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Original Research

Effect of weed management strategies on the yield performance of aromatic rice in *Boro* season

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ABSTRACT

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during November 2016 to May 2017 to study the effect of weed management strategies on the yield of aromatic fine rice in *Boro* season. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan50, BRRI dhan63 and Basmati, and five weed management strategies viz. weedy check (no weeding), two hand weeding at 15 and 30 days after transplanting (DAT), pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} + one hand weeding at 30 DAT, post emergence herbicide, Granite 240 SC @ 95 ml ha^{-1} + one hand weeding at 30 DAT, pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} + post emergence herbicide, Granite 240 SC @ 95 ml ha^{-1}. The experiment was laid out in a randomized complete block design with three replications. BRRI dhan50 produced the highest number of effective tillers hill^{-1} (8.87), number of grains panicle^{-1} (95.51 grain) and 1000-grain weight (21.45 g) and straw (5.59 t ha^{-1}) yields compared to BRRI dhan63 and Basmati. The highest grain yield (4.31 t ha^{-1}) was produced in BRRI dhan50 which was at par with BRRI dhan63 and the lowest one (3.21 t ha^{-1}) was recoded in Basmati. In case of weed management, the highest number of effective tillers hill^{-1} (9.62), 1000-grain weight (21.70 g), grain (5.22 t ha^{-1}) and straw (5.64 t ha^{-1}) yields were obtained in pre-emergence herbicide + post emergence herbicide compared to other treatments. In interaction, the highest grain yield (5.54 t ha^{-1}) was obtained in BRRI dhan50 with pre-emergence herbicide + post emergence herbicide, which was statistically identical to BRRI dhan63 with pre-emergence herbicide + post emergence herbicide. Therefore, BRRI dhan50 or BRRI dhan63 can be cultivated with pre-emergence herbicide + post emergence herbicide in *Boro* season for appreciable grain yields.

Introduction

Rice (*Oryza sativa* L.) is a staple food of more than fifty percent of the world's population and plays a vital role in household food security (Langaro et al. 2016). It is the most extensively cultivated food grain crop which contributes near about 95% of total food production in

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Bangladesh. Fertile land and favorable weather conditions are very advantageous for year round rice cultivation in Bangladesh. About 74.85% of cropped area of Bangladesh is used for rice production, where *Aus*. *Aman* and *Boro* rice covers 8.94%, 49.12% and 41.94%, respectively (BBS, 2018). The area and production of rice in Bangladesh is about 11.01 million hectares and 33.80 million tons, respectively (BBS, 2018). The average rice yield in Bangladesh is about 3.07 t ha^{-1} (BBS, 2018) including low yield of aromatic rice. Although the yield of aromatic rice is considerably low but its higher price and low cost of cultivation generated higher profit margins compared to other non-aromatic rice (Islam et al. 1996a). Aromatic rice has great potential to attract rice consumer for its taste and deliciousness, and high price to boost up the economic condition of the rice growers. In Bangladesh, a number of fine rice cultivars such as Chinisagar, Badshabhog, Kataribhog, Kalizira, Tulsimla, Dulabhog, Basmati, Banglamati (BRRI dhan50), BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan63, Binadhan-9 and Binadhan-13 are grown as aromatic rice (Adhikari et al. 2018). Most of the aromatic rice varieties are the traditional type, photoperiod sensitive, and are grown during transplanted *Aman* season in the rainfed lowland ecosystem [Islam et al. 1996b; Kabir et al. 2004]. Potentialities of some varieties are chosen to be tested in irrigated ecosystem in *Boro* season. The yield of rice is depending on agronomic factors including selection of variety and weed management options. Weeds are the major biotic constraint to increased rice production worldwide. Weeds, besides harboring insects, compete with crop for water, light and plant nutrients and adversely affect the micro-climate around the plant (Nojavan, 2001). The climatic and edaphic conditions of Bangladesh are favorable for the growth of numerous noxious weed species. Weed is one of the most important agricultural pests in Bangladesh, which infestation reduces the grain yield by 70–80% in *Aus* rice (early summer), 30–40% for transplanted *Aman* rice (Autumn) and 22–36% for modern *Boro* rice (Winter) cultivation in Bangladesh (Sarkar et al. 2017). In case of aromatic fine rice, grain yield reduced by 28.16% in Binadhan-9 (Zannat et al. 2014) and by 59.82% in BRRI dhan50 (Sinha et al. 2018). Weed control by hand using *Nirri* or *Khurpi* is the traditional method of weed control in Bangladesh which is very much laborious and time consuming. So, weed control at the critical period by traditional method sometimes difficult due to the unfavorable weather conditions and at the peak period of laborer demand. Chemical weed control has become popular in Bangladesh mainly due to scarcity of labour during peak growing season, and lower weeding cost. Herbicides in combination with hand weeding would help to obtain higher crop yield with less efforts and cost (Sathyamoorthy et al. 2004; Ahmed et al., 2005). Weed competition at early growth stage can be controlled through pre-emergence herbicides like Panida, Ronstar 25 EC and Refit 50 EC and post emergence herbicides Granaite and 2,4-D amine because they are effective against mono and dicotyledonous weeds in rice fields (Paul

et al. 2019). Replacement of traditional weed control techniques in *Boro* season by applying pre-emergence and post-emergence herbicides or herbicides along with hand weeding would helpful to successful weed control (Nahar et al. 2019). Therefore, the present study was undertaken to assess the weed management strategies on the performance of aromatic fine rice in *Boro* season.

Materials and Methods

Experimental Site

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during the period from November 2016 to May 2017. The experimental site is located at 24.7° N latitude and 90.50° E longitude at an elevation of 18 m above the sea level belonging 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 topography of the experimental field was a medium high land with flat and well drained condition. The soil of the experimental field belongs to the Sonatala soil series which is slightly acidic in reaction with 1.29% organic matter content having pH 6.5.

Experimental treatments and design

The experiment consisted of three varieties viz. BRRI dhan50 (Banglamoti) (V_1), BRRI dhan63 (V_2) and Basmati (V_3) and five weed management options viz. weedy check (no weeding) (W_0), two hand weeding at 15 and 30 DAT (W_1), pre-emergence herbicide (Panida 33 EC @ 2.5 l ha^{-1}) followed by one hand weeding at 30 DAT (W_2), post emergence herbicide (Granite 240 SC @ 95 ml ha^{-1}) followed by one hand weeding at 30 DAT (W_3) and pre-emergence herbicide (Panida 33 EC @ 2.5 l ha^{-1}) + post emergence herbicide (Granite 240 SC @ 95 ml ha^{-1}) (W_4). The experiment was laid out in a randomized complete block design (RCBD) with three replications. The size of a unit plot was 2.5 m × 2.0 m (5 m^2).

Crop husbandry

The land was first opened with a tractor drawn disc plough on 29 November 2016. The experimental 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 2017 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 (TSP), muriate of potash (MoP), gypsum, zinc sulphate @ 250 kg, 120 kg, 120 kg,

100 kg and 10 kg ha^{-1}, respectively. The entire amounts of TSP, MoP, gypsum and zinc sulphate were applied during final land preparation. Urea was applied as top dressing in three equal splits at 15, 30 and 45 days after transplanting (DAT). Transplanting was done by 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. Other intercultural operations were done successfully.

Data collection for weeds

Weed density was calculated species-wise at 60 DAT and maturity stage using 1 m^2 quadrate as per method described by Cruz et al. (1986) from three spots in each plot at random and converted to number m^{-2}. After determining the weed density, the weeds inside each quadrate were uprooted and cleaned. The collected weeds were dried in an electric oven for 72 hours at a temperature of 85 ± 5 °C and their dry weights recorded by an electrical balance. Weed control efficiency (WCE) was calculated based on weed biomass using following formula:

$$WCE\ (\%) = \frac{\text{weed dry matter in weedy check} - \text{weed dry matter in treated plot}}{\text{weed dry matter in weedy check}} \times 100$$

Data collection at harvest

Prior to harvest four hills were randomly selected from each plot (excluding border rows and central 1 m^2) for recording the data on yield contributing characters. The crop was harvested at full maturity when 90% of the grains became golden yellow in color. After sampling, the central 1.0 m × 1.0 m area was harvested to record data on grain and straw yields. BRRI dhan63 was harvested on 23 April 2017, on the other hand BRRI dhan50 and Basmati were harvested on 30 April 2017. The harvested crops of each plot was separately bundled, properly tagged and threshed properly. The grains were cleaned and sun dried to 14% moisture content. Straws were also dried properly. Finally grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}. Harvest index (%) was calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{grain yield}}{\text{biological yield}} \times 100$$

Statistical analysis

Analysis of variance was done following randomized complete block design with the computer package MSTAT (version 4.0). The mean differences among the weed control treatments were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results and Discussion

Weed flora

The experimental plots were infested with eleven weed species belonging to eight families. Two weed species were of the family Cyperaceae, three of the family Gramineae and one each of the family Pontederiaceae, Compositae, Amaranthaceae, Oxalidaceae, Marsileaceae and Onagraceae. Among the total weed vegetation most of them were annual (Table 1).

Table 1. Infesting species of weed in the fine aromatic rice field of *Boro* season.

Sl. no.	Local name	English name	Scientific name	Family	Morphological type
1	Shama	Barnyard grass	*Echinochloa crus-galli* (L.) P. Beauv.	Gramineae	Grass
2	Angta	Joint grass	*Panicum repens* L.	Gramineae	Grass
3	Arail	Swamp rice grass	*Leersia hexandra* Swartz	Gramineae	Grass
4	Pani kachu	Pickerel weed	*Monochoria vaginalis* (Burm. F.) C. Presl	Pontederiaceae	Broad leaved
5	Malancha	Alligator weed	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	Broad leaved
6	Keshuti	False daisy/ White eclipta	*Eclipta alba* L.	Compositae	Broad leaved
7	Sabuj nakphul	Small flowered umbrella plant	*Cyperus difformis* L.	Cyperaceae	Sedge
8	Pani chaise	Purple spike rush	*Eleocharis atropurpurea* (Retz.) J. Presl & C. Pres	Cyperaceae	Sedge
9	Pani long	Winged water primerose	*Ludwigia hyssopifolia* (G. Don) Exell	Onagraceae	Broad leaved
10	Amrul	Indian sorrel	*Oxalis corniculata*	Oxalidaceae	Loabed leaved
11	Shusni shak	4-leaved water clover	*Marsilea crenata* C. Presl	Marsileaceae	Broad leaved

Weed parameters and weed control efficiency

Weed density and dry weight represented the extent of competition posed by weeds on the crop. The treatment which exhibited the minimum density and dry weight for the weeds was considered the best. Irrespective of variety weed population in weedy check treatments decreased at maturity stage compared to weed populations at 60 DAT. The highest weed density (263.00 m^{-2}) and weed dry matter (137.30 g m^{-2}) were recorded in $V_2 \times W_0$ (BRRI dhan63 × no weeding) and the lowest number of weed population (12.00 m^{-2}) and weed dry matter (2.67 g m^{-2}) were obtained in $V_1 \times W_3$ (BRRI dhan50 × post emergence herbicide Granite 240 SC followed by one hand weeding at 30 DAT) while at maturity the highest (112.00 m^{-2}) and lowest (15.00 m^{-2}) weed population were found in $V_1 \times W_0$ (BRRI dhan50 × no weeding) and $V_2 \times W_4$ (BRRI dhan63 × pre emergence herbicide, Panida 33 EC + post emergence

herbicide Granite 240 SC), respectively (Table 2). On the other hand the highest (132.40 gm^{-2}) and lowest weed dry matter (4.45 g m^{-2}) were recorded in $V_2 \times W_0$ (BRRI dhan63 × no weeding) and $V_2 \times W_3$ (BRRI dhan63 × post emergence herbicide Granite 240 SC followed by one hand weeding) treatments, respectively. Gnanavel and Anbhazhagan (2010) reported that maximum weed dry weight was observed in the weedy check. Weed control efficiency varies due to various treatment combinations. Among the combinations of variety along with different weed management options, the excellent weed control efficiency (WCE) was observed in $V_1 \times W_3$, $V_2 \times W_3$ and $V_3 \times W_3$ those were near to $V_1 \times W_4$, $V_2 \times W_4$ and $V_3 \times W_4$, respectively and higher that other treatment combinations at both dates of sampling (Table 2).

Table 2. Interaction effect of variety and weed management on the weed density, weed dry matter and weed control efficiency in *Boro* season

Interaction (Variety × weed management)	Weed density/population (no. m^{-2})		Weed dry matter (g m^{-2})		Weed control efficiency (%)	
	At 60 DAT	At maturity	At 60 DAT	At maturity	At 60 DAT	At maturity
$V_1 \times W_0$	216.70 b	112.00 a	86.07c	102.30 b	0.00e	0.00f
$V_1 \times W_1$	38.67cd	15.33gh	8.92e	10.27ef	89.63cd	89.96c
$V_1 \times W_2$	33.67cd	30.67d	10.85e	27.73c	87.86d	72.89e
$V_1 \times W_3$	12.00e	20.00efgh	2.67h	4.60g	96.89a	95.50ab
$V_1 \times W_4$	33.33d	19.33efgh	6.05f	13.33de	92.97b	86.96c
$V_2 \times W_0$	263.0a	106.00b	137.30a	132.40a	0.00e	0.00f
$V_2 \times W_1$	41.00cd	24.67e	9.31e	16.00d	93.22b	87.92c
$V_2 \times W_2$	38.00cd	30.67d	13.68d	30.73c	90.04c	76.79d
$V_2 \times W_3$	18.00e	17.50fgh	3.53gh	4.45g	97.42a	96.63a
$V_2 \times W_4$	20.33e	15.00h	5.26fg	5.20 g	96.17a	96.07ab
$V_3 \times W_0$	221.7b	100.70 c	111.7b	129.30a	0.00e	0.00f
$V_3 \times W_1$	36.67cd	20.67efg	11.12e	14.40de	90.04c	88.86c
$V_3 \times W_2$	45.33c	21.00ef	10.05e	14.93de	91.00c	88.45c
$V_3 \times W_3$	14.33e	18.00fgh	2.740h	8.60fg	97.55a	93.34b
$V_3 \times W_4$	22.00e	20.67efg	4.68fgh	13.87de	95.81a	89.27c
ANOVA						
Variety (V)	**	**	**	**	**	**
Weed Management (W)	**	**	**	**	**	**
V × W	**	**	**	**	*	**
CV (%)	8.83	7.69	4.31	7.37	1.56	2.29

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

Crop characters, yield components and yield

Varietal performance

Variety exerted significant influence on crop characters, yield components and yield of aromatic rice except plant height and number of non-effective tillers hill^{-1} (Table 3).

Table 3. Effect of variety on crop characters, yield components and yield of aromatic fine rice in *Boro* season.

Variety	Plant height (cm)	Total tiller hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Length of panicle (cm)	Total spikelet panicle^{-1} (no.)	Grains panicle^{-1} (no.)	Sterile spikelet panicle^{-1} (no.)	1000-grain weight (g)	Straw yield (t ha^{-1})	Harvest index (%)
BRRI dhan50 (V_1)	71.17	10.08a	8.87a	1.21	20.61ab	105.6a	95.51a	11.51b	21.45a	5.59a	43.03b
BRRI dhan63 (V_2)	71.67	9.815b	8.60b	1.21	20.14b	100.8b	93.26a	12.04ab	20.69b	5.08b	44.74a
Basmati (V_3)	71.52	8.985c	7.77c	1.21	21.35a	106.8a	88.90 b	12.86a	19.24c	4.61c	40.36c
Level of significance	NS	**	**	NS	**	**	**	*	**	**	**
CV (%)	3.08	2.84	3.93	21.54	4.98	3.04	3.66	10.13	3.05	4.07	3.09

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

The highest number of total tillers hill^{-1} (10.08), effective tillers hill^{-1} (8.87), 1000-grain weight (21.45 g) and straw yield (5.59 t ha^{-1}) were recorded in BRRI dhan50 followed by BRRI dhan63 and the lowest values were recorded in Basmati. The highest number of total tillers hill^{-1} and effective tillers hill^{-1} are probably responsible for higher straw yield in BRRI dhan50 compared to other varieties. The results were associated with the findings by Sarkar et al. (2014) and Adhikari et al. (2018) concerning the varietal influence on above mentioned characteristics. The longest panicle (21.35 cm) and number of total spikelets panicle^{-1} (106.8) were found in Basmati which was at par with BRRI dhan50 while the lowest one was recorded in BRRI dhan63. Similar result was reported by Shaha et al. (2014) who mentioned that panicle length and total spikelets panicle^{-1} in rice significantly influenced by variety. The highest sterile spikelets panicle^{-1} (12.86) was found in Basmati which was statistically identical with BRRI dhan63 and lowest one (11.51) was found in BRRI dhan50. The highest number of grains panicle^{-1} (95.51) and grain yield (4.31 t ha^{-1}) were recorded in BRRI dhan50 which was as good as BRRI dhan63 while the lowest number of grains

panicle^{-1} (88.90) and grain yield (3.21 t ha^{-1}) were recorded in Basmati (Figure 1). The highest number of effective tillers hill^{-1}, maximum number of grains panicle^{-1} and heavier seeds might be responsible the highest grain yield in BRRI dhan50. Variation of yield components and yield might be due to the differences in their genetic make-up. Jisan et al. (2014) and Chowdhury et al. (2016) reported variable grains panicle^{-1} and grain yield among the varieties. The highest harvest index (44.74%) was recorded in BRRI dhan63 followed by BRRI dhan50 (43.03) while the lowest one was found in Basmati (40.36%). Harvest index was varied among the rice cultivars were reported elsewhere (Tyeb et al. 2013; Ray et al. 2015; Pal et al. 2016).

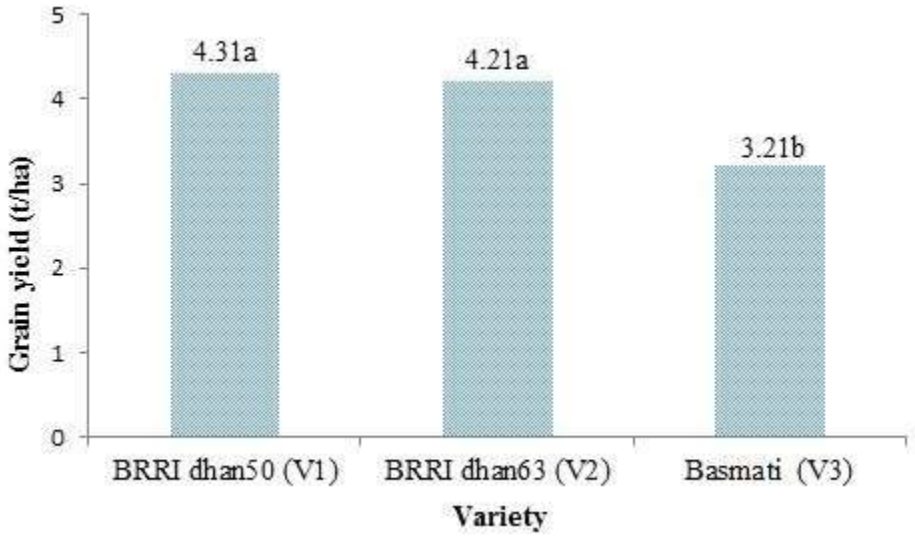

Figure 1. Yield performance of aromatic rice varieties in *Boro* season

Effect of weed management

Weed management exerted significant influence on crop characters, yield components and yield of aromatic rice except panicle length (Table 4). The highest plant height (72.65 cm) was recorded in W_4 (pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} + post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1}) which was at par with W_1 (hand weeding at 15 and 30 DAT), W_2 (pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} followed by one hand weeding at 30 DAT) and W_3 (post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1} followed by one hand weeding at 30 DAT) while the lowest one (67.76) was recorded in W_0 (weedy check). The highest number of total tillers hill^{-1} (10.93) and number of effective tillers hill^{-1} (9.62) were recorded inW_4 (pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} + post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1}) followed by W_3 (post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1} followed by one hand weeding at 30 DAT) while the highest number of non-effective tillers hill^{-1} (1.53) were recorded in W_1 (hand weeding at 15 and 30 DAT) which was statistically

identical with W_4 (pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} + post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1}) and lowest values were recorded in W_0 (weedy check). Weed control in an effective way might keep the experimental plots reduce weed crop competition so that crops can easily absorb essential nutrients properly for their growth and development. This observation was in agreement with the findings of Paul *et al.* (2019). The highest number of grains panicle^{-1} (107.40) was recoded in W_1 (hand weeding at 15 and 30 DAT) which was as good as W_2 (pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} followed by one hand weeding at 30 DAT), W_3 (post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1} followed by one hand weeding at 30 DAT) and W_4 (pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} + post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1})while the lowest grains panicle^{-1} and sterile spiketlets panicle^{-1} were found in W_0 (weedy check). On the other hand the highest 1000-grain weight (21.70 g) was recorded in W_4 (pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} + post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1}) which was at par with W_3 (post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1} followed by one hand weeding at 30 DAT) and the lowest one was found in (weedy check). The highest grain yield (5.22 t ha^{-1}) (Figure 2), straw yield (5.64 t ha^{-1}) and harvest index (47.97%) were recorded in W_4 (pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} + post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1}) followed by W_3 while the lowest values were found in (weedy check) (Table 4).

Table 4. Effect of weed management on crop characters, yield components and yield of aromatic fine rice in *Boro* season.

Weed management	Plant height (cm)	Total tiller hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Length of panicle (cm)	Total spikelet panicle^{-1} (no.)	Grains panicle^{-1} (no.)	Sterile spikelet panicle^{-1} (no.)	1000-grain weight (g)	Straw yield (t ha^{-1})	Harvest index (%)
W_0	67.76b	7.48 e	6.57d	0.91c	20.59	86.46d	97.79b	10.70c	19.41c	4.68d	34.85e
W_1	72.25a	9.51d	7.97c	1.53a	20.22	91.29c	107.40a	13.96a	19.68c	4.85cd	41.38d
W_2	72.09a	9.95c	8.80b	1.15bc	20.82	92.61bc	106.00a	12.54b	20.34b	5.02c	43.67c
W_3	72.53a	10.24b	9.08b	1.15bc	20.63	95.01ab	104.60a	12.15b	21.16a	5.260b	45.70b
W_4	72.65a	10.93a	9.62a	1.31ab	21.23	97.42a	106.30a	11.33bc	21.70a	5.64a	47.97a
Level of significance	**	**	**	**	NS	**	**	**	**	**	**
CV (%)	3.08	2.84	3.93	21.54	4.98	3.66	3.04	10.13	3.05	4.07	3.09

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). ** =Significant at 1% level of probability, NS = Not significant. W_1 = Hand weeding at 15 and 30 days after transplanting, W_2 = Pre-emergence herbicide (Panida 33 EC @ 2.5 l ha^{-1}) followed by one hand weeding at 30 DAT, W_3 = Post-emergence herbicide (Granite 240 SC @ 95 ml ha^{-1}) followed by one hand weeding at 30 DAT, W_4 = Pre-emergence herbicide (Panida 33 EC @ 2.5 l ha^{-1}) + Post-emergence herbicide (Granite 240 SC @ 95 ml ha^{-1})

W_0 (Weedy check) treatment reduced grain yield by 51.91% compared to W_4 (pre-emergence

herbicide, Panida 33 EC @ 2.5 l ha^{-1} + post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1}) (Figure 3). Similar trendwas also documented by Sinha et al. (2018) who obtained yield loss by 59.82% in BRRI dhan50 due to un-weeded control in *Boro* season. Effective weed management reduces crop-weed competition for light, space, nutrient and moisture, and ultimately increased grain and straw yields. Properly weed control might be influenced the production of effective $tillershill^{-1}$, grains $panicle^{-1}$and test weight of grains which finally increased the grain yield of rice. On the other hand, the highest straw yield in W_4 mostly the outcome of the tallest plant and maximum total tillers under this treatments. Similar result was also reported by Sarkar et al. (2017) and Sinha et al. (2018).

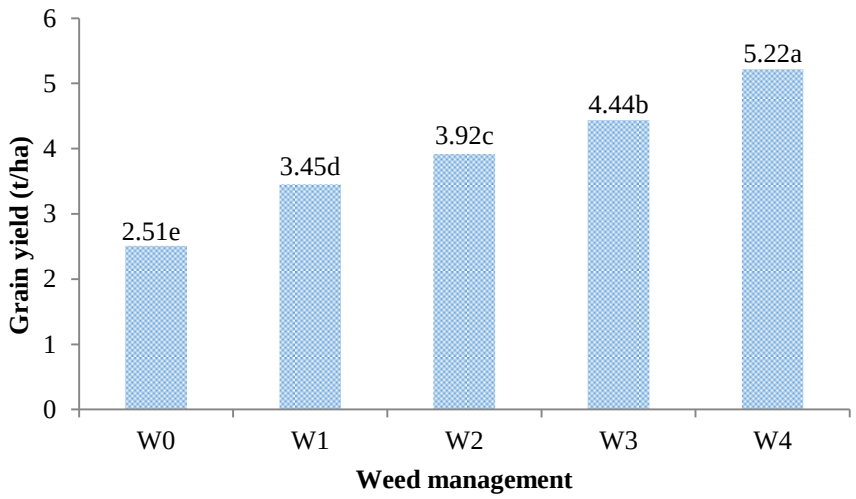

Figure 2. Effect of weed management on yield of aromatic fine rice in *Boro* season

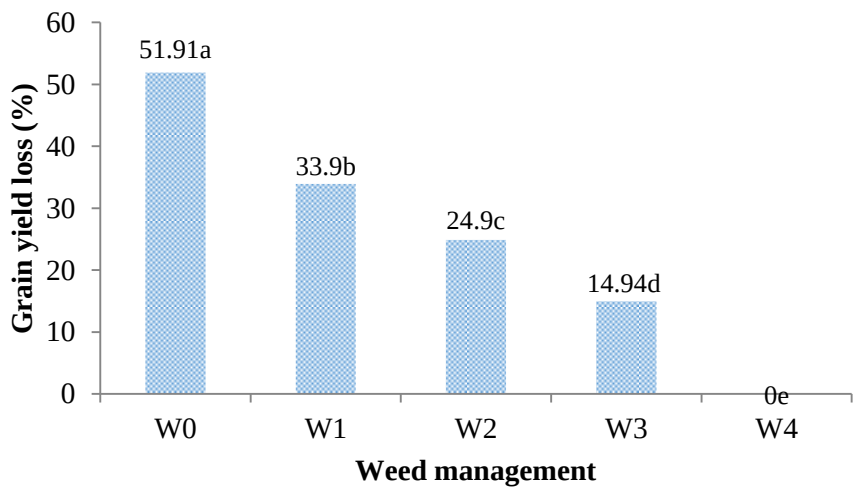

Figure 3. Grain yield loss (%) under various weed management options.

Effect of interaction between variety and weed management strategies

The interaction effect of variety and weed management was significantly influenced on crop characters; yield components and yield of aromatic fine rice except plant height, grains panicle^{-1}, sterile spikelets panicle^{-1} and harvest index (Table 5).

Table 5. Interactions effects of variety and weed management on crop characters, yield components and yield of aromatic fine rice in *Boro* season.

Interaction (variety × weed manag)	Plant height (cm)	Total tiller hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Length of panicle (cm)	Total spikelet panicle^{-1} (no.)	Grains panicle^{-1} (no.)	Sterile spikelet panicle^{-1} (no.)	1000-grain weight (g)	Straw yield (t ha^{-1})	Harvest index (%)
$V_1 \times W_0$	67.60	7.93h	7.20f	0.73d	20.95abc	100.20def	88.49	11.71	20.56	5.29cde	35.00
$V_1 \times W_1$	71.87	10.07cde	8.73cde	1.33b	20.21bcd	104.7bcd	94.95	12.38	20.89	5.37cde	41.86
$V_1 \times W_2$	71.93	10.47bcd	9.07bcd	1.40b	20.04cd	112.8a	96.61	12.39	21.09	5.63abc	44.19
$V_1 \times W_3$	73.07	10.53bc	9.40ab	1.13bcd	21.20abc	102.6cde	97.12	10.38	21.98	5.87a	45.21
$V_1 \times W_4$	71.40	11.40a	9.93a	1.47b	20.65abc	107.8abc	100.39	10.69	22.71	5.79ab	48.91
$V_2 \times W_0$	68.67	7.60h	6.40g	1.20bcd	20.99abc	96.81ef	85.02	9.88	19.73	4.63hij	36.59
$V_2 \times W_1$	70.60	10.00de	8.73cde	1.27bc	19.91cd	105.3bcd	92.29	14.54	19.94	4.89fgh	43.59
$V_2 \times W_2$	73.33	10.27cde	9.00bcd	1.27bc	20.59abc	96.98ef	92.85	11.97	20.80	5.03efg	45.96
$V_2 \times W_3$	72.67	10.33cde	9.33abc	1.00bcd	18.34d	101.3def	97.08	12.94	21.33	5.17def	48.29
$V_2 \times W_4$	73.07	10.87b	9.53ab	1.33b	20.85abc	103.7cd	99.06	10.87	21.65	5.66abc	49.27
$V_3 \times W_0$	67.00	6.93 i	6.13g	0.80cd	19.84cd	96.38f	85.86	10.52	17.95	4.13k	32.95
$V_3 \times W_1$	74.27	8.47g	6.46g	2.00a	20.56abc	112.20a	86.63	14.97	18.21	4.31jk	38.68
$V_3 \times W_2$	71.00	9.13f	8.33e	0.80cd	21.84abc	108.2abc	88.36	13.25	19.11	4.40ijk	40.85
$V_3 \times W_3$	71.87	9.86e	8.53de	1.33b	22.35a	109.8ab	90.82	13.13	20.17	4.74ghi	43.61
$V_3 \times W_4$	73.47	10.53bc	9.40ab	1.13bcd	22.18ab	107.4abc	92.81	12.43	20.74	5.48bcd	45.74
ANOVA											
Variety (V)	NS	**	**	NS	**	**	**	*	**	**	**
Weed Manag (W)	**	**	**	**	NS	**	**	**	**	**	**
V × W	NS	*	**	**	**	**	NS	NS	NS	*	NS
CV (%)	3.08	2.84	3.93	21.54	4.98	3.04	3.66	10.13	3.05	4.07	3.09

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). ** =Significant at 1% level of probability, * =Significant at 5% level of probability, NS = Not significant. V_1 = BRRI dhan50, V_2 = BRRI dhan63, V_3 = Basmati, W_0 = Weedy check (No weeding), W_1 = Hand weeding at 15 and 30 days after transplanting, W_2 = Pre-emergence herbicide (Panida 33 EC @ 2.5 l ha^{-1}) followed by one hand weeding at 30 DAT, W_3 = Post-emergence herbicide (Granite 240 SC @ 95 ml ha^{-1}) followed by one hand weeding at 30 DAT, W_4 = Pre-emergence herbicide (Panida 33 EC @ 2.5 l ha^{-1}) + Post-emergence herbicide (Granite 240 SC @ 95 ml ha^{-1})

The highest number of total tillers hill^{-1} (11.40) and number of effective tillers hill^{-1} (9.93) were recorded in $V_1 \times W_4$ (BRRI dhan50 × pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} +post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1}), and the lowest values were recorded in $V_3 \times W_0$ (Basmati × no weeding) while the highest (2.00) and lowest (0.73) number of non-effective tillers were recorded in $V_3 \times W_1$ (Basmati × hand weeding at 15 and 30 DAT) and $V_1 \times W_0$ (BRRI dhan50 × no weeding), respectively. The longest panicle (22.35 cm) and highest number of total spikelets panicle^{-1} (112.20) were found in $V_3 \times W_3$ (Basmati × post-emergence herbicide, Granite 240 SC @ 95

ml ha^{-1} followed by one hand weeding at 30 DAT) and V 3 × W 1 (Basmati × hand weeding at 15 and 30 DAT), respectively and numerically the highest number of grains panicle^{-1} (100.39) and 1000-grain weight (22.71 g) were found in $V_1 \times W_4$ (BRRI dhan50 × pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} + post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1}). The highest grain yield (5.54 t ha^{-1}) was recorded in $V_1 \times W_4$ (BRRI dhan50 × pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} + post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1}) which was at par with $V_2 \times W_4$ (BRRI dhan63 × pre-emergence herbicide, Panida 33 EC @ 2.5 l ha^{-1} + post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1}) (Figure 4). The results are in contradiction with those of Adeosun et al. (2009), who found that the combination of herbicide and hand weeding was the best source of yield improvement in rice. The highest straw yield (5.87 t ha^{-1}) was recorded in $V_1 \times W_3$ (BRRI dhan50 × post-emergence herbicide, Granite 240 SC @ 95 ml ha^{-1}) followed by one hand weeding at 30 DAT) which was at par with $V_1 \times W_2$ and $V_1 \times W_4$ and the lowest grain (2.03 t ha^{-1}) and straw (4.13 t ha^{-1}) were found in $V_3 \times W_0$ (Basmati × no weeding) (Table 5).

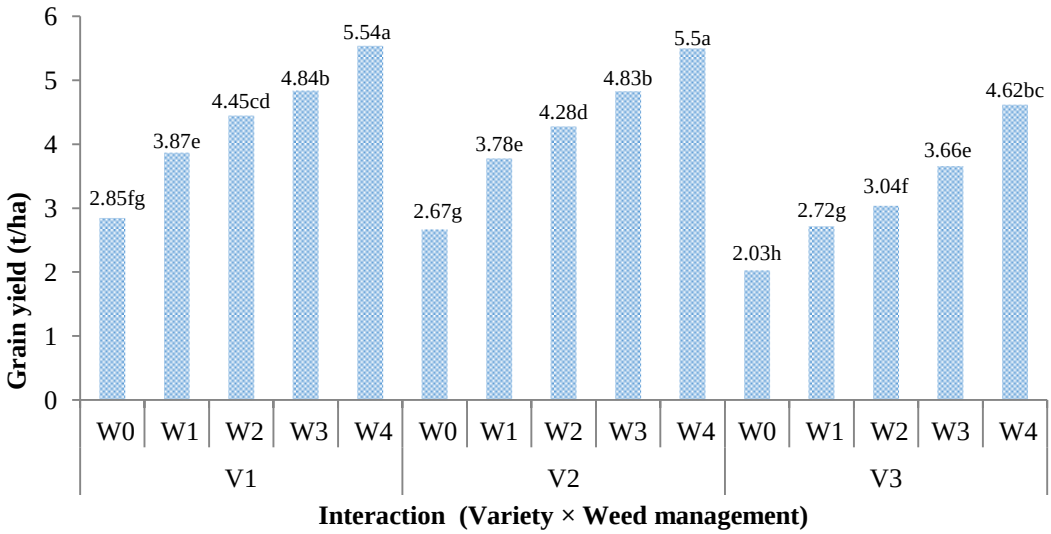

Figure 4. Effect of interaction between variety and weed management on the grain yield of aromatic fine rice in *Boro* season (Figures with same letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT).

Conclusion

BRRI dhan50 produced the highest grain yield which was as good as BRRI dhan63 and the lowest one was recoded in Basmati. Among various weed control treatments pre-emergence herbicide (Panida 33 EC @ 2.5 l ha^{-1}) + post emergence herbicide (Granite 240 SC @ 95 ml ha^{-1}) gave the highest grain yield compared to other options. BRRI dhan50 with pre-emergence herbicide

(Panida 33 EC @ 2.5 l ha^{-1}) + post emergence herbicide (Granite 240 SC @ 95 ml ha^{-1}) produced the highest grain yield which was statistically identical to BRRI dhan63 with pre-emergence herbicide (Panida 33 EC @ 2.5 l ha^{-1}) + post emergence herbicide (Granite 240 SC @ 95 ml ha^{-1}). So, variety BRRI dhan50 or BRRI dhan63 can be suggested along with pre-emergence herbicide (Panida 33 EC @ 2.5 l ha^{-1}) + post emergence herbicide (Granite 240 SC @ 95 ml ha^{-1}) in terms of grain yield in *Boro* season.

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Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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