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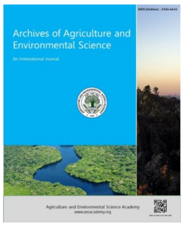

ORIGINAL RESEARCH ARTICLE

Effectiveness of integrated weed management in five varieties of aromatic rice in Bangladesh

Md. Azhiat-Ul Huq Hia, A.K.M. Mominul Islam*, Shubroto Kumar Sarkar and Md. Parvez Anwar

Weed Management Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh-2202, BANGLADESH
*Corresponding author's E-mail: akmmominulislam@bau.edu.bd

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ABSTRACT

An experiment was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh to evaluate the efficacy, rice selectivity and cost-effectiveness of some integrated weed control methods on the productivity of aromatic rice under randomized complete block design with three replications. The experiment consisted of five aromatic rice varieties; Kalijira, BRRI dhan34, BRRI dhan37, BRRI dhan38 and Binadhan-13, and six different weed management practices comprising no weeding, weed free, mechanical + manual weeding, pre–emergence herbicide + manual weeding, post–emergence herbicide + manual weeding, pre– + post–emergence herbicide. Ten weed species belonging to five families infested the experimental plots. Herbicide treatments provided excellent weed control efficiency and produced much higher net benefit and cost benefit ratio than weedy plot. Among the herbicidal and mechanical treatments, sequential application of Bensulfuran methyl + Acetachlor at early growth stage (pre-emergence herbicide) followed by Pyrazosulfuran ethyl at mid growth stage (post-emergence herbicide) provided the highest weed control efficiency, productivity and net benefit. Single application of Pyrazosulfuran ethyl at mid growth stage followed by one hand weeding performed very close to the pre– + post–emergence herbicide application in terms of productivity and net benefit but in terms of weed control efficiency at 45 days after transplanting application of Bensulfuran methyl + Acetachlor at early growth stage followed by one hand weeding performed very close to pre– + post–emergence herbicide application. Mechanical weeding followed by one hand weeding and application of Bensulfuran methyl + Acetachlor at early growth stage followed by one hand weeding also provided satisfactory results in terms of productivity and economic return. Since manual weeding was less economic, sequential application of pre- and post-emergence herbicides may be recommended for effective weed management in aromatic rice.

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INTRODUCTION

Thousands of rice land races are considered to exist in Bangladesh (Haque and Miah, 1990). Each of them possesses some special characteristics. Only some of these are unique for quality traits including fineness, aroma, taste and protein contents. Bangladesh has a stock of above 8,000 rice germplasms of which nearly 100 are aromatic (Islam *et al.,* 2016). Cultivation of this rice has been gaining popularity in the country over the recent years, because of its huge demand both for internal consumption and export (Das and Baqui, 2000). About 27% of the total rice cropped area (BBS, 2003), and 12.5% of the total monsoon rice (BBS, 2005) are occupied by aromatic fine rice varieties of Bangladesh. Moreover, the production of aromatic fine rice is profitable due to its high price over low price coarse milled rice (Raju and Reddy, 2000; Sikdar *et al.,* 2008). Recently, some aromatic fine rice varieties being cultivated in Bangladesh are of international standard and attracting the buyers in the global markets. However, the yield of aromatic rice was lower (1.5–2.0 t ha^{-1}) than the coarse rice (Islam *et al.,* 2010).

Weeding has a great influence on the performance of the associated crop (Kumar and Chopra, 2013, 2016). Thus the best weeding practice needs to be adopted by the farmers with a view to reducing weed infestation and maximizing rice yield. Mechanical and manual methods of weed controls are mainly practiced by the farmers that are very much laborious and time consuming (Kumar and Chopra, 2013, 2016). Moreover, the availability of labor is decreasing due to the out migration of agricultural labors to industries with higher wages than agriculture, increases the need of using herbicides. Use of herbicides may be an alternative method in controlling weeds more easily and effectively at low cost (Rashid *et al.,* 2007). But no single herbicide can control all weeds effectively in all environments. To date very few studies have been conducted to find out the best weed management practices for aromatic rice. On the other hand, a suitable combination of variety and weed management practices might be helpful to increase the yield of aromatic rice. Information on the varietal performance of aromatic rice and its management practices are sporadic and scattered (Raju and Reddy, 2000; Rashid *et al.,* 2007; Islam *et al.,* 2010, 2016). In this backdrop, the current research was undertaken to evaluate the efficacy and economics of some integrated weed control methods on the productivity of some selected aromatic rice varieties of Bangladesh grown in monsoon season.

MATERIALS AND METHODS

Experimental site and crop husbandry: The experiment was carried out at the Agronomy Field Laboratory (24°75' N latitude and 90°50' E longitude), Bangladesh Agricultural University, Mymensingh, Bangladesh. The soil is characterized by non-calcareous dark gray floodplain soils having pH value of 6.5. During the growing season (July–December, 2015), monthly average maximum temperature, minimum temperature, relative humidity, air pressure, wind speed, solar radiation, dew point, pan evaporation and water temperature were 29 °C, 20 °C, 85%, 1006 mb, 6 km h^{-1}, 271 W m^{-2}, 21 °C, 3 mm and 23°C, respectively, while monthly total rainfall and sunshine hours were 0–387.9 mm and 84.4–205.9 h, respectively. The average soil temperature at a depth of 5, 10, 20 and 30 cm were 29, 27, 27 and 25°C, respectively. The experiment was laid out in randomized complete block design with three replications. The experiment was conducted with five aromatic rice varieties *viz.,* Kalijira, BRRI dhan34, BRRI dhan37, BRRI dhan38 and Binadhan-13, and six weed management practices namely; no weeding, weed free, mechanical (by using weeder) + manual (hand pooling) weeding, pre-emergence herbicide + manual weeding, post-emergence herbicide + manual weeding, pre-emergence herbicide + post-emergence herbicide during the crop growth period. Here, bensulfuran methyl + acetachlor @ 750 g ha^{-1} was used as pre-emergence herbicide and pyrazosulfuran ethyl @ 125-150 g ha^{-1} was used as post-emergence herbicide. After subsequent ploughing followed by laddering, the land was fertilized with 150, 97, 70, 60 and 12 kg ha^{-1} urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate, respectively. All the fertilizers except urea was applied in the unit plots at the time of final land preparation; while urea was top-dressed in three equal splits at 30, 50 and 70 days after transplanting (DAT). Thirty five days old seedlings of aromatic rice varieties were transplanted at the rate of two to three seedlings $hill^{-1}$ maintaining row and hill spacing of 25 cm and 15 cm, respectively. Other intercultural operations were done properly as per standard practices. Pre-emergence herbicide (bensulfuran methyl + acetachlor @ 750 g ha^{-1}) was applied to the target plots at 5 days after transplantation (DAT) and post-emergence herbicide (pyrazosulfuran ethyl @ 125-150 g ha^{-1}) was applied to the target plots at 30 DAT. The data of weed parameters were collected at 45 DAT, 65 DAT and 85 DAT of rice plants.

The relative density and dry weight, summed dominance ratio of weeds were obtained using the following formula by Janiya and Moody (1989).

$$\text{Relative density of weed}=\frac{\text{Density of a given weed}}{\text{Total weed density}}\times 100$$

$$\text{Relative dry weight of weed}=\frac{\text{Dry weight of a given weed species}}{\text{Total weed dry weight}}\times 100$$

$$\text{Summed dominance ratio}=\frac{\text{Relative density+Relative dry weight}}{2}\times 100$$

Weed control efficiency (WCE) was determined by the formula stated in Bangi *et al.* (2014).

$$\text{Weed control efficiency (WCE)}=\frac{\text{WDC-WDT}}{\text{WDC}}\times 100$$

Where,
WDC = weed dry mass from the control plot
WDT = weed dry mass from the treated plot
Weed index (WI) was determined by the following formula stated in Bangi *et al.* (2014).

$$\text{Weed index (WI)}=\frac{\text{X-Y}}{\text{X}}\times 100$$

Where,
X= total yield from the weed free check
Y= total yield from the treatment for which weed index has to be calculated

Relative yield loss (RYL) and yield increase over control (YOC) were calculated using the following formula:

$$\text{RYL (\%)}=\frac{\text{Weed fre yield-Treatment yield}}{\text{Weed free yield}}\times 100$$

$$\text{YOC (\%)}=\frac{\text{Treatment yield-Weedy yield}}{\text{Weedy yield}}\times 100$$

Five hills (excluding border hills) were randomly selected in each plot and uprooted before harvesting for recording the necessary data. The crop was threshed by pedal thresher and grains were sun dried and cleaned. Final grain weight was adjusted to 14% moisture content using the following formula.

$$\text{Moisture (\%)}=\frac{\text{Fresh weight-Oven dry weight}}{\text{Fresh weight}}\times 100$$

$$\text{Adjusted yield at 14\% moisture content (MC)}=\frac{100-\%MC}{86\,(100-14)}\times \text{Fresh weight}$$

The cost of individual head of expenditure was recorded and partial budget analysis was done. The budget consists of the variable cost, gross return, net income and benefit cost ratio.

Statistical analysis of data: The collected data were compiled and tabulated in proper form and were subjected to statistical analysis. Data were analyzed using the analysis of variance (ANOVA) technique with the help of computer package program MSTAT and mean differences were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Weed composition: The experimental field was infested with the naturally occurring weed community of grass, broad leaved and sedge families. Ten weed species belonging to five families (5 grasses, 3 broad leaved and 2 sedges) were found growing on the field (Table 1). Among the weeds, grasses constituted about 53.6% RD and 72.7% RDW, followed by broad leaved species (33.3% RD and 20.2% RDW) and sedges (12.9% RD and 7.0% RDW) (Figures 1 and 2). Based on the summed dominance ratio (SDR) values, grass weed species *Echinochloa crusgalli* (SDR of 42.5) was the most dominant species in the weedy plot followed by the broadleaf weed *Monochoria vaginalis* (SDR of 25.1). On the other hand, the least dominant weed species of the experimental plot was broadleaf weed *Nymphaea nouchali* (SDR of 0.83) followed by broadleaf weed species *Marsilea crenata* (SDR of 0.95) (Table 1).

The results indicate that weedy plot was mostly infested with grasses than broad leaved or sedge weeds. This might be due to the availability of moisture on the field during the experiment because rice weed community is strongly influenced by soil moisture as reported by *Juraimi et al.* (2009). Bhagat *et al.* (1999) also recorded the dominance of grasses under higher moisture regimes. According to the SDR values, the grasses were found more aggressive on the study. The variations in the floristic composition and dominance pattern of weeds might be due to the differences in the agro-ecological conditions, cropping pattern, management practices, and weed seed bank composition (Juraimi *et al.,* 2010).

Total weed density: The highest weed density at all DATs was observed in Kalijira whereas the lowest ones in BRRI dhan38 (Table 2). At 45 DAT, the highest weed density (35.6 m^{-2}) was found in Kalijira and lowest one (11.9 m^{-2}) was found in BRRI dhan38 which was statistically identical to BRRI dhan34 (13.3 m^{-2}). At 85 DAT, the highest weed density (11.2 m^{-2}) was found in Kalijira which was statistically identical to Binadhan-13 (10.4 m^{-2}) and lowest one (5.5 m^{-2}) was found in BRRI dhan38 (Table 2). It was evident that higher weed density (no. m^{-2}) was observed in the local variety Kalijira and lower weed density (no. m^{-2}) was observed in the variety BRRI dhan38. Variation of weed population due to variety was also reported by Faruk *et al.* (2013).

No weed was found in the weed free plot at all DATs as no weeds were allowed to grow as per treatment specification. Among the other treatments, the weedy plot treatment gave the highest weed density at all DATs whereas, the lowest one in pre + post-emergence herbicide treatment (Table 3). At 45 DAT, the highest weed density (45.6 m^{-2}) was found in weedy plot and the lowest weed density (10.7 m^{-2}) was found in pre + post-emergence herbicide treatment which was statistically identical to pre-emergence herbicide + manual weeding (12.6 m^{-2}) (Table 3). At 85 DAT, the highest weed density (14.8 m^{-2}) was found in weedy plot and the lowest weed density (8.4 m^{-2}) was found in pre + post-emergence herbicide treatment which was statistically identical to pre-emergence herbicide + manual weeding treatment (9.3 m^{-2}) (Table 3). Rekha *et al.* (2002) also reported that weed density was lower in all weeding practices compared to the unweeded control plot.

In the interaction the highest weed densities 82.0 m^{-2}, 38.7 m^{-2} and 38.7 m^{-2} were found in BRRI dhan34 × weedy plot at 45, 65 and 85 DAT, respectively (Table 4). Mokhlesur (2014) also reported that the highest weed density was found in the interaction between no weeding plot and the cultivar. The lowest weed density (4.20 m^{-2}) at 45 DAT was found in Kalijira × pre-emergence herbicide + manual weeding, which was statistically identical with BRRI dhan38 × pre-emergence herbicide + manual weeding (5.00 m^{-2}), BRRI dhan38 × pre + post-emergence herbicide (5.33 m^{-2}), BRRI dhan37 × pre-emergence herbicide + manual weeding (6.00 m^{-2}), BRRI dhan37 × pre- + post-emergence herbicide (6.33 m^{-2}), BRRI dhan37 × pre- +post emergence herbicide (6.67 m^{-2}), BRRI dhan38 × post-emergence herbicide + manual weeding (7.33 m^{-2}) and Kalijira × post-emergence herbicide + manual weeding (Table 4).

Weed dry weight: The results exposed that at all DATs, the highest weed dry weights were found in Kalijira whereas the lowest in BRRI dhan38 (Table 2). The highest weed dry weights 22.70 g m^{-2}, 150.50 g m^{-2} and 58.99 g m^{-2} were found in Kalijira at 45, 65 and 85 DAT, respectively and the lowest values (3.47 g m^{-2}, 58.95 g m^{-2} and 25.00 g m^{-2}) for the same parameter at the same DATs respectively were observed in BRRI dhan38 (Table 2). Similarly, Mokhlesur (2014) also reported that cultivar has significant effect on weed dry weight (g m^{-2}) at different date of DAT.

Among the treatments except weed free plot, the highest weed dry weight was observed in weedy plot whereas the lowest in pre- emergence herbicide + post-emergence herbicide at all sampling dates (Table 3). The highest total weed dry weights 44.5 g m^{-2}, 194.3 g m^{-2} and 58.48 g m^{-2} at 45, 65 and 85 DATs, respectively were observed in weedy plot. At 45 DAT, the lowest total weed dry weight was observed (3.54 g m^{-2}) in pre + post-emergence herbicide treatment which was statistically identical with pre-emergence herbicide + manual weeding treatment (4.05 g m^{-2}) (Table 3). At 85 DAT, the lowest total weed dry weight was observed (30.1 g m^{-2}) in pre + post-emergence herbicide (Table 3). Similarly Mokhlesur (2014) also reported that cultivar has significant effect on weed dry weight (g m^{-2}) at different DAT and highest weed dry weight (g m^{-2}) was observed in weedy plot or no weeding plot.

At 45 DAT, the highest weed dry weight (113.1 g m^{-2}) was found in Kalijira × weedy plot and the lowest weed dry weight was found (1.2 g m^{-2}) in BRRI dhan34 × pre- + post-emergence herbicide, which was statistically identical with BRRI dhan38 × pre-emergence herbicide + manual weeding (1.5 g m^{-2}), BRRI dhan34 × mechanical weeding + manual weeding (1.5 g m^{-2}), BRRI dhan37 × pre-emergence herbicide + manual weeding (1.8 g m^{-2}) and Binadhan-13 × mechanical + manual weeding (2.0 g m^{-2}) (Table 4). At 85 DAT, the highest weed dry weight (117.0 g m^{-2}) was found in BRRI dhan38×weedy plot and the lowest weed dry weight was found (15.7 g m^{-2}) in BRRI dhan37 × pre-emergence herbicide + manual weeding, which was statistically identical with Kalijira × weedy plot (16.8 g m^{-2}), BRRI dhan37 × pre- + post-emergence herbicide (16.8 g m^{-2}) and Kalijira × pre- + post-emergence herbicide (16.9 g m^{-2}) (Table 4).

Grain yield: BRRI dhan38 produced the highest grain yield (3.35 t ha^{-1}). The lowest grain yield (1.47 t ha^{-1}) was found in Kalijira (Table 2). The findings are parallel with the findings of Sarkar *et al.* (2014), Tyeb *et al.* (2013) and Islam *et al.* (2012), who reported that variety exerted variable effect on the yield of aromatic rice. Varietal variations regarding grain yield might be due to their variation in genetic constituents. The highest grain yield (3.2 t ha^{-1}) was found in weed free treatment. The lowest grain yield (1.4 t ha^{-1}) was found in weedy plot treatment (Table 3). The treatment of pre + post-emergence herbicide gave the second highest grain yield (2.5 t ha^{-1}). Grain yield was significantly affected by interaction of variety and weed management. The highest grain yield (3.7 t ha^{-1}) was found in BRRI dhan38 in weed free treatment which was statistically identical with (3.6 t ha^{-1}) Binadhan-13 in weed free treatment. The lowest grain yield (0.68 t ha^{-1}) was produced by BRRI dhan34 in weedy plot treatment which was statistically identical with Binadhan-13 (1.05 t ha^{-1}) and Kalijira (1.02 t ha^{-1}) in weedy plot (Table 4).

Weed control efficiency (WCE): The highest weed control efficiency (100%) was observed in weed free plot and no weed control efficiency was observed in weedy plot where no weed control measures were taken. Among the other treatments pre + post-emergence herbicide treatment had the highest weed control efficiency in all DAT (Table 5). At 45 DAT, pre + post-emergence herbicide treatment showed the highest WCE (48.59%) followed by pre-emergence herbicide + manual weeding (27.39%) treatment (Table 5). Anwar *et al.* (2012) reported that WCE was considered as the percentage of weed dry weight that is reduced by a particular herbicide treatment in comparison with weedy check. Similarly, Alhassan *et al.* (2015) reported that highest weed control efficiency was observed in weed free plot where manual weeding was performed.

Relative yield loss (RYL) and yield increase over control (YOC): Among the weed management treatments except weedy and weed free plots, pre- + post-emergence herbicide treatment allowed the least yield penalty (21.87%), and pre-emergence herbicide + manual weeding treatment showed the highest value of relative yield loss (35.94 %) whereas, post -emergence herbicide + manual weeding had the highest value of yield increase over control (69.78%), and pre + post-emergence herbicide had the lowest value of yield increase over control (43.88%) (Table 5).

Weed index: The highest weed index (56.56%) was observed in weedy plot treatment (Figure 3). Among the weed management treatments pre + post-emergence herbicide treatments had the lowest value of weed index (21.87%) and pre-emergence herbicide + manual weeding treatments had the highest value of weed index (35.94%). Bangi *et al.* (2014) also found the lowest weed index in weed free plot (Figure 3).

Economics of different weed control treatments: Although, from the partial budget analysis, the highest gross return (Tk. 1,55,480) was found in the weed-free treatment, the highest net income (Tk. 75296) and the highest benefit-cost ratio (2.68) were found in the application of pre- + post-emergence herbicide followed by the treatment of post-emergence herbicide + manual weeding (BCR 2.43) (Table 6). The lowest net income (Tk. 29062) and the lowest BCR (1.67) was found in the weedy plot (Table 6). From present study, it was evident that the application of pre-emergence herbicide (Bensulfuran methyl +Acetachlor@750 g ha^{-1}) + post-emergence herbicide (Pyrazosulfuran ethyl@125-150 g ha^{-1}) was the most profitable treatment because of the highest net income and the highest BCR. Although the maximum gross return was found in weed-free treatment, due to high cost involvement in manual weeding, the net benefit and BCR were low (1.92) (Table 6).

Table 1. Weed composition found in untreated weedy plots of the experimental field with their summed dominance ratio (SDR).

S.N.	Local name	Scientific name	Family	Morphological type	Life cycle	RD (%)	RDW (%)	SDR (%)
1	Shama	*Echinochloa crusgalli* (L.) Beauv.	Gramineae	Grass	Annual	24.19	60.81	42.50
2	Pani kachu	*Monochoria vaginalis* (Burm. F.) C. Presl.	Pontederiaceae	Broad leaved	Perennial	30.24	19.87	25.06
3	Sabuj nakful	*Cyperus difformis*	Gramineae	Grass	Annual	12.90	2.33	7.61
4	Anguli ghash	*Digitaria sanguinalis* L.	Gramineae	Grass	Annual	12.50	0.63	6.56
5	Pani chaise	Eleocharis atropurpurea (Retz.) J. & K. Presl	Cyperaceae	Sedge	Annual	10.48	0.42	5.45
6	Arail	*Leersia hexandra*	Gramineae	Grass	Perennial	1.61	8.28	4.94
7	Bara Chucha	*Cyperus iria*	Cyperaceae	Sedge	Annual	2.42	6.62	4.52
8	Angta	*Paspalum scrobiculatum* L.	Gramineae	Grass	Perennial	2.42	0.69	1.55
9	Sushni shak	*Marsilea crenata*	Marsileaceae	Broad leaved	Annual	1.61	0.29	0.95
10	Shapla	*Nymphaea nouchali*	Nymphaeaceae	Broad leaved	Annual	1.61	0.05	0.83

RD- Relative density, RDW- Relative dry weight.

Table 2. Weed density, weed dry weight and grain yield in aromatic rice as influenced by variety.

Variety	Weed density (no. m^{-2})			Weed dry weight (g m^{-2})			Grain yield (t ha^{-1})
	45 DAT	65 DAT	85 DAT	45 DAT	65 DAT	85 DAT	
Kalijira	35.56a	26.89a	11.22a	22.70a	150.50a	58.99a	1.47d
BRRI dhan34	13.28d	19.89b	9.00b	5.88c	104.41c	38.87c	2.17c
BRRI dhan37	15.83c	14.67c	9.39b	6.30c	119.29b	46.56b	2.33b
BRRI dhan38	11.97d	13.56c	5.50c	3.47d	58.95d	25.00e	3.35a
Binadhan-13	20.11b	13.83c	10.44ab	12.99b	108.42c	33.80d	2.93b
CV (%)	17.6	15.41	15.23	7.31	11.48	13.58	27.66
Level of significance	**	**	**	**	**	**	**

In a column, values having similar letter do not differ significantly whereas values with dissimilar letter differ significantly as per DMRT. **Significant at 1% level of probability.

Table 3. Weed density, weed dry weight and grain yield in aromatic rice as influenced by weed management.

Weed Management	Weed density (no. m^{-2})			Weed dry weight (g m^{-2})			Grain yield (t ha^{-1})
	45 DAT	65 DAT	85 DAT	45 DAT	65 DAT	85 DAT	
Weedy plot	45.60a	23.60a	14.80a	44.48a	194.32a	58.48a	1.39d
Weed free plot		Weed free			Weed free		3.20a
Mechanical weeding + manual weeding	21.47c	20.93b	10.67c	4.75b	121.38b	57.90a	2.18c
Pre-emergence herbicide + manual weeding	12.64d	20.80b	9.33d	4.05c	130.10b	42.46b	2.05c
Post-emergence herbicide + manual weeding	25.66b	21.87ab	11.47b	4.79b	108.29c	54.97a	2.36c
Pre-emergence + post-emergence herbicide	10.73d	19.40b	8.40d	3.54c	95.79d	30.06c	2.50b
CV (%)	17.6	15.41	15.23	7.31	11.48	13.58	7.06
Level of significance	**	**	**	**	**	**	**

In a column, values having similar letter do not differ significantly whereas values with dissimilar letter differ significantly as per DMRT. **Significant at 1% level of probability.

Table 4. Interaction effect of variety and weed management practices on weed density, weed dry weight and yield in aromatic rice.

Interaction		Weed density (no.m^{-2})			Weed dry weight (g m^{-2})			Grain yield (t ha^{-1})
Variety	Weed management	45 DAT	65 DAT	85 DAT	45 DAT	65 DAT	85 DAT	
Kalijira	Weedy plot	43.33b	35.33a	18.00ab	113.12a	126.47e	16.79j	1.02klm
	Weed free plot				Weed free			2.37f-j
	Mechanical weeding + manual weeding	9.33gh	29.33bc	10.67d-g	9.95e	201.95c	45.13fg	1.11jkl
	Pre-emergence herbicide + manual weeding	4.20h	24.67cd	6.67ghi	4.31hij	164.12d	22.64i	1.27i-l
	Post-emergence herbicide + manual weeding	8.30h	34.67ab	9.33e-h	5.11ghi	299.56a	48.52ef	1.26i-l
	Pre-emergence + post-emergence herbicide	6.67h	37.33a	9.33e-h	3.72ijk	110.92e	16.93j	1.80h-k
BRRI dhan34	Weedy plot	82.00a	38.67a	21.33a	18.71d	303.28a	25.36i	0.68m
	Weed free plot				Weed free			3.17c-g
	Mechanical weeding + manual weeding	44.67b	13.33ghi	10.67d-g	1.46n	76.83gh	61.96d	2.14hij
	Pre-emergence herbicide + manual weeding	24.67ef	18.67d-g	18.67ab	7.40f	115.19e	86.43b	2.27g-j
	Post-emergence herbicide + manual weeding	47.33b	23.33cde	12.00c-f	6.47fg	68.36ghi	30.48hi	2.71e-i
	Pre-emergence + post-emergence herbicide	14.67g	25.33cd	4.67i	1.21n	62.79hij	28.99hi	2.91d-h
BRRI dhan37	Weedy plot	24.67ef	19.33d-f	7.33ghi	4.21h-k	300.01a	77.53bc	2.03l
	Weed free plot				Weed free			2.67cd
	Mechanical weeding + manual weeding	6.67h	14.00f-i	8.00f-i	5.06hi	55.91hij	83.75bc	2.23d-h
	Pre-emergence herbicide + manual weeding	6.00h	9.33hi	6.00hi	1.84mn	203.79c	15.73j	2.29d-h
	Post-emergence herbicide + manual weeding	36.00c	23.33cde	8.00f-i	4.15h-k	51.52ij	85.55b	2.44e-h
	Pre-emergence + post-emergence herbicide	6.33h	15.33fgh	3.67i	5.56gh	104.49ef	16.81j	2.33efg
BRRI dhan38	Weedy plot	45.33b	22.67de	15.33bc	21.81c	115.45e	117.03a	2.21g-j
	Weed free plot				Weed free			3.72a
	Mechanical weeding + manual weeding	32.00cd	20.67def	13.33cde	5.27gh	227.03b	74.73c	3.02c-f
	Pre-emergence herbicide + manual weeding	5.00hi	17.33efg	6.00hi	1.45n	125.76e	49.60ef	3.26c-h
	Post-emergence herbicide + manual weeding	7.33h	19.33d-g	15.33bc	4.99hi	67.57ghi	61.19d	3.22c-h
	Pre-emergence + post-emergence herbicide	5.33hi	8.00i	6.33ghi	4.31hij	114.71e	51.40ef	3.44bc
Binadhan-13	Weedy plot	32.67cd	8.00i	14.67bcd	64.55b	126.37e	55.71de	1.05klm
	Weed free plot				Weed free			3.58ab
	Mechanical weeding + manual weeding	14.67g	19.67d-g	10.67d-g	2.00lmn	45.19ij	23.93i	2.38f-i
	Pre-emergence herbicide + manual weeding	23.33ef	19.33d-g	6.67ghi	5.27gh	41.64j	37.88gh	1.87h-k
	Post-emergence herbicide + manual weeding	29.33de	17.33efg	12.67cde	3.24jkl	54.45hij	49.13ef	2.21c-f
	Pre-emergence + post-emergence herbicide	20.67f	18.67d-g	18.00ab	2.89klm	86.04fg	36.16gh	2.54cde
	CV (%)	17.6	15.41	15.23	7.31	11.48	13.58	5.46
	Level of significance	**	**	**	**	**	**	*

*Significant at 5% level of probability, In a column, values having similar letter do not differ significantly whereas values with dissimilar letter differ significantly as per DMRT; ** Significant at 1% level of probability.

Table 5. Weed control efficiency, weed inflicted relative yield loss and yield increase over control of rice due to different weed management treatments.

Weed management	Weed control efficiency (%)			RYL (%)	YOC (%)
	45 DAT	65 DAT	85 DAT		
Weedy plot	0	0	0	56.56	0
Weed free plot	100	100	100	0	130.212
Mechanical weeding + manual weeding	89.32	37.53	0.99	31.88	56.83
Pre-emergence herbicide + manual weeding	90.89	33.04	27.39	35.94	47.48
Post-emergence herbicide + manual weeding	89.23	44.27	6.00	26.25	69.78
Pre-emergence + post-emergence herbicide	92.04	50.70	48.59	21.87	43.88

Table 6. Cost effectiveness (partial cost analysis) of different weed control treatments.

Treatments	Variable cost except herbicide and weeding cost	Herbicide cost	Laborer cost for spraying/ weeding	Total cost	Gross income	Net income	Benefit-cost ratio
Weedy plot	43458	0	0	43458	72520	29062	1.67
Weed free plot	42038	0	39000	81038	155480	74442	1.92
Mechanical weeding + manual weeding	44708	0	5200	49908	110200	60292	2.21
Pre-emergence herbicide + manual weeding	43458	617.5	5720	49795.5	106280	56484.5	2.13
Post-emergence herbicide + manual weeding	43458	308.75	5720	49486.75	120200	70713.25	2.43
Pre- + post-emergence herbicide	42938	926.25	1040	44904.25	120200	75295.75	2.68

In a column, values having similar letter do not differ significantly whereas values with dissimilar letter differ significantly as per DMRT. **Significant at 1% level of probability.

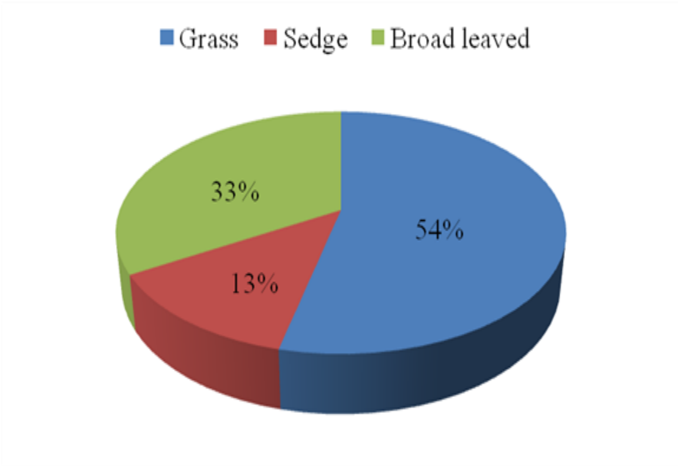

Figure 1. *Relative density of different weeds.*

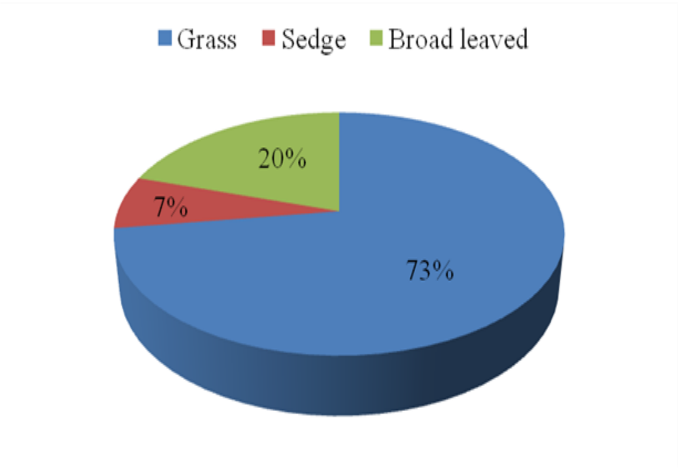

Figure 2. *Relative dry weight of different weed groups.*

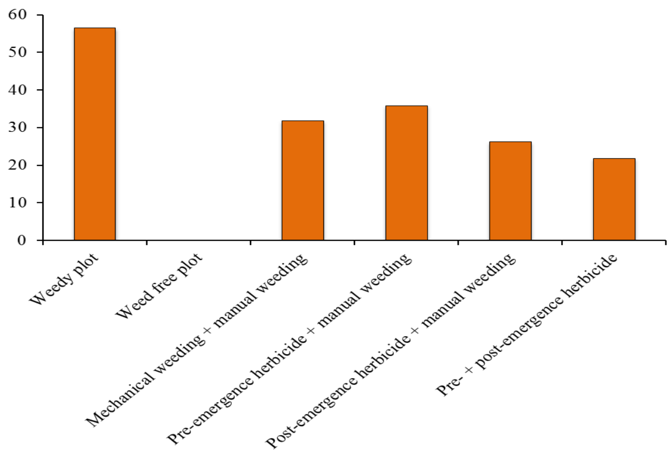

Figure 3. *Weed Index of different weed management practices.*

Conclusions

The yield of aromatic rice is lower than that of coarse and medium rice varieties but its higher market price makes it more remunerative to the farmers. Among the several factors, weed management in aromatic rice play an important role for lowering its grain yield. The farmers of Bangladesh mainly practiced manual and mechanical weeding to manage the weeds from the crop fields. Recently they started to adopt chemical weed management. Moreover, before making the final choice of any weed control method, farmers' available resources e.g., labour, have to be considered first. The current research revealed that despite high weed control efficiency, manual weeding is not cost-effective, whilst chemical weed controls are highly efficient and economic as well. Among the tested herbicides, Bensulfuran methyl +Acetachlor@750 g ha^{-1} followed by Pyrazosulfuran ethyl@125-150 g ha^{-1} may be considered for their high efficacy and cost-effectiveness for weed management in aromatic rice.

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