cyperaceae	Annual
Chesra	Bulrush	*Scirpus juncoides* Roxb.	Cyperacea	Annual
Amrul	Yellow wood sorrel	*Oxalis europaea* Jord.	Oxalidaceae	Annual
Chela ghash	Curved sickle grass	*Parapholis incurva* (L.) C.E. Hubb	Gramineae	Annual
Topapana	Water lettuce	*Pistia stratiotes* Var.	Araceae	Perennial
Anguli ghash	Crab grass	*Digitaria sanguinalis* L. Scop.	Gramineae	Annual
Motka	Bushy matgrass	*Lippia germinata* H.B.K.	Verbenaceae	Annual
Kachuripana	Water hyacinth	*Eichhornia crassipes* (Mart.) Solms	Pontederiaceae	Perennial

Table 3. Weed density (no. m^{-2}) at 20 DAT and 40 DAT.

Weed Species	At 20 DAT			At 40 DAT			
	T_2	T_3	T_4	T_3	T_5	T_6	T_8
Echinochloa crusgalli L. Beauv	65.00	38.00	3.00	44.00	-	17.00	143.50
Scirpus juncoides Roxb.	36.50	23.00	34.50	82.75	8.25	5.00	-
Monochoria hastate L.	-	-	0.50	4.00	-	-	-
Panicum repens L.	3.00	5.00	4.50	-	10.50	4.50	2.50
Leersia hexandra Sw.	-	-	-	-	0.50	-	-
Oxalis europaea Jord.	1.50	-	-	-	-	0.50	-
Pistia stratiotes Var.	1.50	2.50	1.50	-	-	-	-
Digitaria sanguinalis L.	0.50	0.50	0.50	-	-	-	-

Treatments: T_1: Unweeded, T_2: One hand weeding at 20 DAT + pre-emergence herbicide after hand weeding, T_3: Two hand weeding at 20 and 40 DAT, T_4: Pre-emergence herbicide followed by one hand weeding at 20 DAT, T_5: Pre-emergence herbicide followed by one hand weeding at 40 DAT, T_6: Post-emergence herbicide + one hand weeding at 40 DAT, T_8: Pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT.

Table 4. Weed density (no. m^{-2}) at dough stage of plant.

Weed Species	Treatment							
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Echinochloa crusgalli L. Beauv	41.50	11.00	10.00	7.50	5.50	13.00	5.50	2.50
Scirpus juncoides Roxb.	47.50	42.62	46.00	90.50	44.00	32.50	61.50	49.00
Monochoria hastate L.	41.00	39.00	48.50	16.50	12.00	26.50	12.00	11.00
Cyperus esculentus L.	0.50	1.00	-	-	0.50	0.50	-	-
Panicum repens L.	0.50	1.00	-	-	3.00	1.00	4.00	0.50
Leersia hexandra Sw.	1.50	-	-	-	3.00	1.50	2.50	-
Oxalis europaea Jord.	1.00	-	1.50	-	-	3.00	0.50	0.50
Parapholis incurva (L.) C. E. Hubb	1.00	-	-	-	-	-	-	-
Pistia stratiotes Var.	3.50	-	-	6.00	3.00	-	1.50	6.00
Digitaria sanguinalis L.	3.50	-	-	-	-	0.50	1.00	1.50
Lippia germinata H.B.K.	-	-	1.00	-	-	1.00	0.50	1.00

Table 5. Weed dry weight (g m^{-2}) at different stages.

Treatment	20 DAT	40 DAT	At dough stage
T_1	-	-	183.14
T_2	2.35	-	123.48
T_3	1.86	10.86	75.14
T_4	2.27	-	91.19
T_5	-	8.37	35.71
T_6	-	9.54	49.56
T_7	-	-	66.84
T_8	-	5.53	34.76
T_9	-	-	-

Treatments: T_1: Unweeded, T_2: One hand weeding at 20 DAT + pre-emergence herbicide after hand weeding, T_3: Two hand weeding at 20 and 40 DAT, T_4: Pre-emergence herbicide followed by one hand weeding at 20 DAT, T_5: Pre-emergence herbicide followed by one hand weeding at 40 DAT, T_6: Post-emergence herbicide + one hand weeding at 40 DAT, T_7: Pre-emergence herbicide + post-emergence herbicide, T_8: Pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT, T_9: Weed free throughout the growth period.

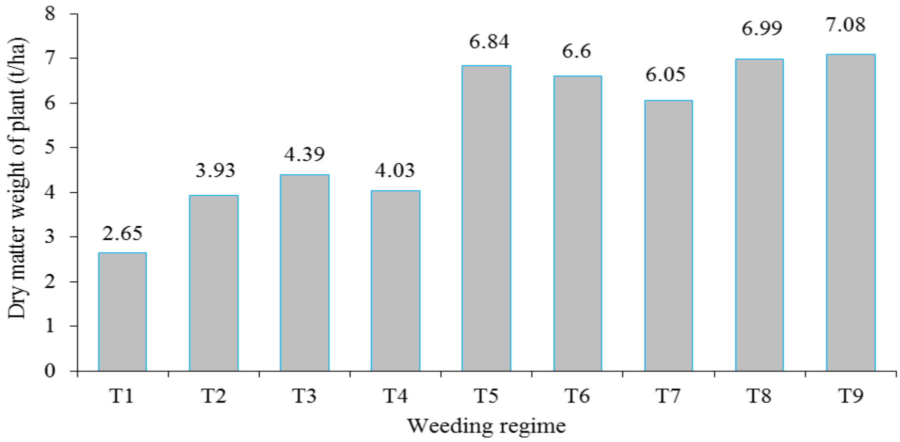

Figure 1. *Effect of weeding regime on dry matter weight (t ha^{-1}) of plant at dough stage of aromatic Boro rice (cv. BRRI dhan50).*

Treatments: T_1: Unweeded, T_2: One hand weeding at 20 DAT + pre-emergence herbicide after hand weeding, T_3: Two hand weeding at 20 and 40 DAT, T_4: Pre-emergence herbicide followed by one hand weeding at 20 DAT, T_5: Pre-emergence herbicide followed by one hand weeding at 40 DAT, T_6: Post-emergence herbicide + one hand weeding at 40 DAT, T_7: Pre-emergence herbicide + post-emergence herbicide, T_8: Pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT, T_9: Weed free throughout the growth period.

Table 6. Effect of weeding regime on crop characters, yield components and yield of aromatic *Boro* rice (cv. BRRI dhan50).

Treatment	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	No. of total spikelets panicle^{-1}	No. of grains panicle^{-1}	No. of sterile spikelets panicle^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Yield loss (%)	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)	Benefit Cost Ratio (BCR)
T_1	8.07d	5.88e	2.19a	19.75	87.15d	80.48c	6.67c	17.97c	2.58g	56.42	3.87e	6.45g	40.00e	1:40
T_2	9.07bc	6.94d	2.13a	20.33	89.14cd	81.91c	7.23bc	17.99c	3.13f	47.13	4.50d	7.63f	41.02de	1:58
T_3	9.19abc	7.44d	1.75b	20.40	92.40bc	84.55bc	7.85b	18.77b	3.78e	36.42	5.25c	9.03e	41.86cde	1:65
T_4	8.87cd	7.06d	1.81b	20.34	91.88bc	84.52bc	7.36bc	18.72b	3.25f	45.10	4.64d	7.89f	41.19cde	1:43
T_5	10.06a	8.81ab	1.25d	20.97	97.54a	88.62ab	8.92a	19.03ab	5.31b	10.31	6.53b	11.85bc	44.66ab	2:25
T_6	9.87ab	8.37bc	1.50c	20.78	96.34ab	87.48ab	8.86a	18.99ab	4.87c	17.74	6.38b	11.26c	43.25bc	2.00
T_7	9.88ab	8.12c	1.75b	20.55	92.96bc	85.00bc	7.96b	18.79b	4.31d	27.20	5.73c	10.04d	42.93bcd	1.88
T_8	10.00ab	8.814ab	1.19d	20.99	99.77a	90.36a	9.42a	19.07ab	5.46b	7.77	6.68ab	12.15b	44.94ab	2:28
T_9	10.13a	9.19a	0.94e	21.12	99.88a	90.41a	9.47a	19.51a	5.92a	0.00	7.13a	13.06a	45.33a	1:93
Level of significance	**	**	**	NS	**	**	**	**	**	-	**	**	**	-
CV (%)	6.36	4.19	6.67	3.67	3.14	3.41	7.21	1.83	5.47	-	6.64	4.54	3.16	-

Figures in a column, having the same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant.

Treatments: T_1: Unweeded, T_2: One hand weeding at 20 DAT + pre-emergence herbicide after hand weeding, T_3: Two hand weeding at 20 and 40 DAT, T_4: Pre-emergence herbicide followed by one hand weeding at 20 DAT, T_5: Pre-emergence herbicide followed by one hand weeding at 40 DAT, T_6: Post-emergence herbicide + one hand weeding at 40 DAT, T_7: Pre-emergence herbicide + post-emergence herbicide, T_8: Pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT, T_9: Weed free throughout the growth period.

Dry matter weight of plant at dough stage

The weed control treatment exerted significant effect on the dry matter weight of plant at dough stage (Figure 1). The highest dry matter weight (7.08 t ha^{-1}) was produced by weed free throughout the growth period which was statistically identical with pre-emergence herbicide followed by one hand weeding at 40 DAT, Post-emergence herbicide + one hand weeding at 40 DAT and pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT. The lowest dry matter weight (2.65 t ha^{-1}) was obtained from unweeded treatment, which was significantly lower than the rest of the treatments. Similar results were obtained by Islam *et al.* (2014).

Crop characters, yield components and yield

Crop characters, yield components and yield of BRRI dhan50 were significantly influenced by different weed control treatments have been presented in Table 6.

The highest number of tillers (10.13) was obtained in weed free throughout the growth period, which was statistically identical with two hand weeding at 20 DAT + 40 DAT, pre-emergence herbicide followed by one hand weeding at 40 DAT, post-emergence herbicide + one hand weeding at 40 DAT, pre-emergence herbicide + post-emergence herbicide, pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT. The lowest number of tillers (8.07) was obtained in unweeded treatment (Table 6). This result is agreement with the findings of Ahmed *et al.* (1998). The highest number of effective tillers hill^{-1} (9.19) was obtained from the plots weed free throughout the growth period, which was statistically identical with pre-emergence herbicide followed by one hand weeding at 40 DAT and pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT. The lowest one (5.88) was obtained in unweeded plots (Table 6). Similar results were reported elsewhere (Khan, 2013; Zannat *et al.*, 2014; Islam *et al.*, 2015 and Sinha *et al.*, 2018). The highest number of non-effective tillers hill^{-1} (2.19) was observed in unweeded treatment, which was statistically identical with one hand weeding at 20 DAT + pre-emergence herbicide after hand weeding. The lowest number of non-effective tillers hill^{-1} (0.94) was observed in weed free treatment throughout the growth period (Table 6). Numerically the longest panicle was observed in weed free throughout the growth period (21.12 cm) and the shortest panicle was observed under unweeded treatment (19.75 cm) (Table 6). This result is agreement with the findings of Sinha *et al.* (2018). The total number of spikelets panicle^{-1} was the highest (99.88) in the treatment weed free throughout the growth period, which was statistically identical with pre-emergence herbicide followed by one hand weeding at 40 DAT, post-emergence herbicide + one hand weeding at 40 DAT, pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT. The lowest number of spikelets panicle^{-1}(87.15) was produced in unweeded treatment, which was statistically identical with one hand weeding at 20 DAT + pre-emergence herbicide after hand weeding (Table 6). This result is agreement with the findings of Singh *et al.* (2005). The highest number of grains panicle^{-1} (90.41) obtained from the plots weed free throughout the growth period, which was statistically identical with pre-emergence herbicide followed by one hand weeding at 40 DAT, post-emergence herbicide + one hand weeding at 40 DAT, pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT. The lowest number of grains panicle^{-1} (80.48) was obtained in the unweeded treatment, which was statistically identical with one hand weeding at 20 DAT + pre-emergence herbicide after hand weeding, two hand weeding at 20 DAT + 40 DAT, pre-emergence herbicide followed by one hand weeding at 20 DAT (Table 6). Similar results were reported elsewhere (Khan, 2013; Zannat *et al.*, 2014 and Islam *et al.*, 2015). The highest number of sterile spikelets panicle^{-1} (9.47) was found from weed free throughout the growth period, which was statistically identical with pre-emergence herbicide followed by one hand weeding at 40 DAT, post-emergence herbicide + one hand weeding at 40 DAT and pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT. The lowest number of sterile spikelets panicle^{-1} (6.67) was obtained from unweeded condition period, which was statistically identical with one hand weeding at 20 DAT + pre-emergence herbicide after hand weeding and pre-emergence herbicide followed by one hand weeding at 20 DAT (Table 6). The highest 1000-grain weight (19.51 g) was found from weed free throughout the growth period, which was statistically identical with pre-emergence herbicide followed by one hand weeding at 40 DAT, post-emergence herbicide + one hand weeding at 40 DAT and pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT. The lowest 1000-grain weight (17.97 g) was obtained from unweeded treatment, which was statistically identical with one hand weeding at 20 DAT + pre-emergence herbicide after hand weeding (Table 6). This result is agreement with the findings of Ganeshwor and Gadadhar (2000). Among the weed control treatments, the highest grain yield (5.92 t ha^{-1}) was produced by weed free throughout the growth period followed by pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT (5.46 t ha^{-1}). The lowest grain yield (2.58 t ha^{-1}) was obtained from unweeded treatment, which was significantly lower than the rest of the treatments. Grain yield reduced by 56.42% in control (unweeded) plots over weed free throughout the growth period (Table 6). This result is agreement with the findings of Sinha *et al.* (2018), who reported that weed infestation reduced drastically reduced grain yield by 59.82% in BRRI dhan50. The highest straw yield (7.13 t ha^{-1}) was found from weed free throughout the growth period followed by pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT (6.68 t ha^{-1}) and this two treatments were statistically identical. The lowest straw yield (3.87 t ha^{-1}) was obtained from no weeding condition (Table 6). This result is agreement with the findings of Sinha *et al.* (2018). The highest biological yield (13.06 t ha^{-1}) was found from weed free throughout the growth period followed by pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT (12.15 t ha^{-1}). The lowest biological yield (6.45 t ha^{-1}) was obtained from no weeding condition (Table 6). The highest harvest index (45.33%) was found in weed free throughout the growth period, which was statistically identical with pre-emergence herbicide followed by one hand weeding at 40 DAT and pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT. The lowest harvest index (40.00%) was found from no weeding treatment (Table 6). Similar results were obtained by Zannat *et al.* (2014) and Islam *et al.* (2015). The highest benefit cost ratio (2.28) was obtained from pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT.

Relationship between dry matter weight of plants and grain yield

Relationship between dry matter weight of plants and grain yield was shown in the graph (Figure 2). Dry matter weight of plants was recorded in dough stage of the plant. A significant relationship was observed in grain yield and dry matter weight of plants. Grain yield increases progressively with the increase in dry matter weight of plant could be adequately described by regression equation Y = 0.6907x + 0.5624 (R^2 = 0.974). The functional relationship indicates that 97% of the variation in grain yield could be explained from the variation in matter production of plant at dough stage. Similar result was reported by Ray *et al.* (2015)

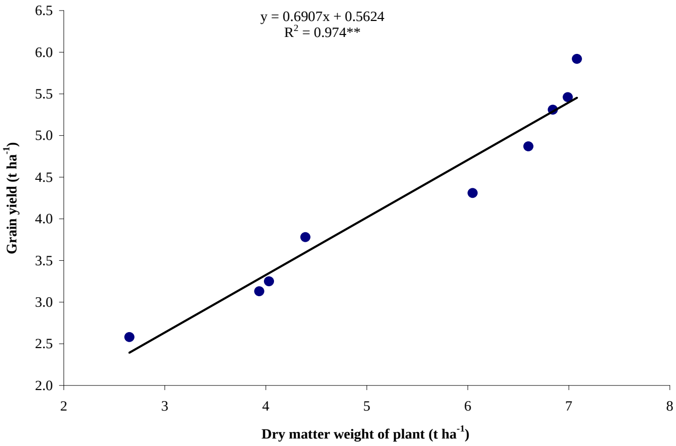

Figure 2. *Relationship between dry matter weight of plants at dough stage and grain yield of aromatic Boro rice (cv. BRRI dhan50).*

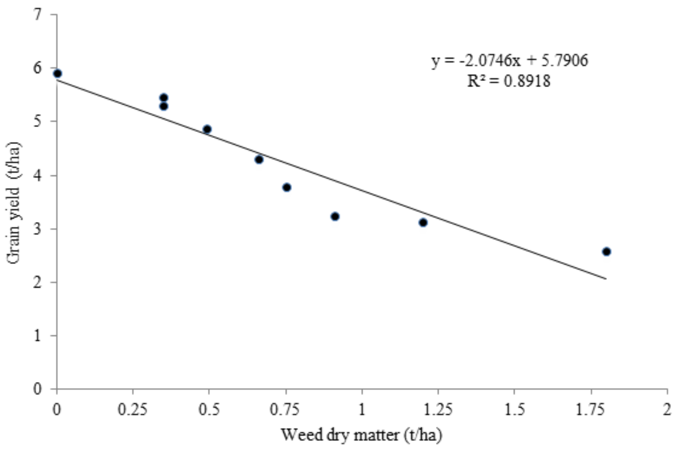

Figure 3. *Relationship between dry matter weight of weeds at dough stage and grain yield of aromatic Boro rice (cv. BRRI dhan50).*

Relationship between dry matter weight of weeds and grain yield

Relationship between dry matter weight of weeds and grain yield was shown in the graph (Figure 3). A reciprocal relationship was observed between dry matter weight of weeds at dough stage and grain yield of *Boro* rice. Dry matter weight of weeds was recorded at 20 DAT, 40 DAT and dough stage of the plant. Grain yield decreased due to increase in dry matter weight of weeds. The response of weed dry matter production to the grain yield of rice followed a linear negative relationship which could be adequately described by regression equation Y = -2.0746x + 5.7906 (R^2 = 0.8918). The functional relationship indicates that 89% of the variation in grain yield could be explained from the variation in weed dry matter production at dough stage. 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

Weeding regime has significant influence on yield and yield contributing characters of aromatic rice. The tallest plant, the highest number of total tillers hill^{-1}, number of effective tillers hill^{-1}, grains panicle^{-1}, 1000 grain weight, grain yield and straw yields were obtained from weed free treatment. From the present study it can be concluded that weed free throughout the growth period had pronounced influence on yield of aromatic *Boro* rice followed by pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT. However, the highest benefit cost ratio was obtained from pre-emergence herbicide + post-emergence herbicide + one hand weeding at 40 DAT. Therefore, application of pre-emergence herbicide (Panida @ 2.5 L ha^{-1}) followed by post-emergence herbicide (Granite @ 93.70 ml ha^{-1}) + one hand weeding at 40 DAT appears as the promising technique for controlling weeds in aromatic *Boro* rice (cv. BRRI dhan50) cultivation in Bangladesh.

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