International Journal of Life Science and Agriculture Research

ISSN (Print): 2833-2091, ISSN (Online): 2833-2105

Volume 03 Issue 12 December 2024

DOI: https://doi.org/10.55677/ijlsar/V03I12Y2024-17

Impact Factor: 6.774 , Page No : 1026-1036

Effects of Weed Control Treatments on *Boro* rice and Associated Weeds

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ABSTRACT: A study was conducted to examine how different rice varieties and weed management strategies impact the yield of *Boro* rice. The trail included two varieties *viz.* BRRI dhan28 and BRRI dhan29, and seven different weeding methods: no weeding, one hand weeding (HW) at 15 days after transplanting (DAT), two HW at 15 and 35 DAT, three HW at 15, 35 and 55 DAT, application of superhit 58 SL @ 0.2% (pre-emergence), application of livina 18 WP @1.5 g/L water (post-emergence) and rice residues 3 t ha^{-1}. The study was structured using a Randomized Complete Block Design (RCBD) and replicated thrice. The findings exposed that ten families were represented by fifteen weed species that infested the experimental plots. Density and dry weight of weed was not notably affected by rice varieties. At 35 and 55 DAT, three HW at 15, 35 and 55 DAT produced the lowest weed density (0.83 m^{-2}), (1.16 m^{-2}) and weed dry weight (0.19 g), (0.33 g). In interaction, three HW at 15, 35 and 55 DAT recorded least weed density (0.66) and (1.00) at 35 and 55 DAT. BRRI dhan29 produced the maximum number of total tillers hill^{-1} (9.61), effective tillers hill^{-1} (9.00), panicle length (22.10 cm), grains panicle^{-1} (126.75), harvest index (47.09 %) and grain yield (4.71 t ha^{-1}) compared to BRRI dhan28. Three HW at 15, 35 and 55 DAT resulted maximum number of total tillers hill^{-1} (10.50), effective tillers hill^{-1} (9.40), panicle length (22.16 cm), grains panicle^{-1} (118.56) and grain yield (5.39 t ha^{-1}). BRRI dhan29 along with three HW at 15, 35 and 55 DAT recorded maximum grain yield (5.55 t ha^{-1}). The study suggests that conducting three rounds of HW at 15, 35 and 55 DAT could be the most efficient method for both weed management and achieving a higher grain yield in *Boro* rice.

Published Online: December 18, 2024

KEYWORDS: Weed species, variety, weeding strategies, boro rice, yield

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INTRODUCTION

Food security, the assurance that all individuals have the opportunity to obtain enough nourishing food to sustain a healthy life, is a significant challenge worldwide. Rice (*Oryza sativa*), a crucial cereal crop, it acts as a primary dietary component for a large segment of the global population. It's cultivated across more than 100 nations, covering over 170 million hectares of land and yielding over 800 million tons yearly (FAO, 2020). With its rich nutrient profile, rice contributes substantially to global protein and energy intake, accounting for 15% of protein and 21% of energy consumption per person worldwide (IRRI, 2010). Bangladesh ranks third among rice-producing countries, cultivating rice on approximately 11.7 million hectares of land and producing around 38.78 million tons annually (BBS, 2022). Despite these impressive figures, the current production falls short of meeting the increasing food demand of Bangladesh's growing population (Rahman *et al.*, 2023). Hence, achieving food security in Bangladesh necessitates a sustainable increase in rice production. Variety plays a significant role in influencing the yield and yield components of a specific crop. The yield components are directly connected to the crop variety and the surrounding environmental conditions in which it is cultivated (Tyeb *et al*., 2013; Islam *et al.*, 2014; Chowdhury *et al.*, 2016). Diversity is an essential genetic factor that enables rice plants to achieve higher yields. Enhancing the production of transplant *Aman* rice can be achieved through superior crop management and the development of better cultivars (Sarkar *et al.*, 2014; Jisan *et al.*, 2016). This improvement results from differences in genetic composition, nutritional requirements, growth processes and environmental conditions.

Weeds globally pose significant challenges to rice production, leading to considerable decreases in yield (Islam *et al.*, 2015).Weed infestation and the absence of improved plant varieties are major contributors to low rice yield (Khatun *et al.*, 2023; Mushtaree *et al.*, 2022). It's crucial to prioritize the development and management of new rice varieties to enhance yield (Roy *et al.*, 2023). Weed free crops allow rice to fully utilize expensive inputs like fertilizers and pesticides, as weed infestation leads to higher yield losses compared to diseases and insects combined. According to BRRI (2008), weed infestation in Bangladesh decreases crop production by approximately 70–80% for Aus rice, 30–40% for transplanted *Aman* rice, and 22–36% for modern *Boro* rice cultivars. Effective weed control techniques are therefore indispensable for successful rice production. The current physical weed control method is labour concentrated, costly and often challenging to execute on schedule (Ahmed *et al.*, 2005). Combining herbicides with manual weeding could boost crop yield while reducing labour and expenses (Kabiraj *et al.*, 2020).

Integrated weed management, a relatively new approach in Bangladesh, involves the use of multiple strategies to control weeds. This method recognizes that no single weed control method suits every situation. By combining various techniques, such as pre-emergence herbicides like Ronstar 25 EC, Rifit 500 EC, and Superhit 500 EC, with tools or HW, effective weed management in Boro rice fields can be achieved (Shathyamoorthy *et al*., 2004; Sarker *et al.*, 2017). These herbicides are selective and potent against both mono and dicotyledonous weeds, particularly in rice fields. Employing integrated weed management not only helps in reducing weeding expenses but also enhances crop yield potential. Therefore, a research was carried out to assess the impact of variety, integrated weed supervision and their interaction on *Boro* rice yield performance.

MATERIALS AND METHOD

Site review

The research spot sat at 24°25' N latitude and 90°50' E longitude, standing 18 meters above sea level. It was found in the dark grey floodplain soil which is not calcareous situated in the Old Brahmaputra Floodplain (AEZ-9). Specifically, the research plot soil fell within the Sonatola range of dark grey calcium-free wetlands in the Old Brahmaputra alluvial zone. The local climate was tropical in nature depicted in (Table 1).

Table 1: Distribution of monthly average air temperature relative humidity, rainfall and sunshine hours of the experiment site during the period from December 2022 to May 2023

Month and year	Air temperature (^{0}C)			Rainfall (mm)	Relative humidity (%)	Sunshine (hrs.)
	Maximum	Minimum	Average			
December, 2022	26.4	14.7	20.6	0.0	84.8	187.8
January, 2023	24.4	12.3	18.3	0.0	83.5	154.4
February, 2023	27.9	16.3	22.1	11.2	78.6	170.9
March, 2023	29.9	19.8	24.8	110.2	76.7	194.9
April, 2023	34.1	22.6	28.3	15.5	74.2	260.7
May, 2023	36.3	25.9	31.1	242.1	93.0	240.8

Source: Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh.

Description of experimentation

The trail was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University during January to May 2023. The experimental treatments included two varieties viz. BRRI dhan28, BRRI dhan29 and seven weeding treatments viz. no weeding (T_1), one HW at 15 DAT (T_2), two HW at 15 and 35 DAT (T_3), three HW at 15, 35 and 55 DAT (T_4), application of superhit 58 SL @ 0.2% (2,4 D-Amine; systemic; pre-emergence herbicide) (T_5), application of livina 18 WP @1.5 g/L water (Acetochlor + Benzosulfuran methyl; systemic; post-emergence herbicide) (T_6) and rice residues 3 t ha^{-1}(T_7). The study followed RCBD method and replicated thrice. A total of 42 plots were organized in a 2 × 7 × 3 layout, each plots measuring 2.5 m by 2.0 m, spaced 0.5 m apart within units and 1.0 m apart between blocks, with treatments being randomly allocated to the plots.

Crop management

After selecting healthy and dense seeds using the gravity method, they were soaked in water for 24 hours and then transferred to a jute bag. The nursery bed was prepared through puddling and pre-germinated seeds were planted in the moist bed. Experimental plots received fertilization with Urea, TSP, MoP, Gypsum and Zinc Sulphate at rates of 160, 60, 80, 60 and 6 kg ha^{-1}. All fertilizers except urea were applied before final soil preparation, with urea applied three times at 15, 30 and 45 DAT. Superhit 58 SL @ 0.2 % spraying was done by a hand crop sprayer at 30 DAT and Livina 18 WP @1.5 g/L spraying was done at 15 DAT. On the morning of transplantation, seedlings that had reached 40 days old were delicately uprooted from the nursery and placed in clusters with a 25 cm gap between rows and 15 cm between each pair of seedlings.

Data collection

The harvest took place upon reaching full maturity indicated by 90% of the seeds turning a golden yellow colour. Data on vegetation characteristics gathered from five randomly selected hills plot^{-1} excluding border rows. The seeds were then cleaned, weighed and adjusted for a moisture content of 14% to determine the grain yield in $plot^{-1}$. While the straw was cleaned, sun-dried, weighed and converted to ton ha^{-1} to measure the paddy and straw production of $plot^{-1}$.

Statistical analysis

The mean of each treatment was calculated, and an analysis of variance was conducted for every trait under study using the MSTAT computer package. Treatment discrepancies were assessed through the utilization of Duncan's Multiple Range Test (Gomez and Gomez, 1984).

RESULTS

Infested weed species in the experimental field

Weeds commonly found in *Boro* rice fields encompass broad leaved grasses and sedges. The conditions conducive to the cultivation of *Boro* rice also promote the unchecked growth and competition of certain weed species with cultivated plants. Fifteen types of weeds from ten different families were found to have infested the experimental plots (Table 2).

Table 2: Infesting species of weed in the experimental field of *Boro* rice

Local name	*Scientific name*	Family	Morphological type
Angta	*Paspalum scrobiculatum* L.	Poaceae	Grass
Shama	*Echinochloa crusgalli* (L.) P. Beauv.	Poaceae	Grass
Arail	*Leersia hexandra* Swartz	Poaceae	Grass
Sabuj nakphul	*Cyperus difformis* L.	Cyperaceae	Sedge
Mutha	*Cyperus rotundus* L.	Cyperaceae	Sedge
Pani chaise	*Eleocharis atropurpurea* (Retz.) J. Presl & C. Pres	Cyperaceae	Sedge
Joina	*Fimbristylis miliacea* L.	Cyperaceae	Sedge
Pani marich	*Polygonum orientale* L.	Polygonaceae	Broad leaved
Keshuti	*Eclipta alba* L.	Compositae	Broad leaved
Pani kachu	*Monochoria vaginalis* (Burm. F.) C. Presl	Pontederiaceae	Broad leaved
Malancha	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	Broad leaved
Shusni sak	*Marsilea crenata* C. Presl	Marsileaceae	Broad leaved
Pani long	*Ludwigia hyssopifolia* (G. Don) Exell	Onagraceae	Broad leaved
Durba	*Cynodon dactylon* L.	Poaceae	Grass
Pani shapla	*Nymphaea nouchali* L.	Nymphaeaceae	Broad leaved

Effects variety and weeding regimes to weed parameters

Total weed density

Weed density was not notably impacted by diverse varieties as recorded at 35 DAT and 55 DAT of the rice plot (Table 3). At 35 DAT, the highest result (8.71 m^{-2}) was calculated in BRRI dhan28 and lowest one (8.00 m^{-2}) was resulted in BRRI dhan29. At 55 DAT the maximum result (5.57 m^{-2}) was obtained in BRRI dhan29 and lowest one (5.42 m^{-2}) was recorded in BRRI dhan28. The density of weeds was notably impacted by the methods employed for weed management at both 35 and 55 DAT (Table 3). At 35 and 55 DAT, the highest result (30.33 m^{-2}) and (12.00 m^{-2}) were found in controlled treatment (T_1) and the lowest one (0.83 m^{-2}) and (1.16 m^{-2}) were found with three HW at 15, 35 and 55 DAT (T_4) which was significantly different from other treatments. The correlation between different varieties and the frequency of weeding was observed to have a notable impact at 35 and 55 DAT (Table 4). The highest result (32.00 m^{-2}) and (13.00 m^{-2}) were found in BRRI dhan28 along with control treatment ($V_1 \times T_1$) at 35 and 55 DAT whereas the lowest result (0.66 m^{-2}) and (1.00 m^{-2}) were resulted in BRRI dhan29 along with three HW at 15, 35 and 55 DAT ($V_2 \times T_4$).

Weeds dry weight

At 35 DAT, there was a notable impact on the overall dry weight of weeds with the greatest increase in total weed dry weight being noted (1.07 g m^{-2}) in BRRI dhan28 compare to BRRI dhan29 (0.90 g m^{-2}). At 55 DAT, the highest result was found (5.24 m^{-2}) in BRRI dhan28 and the lowest one (4.73 g m^{-2}) in BRRI dhan29 (Table 3). There was significant effect of weed management on dry weight at 35 DAT and 55 DAT (Table 3). At 35 and 55 DAT, the highest weed dry weight (2.29 g m^{-2}) and (12.29 g m^{-2}) were found in control treatment (T_1) whereas the lowest dry weight (0.19 g m^{-2}) and (0.33 g m^{-2}) were found with three HW at 15, 35 and 55 DAT (T_4). The significant impact was observed on the interaction between different varieties and the methods of weeding at 35 and 55 DAT (Table 4). The highest result (2.42 g m^{-2}) and (13.66 g m^{-2}) were observed in BRRI dhan28 along with no weeding ($V_1 \times T_1$) at 35 and 55 DAT. The lowest result (0.12 g m^{-2}) was observed in BRRI dhan28 along with three HW at 15, 35 and 55 DAT ($V_1 \times T_4$) at 35 DAT while at 55 DAT, the lowest one (0.25 g m^{-2}) was found with BRRI dhan29 along with rice residues ($V_2 \times T_7$).

Table 3. Effect of variety and weed management on weed density and weed dry weight at 35 and 55 DAT

Treatments	Weed density		Weed dry weight (g)	
	35 DAT	55 DAT	35 DAT	55 DAT
Variety				
BRRI dhan28	8.71	5.42	1.07a	5.24
BRRI dhan29	8.00	5.57	0.90b	4.73
Sig. level	NS	NS	**	NS
CV%	18.72	21.39	23.91	20.73
Weed management				
T_1	30.33a	12.00a	2.29a	12.29a
T_2	15.50b	9.50b	1.60b	9.18b
T_3	7.00c	5.33c	1.04c	5.45c
T_4	0.83d	1.16e	0.19f	0.33f
T_5	1.33d	2.66de	0.49e	1.97e
T_6	1.33d	3.66d	0.76d	2.45de
T_7	2.16d	4.16cd	0.55de	3.23d
Sig. level	**	**	**	**
CV%	18.72	21.39	23.91	20.73

Means with the same letters or without letters within the same column do not differ significantly. ** = Significant at 1% level of probability. Here, T_1 = No weeding, T_2 = one hand weeding at 15 DAT, T_3 = two hand weeding at 15 and 35 DAT, T_4 = Three hand weeding at 15, 35 and 55 DAT, T_5 = application of pre-emergence herbicide, T_6 = application of post-emergence herbicide, T_7 = rice residues 3 t ha^{-1}.

Table 4: Effect of interaction of variety and weed management on weed density and dry weight at 35 and 55 DAT

Interaction	Weed density		Weed dry weight (g m^{-2})	
	35 DAT	55 DAT	35 DAT	55 DAT
$V_1 \times T_1$	32.00a	13.00a	2.42a	13.66a
$V_1 \times T_2$	17.00c	9.66ab	1.91b	10.92b
$V_1 \times T_3$	6.00e	6.00c	1.03c	9.21bc
$V_1 \times T_4$	1.00f	1.33f	0.12f	9.15c
$V_1 \times T_5$	2.00f	1.66ef	0.55de	6.27d
$V_1 \times T_6$	1.33f	2.66def	1.03c	4.64de
$V_1 \times T_7$	1.66f	3.66de	0.46def	3.42ef
$V_2 \times T_1$	28.66b	11.00ab	2.15ab	3.17ef
$V_2 \times T_2$	14.00d	9.33b	1.28c	3.04efg
$V_2 \times T_3$	8.00e	4.66cd	1.05c	2.54fg
$V_2 \times T_4$	0.66f	1.00f	0.26ef	1.73fgh
$V_2 \times T_5$	0.66f	3.66de	0.44def	1.40gh
$V_2 \times T_6$	1.33f	4.66cd	0.50de	0.41h
$V_2 \times T_7$	2.66f	4.66cd	0.65d	0.25h
Sig. level	**	**	**	**
CV%	18.72	21.39	23.91	20.73

Means with the same letters or without letters within the same column do not differ significantly. ** = Significant at 1% level of probability. Here, V_1 = BRRI dhan28, V_2 = BRRI dhan29; T_1= No weeding, T_2 = one hand weeding at 15 DAT, T_3 = two hand weeding at 15 and 35 DAT, T_4 = Three hand weeding at 15, 35 and 55 DAT, T_5 = application of pre-emergence herbicide, T_6 = application of post-emergence herbicide, T_7 = rice residues 3 t ha^{-1}.

Effect variety and weeding regimes to crop characters

Plant height

Different types of varieties and methods for controlling weeds had a notable impact on the height of the plants (Table 5). BRRI dhan28 produced the tallest plants (90.32 cm) while BRRI dhan29 produced the shortest plants (86.95 cm). In weeding strategies, the tallest plant (90.39 cm) was found in application of livina 18 WP @1.5 g/L (post-emergence) (T_6) followed by three HW at 15, 35 and %% DAT (T_4) and application of superhit 58 SL @ 0.2% (pre-emergence) (T_5). And the shortest plant (86.58 cm) was found in control condition (T_1) (Table 5). The height of the plants was notably influenced by the combined effects of different varieties and methods used for weed management (Table 6). The tallest one (92.00 cm) was obtained from BRRI dhan28 with three HW at 15, 35 and 55 DAT ($V_1 \times T_4$) which was statistically similar to BRRI dhan28 applied with application of livina 18 WP @1.5 g/L water (post-emergence) ($V_1 \times T_6$) and the shortest one (83.88 cm) from BRRI dhan29 with two HW at 15 and 35 DAT ($V_2 \times T_3$).

Number of total tillers hill^{-1}

BRRI dhan29 formed the highest total tillers hill^{-1} (9.61) while BRRI dhan28 recorded the lowest result (9.57) (Table 5). Various weed management treatments significantly affected the total number of tillers hill^{-1} (Table 5). The highest result (10.50) was recorded from three HW at 15, 35 and 55 DAT (T_4) while the lowest one (8.78) was calculated from rice residues (T_7). The total number of tillers hill^{-1} exhibited notable diversity as a result of the interplay between the variety of crops and the method of weeding employed (Table 6). The highest total tillers hill^{-1} (10.55) was resulted by BRRI dhan28 with three HW at 15, 35 and 55 DAT ($V_1 \times T_4$) which was identical to (10.44) with BRRI dhan29 with three HW at 15, 35 and 55 DAT ($V_2 \times T_4$) while the lowest one (8.77) was calculated with BRRI dhan28 along with control condition ($V_1 \times T_1$) and BRRI dhan29 along with rice residues ($V_2 \times T_7$).

Number of effective tillers hill^{-1}

The variety did not significantly affect the number of productive tillers hill^{-1} (Table 5). BRRI dhan29 resulted highest result (9.00) compare to BRRI dhan28 (8.80). Various methods of weed management significantly impacted the number of productive tillers hill^{-1} (Table 5). The highest effective tillers hill^{-1} (9.40) was calculated from three HW at 15, 35 and 55 DAT (T_4) which was identical to two HW at 15 and 35 DAT (T_3), application of superhit 58 SL @ 0.2% (pre-emergence) (T_5) and application of livina 18 WP @1.5 g/L (post-emergence) (T_6) and the lowest one (8.31) was obtained from rice residues (T_7). The interaction of different varieties and weed management techniques resulted in notable differences in the productive tillers hill^{-1} (Table 6). The highest result (9.74) was found by BRRI dhan29 along application of superhit 58 SL @ 0.2% (pre-emergence) ($V_2 \times T_5$) followed by BRRI dhan29 along with three HW at 15, 35 and 55 DAT ($V_2 \times T_4$). The lowest one (8.16) was produced by BRRI dhan28 applied with rice residues ($V_1 \times T_7$).

Number of non-effective tillers hill^{-1}

The variety did not significantly impact the number of non-effective tillers hill^{-1} (Table 5). The highest non-effective tillers hill^{-1} (0.77) was found in BRRI dhan28 while lowest result (0.60) was calculated in BRRI dhan29. Various weed management practices significantly impacted the quantity of ineffective tillers hill^{-1} (Table 5). The highest non-effective tillers hill^{-1} (1.09) was resulted from three HW at 15, 35 and 55 DAT (T_4) and the lowest one (0.42) was obtained from application of superhit 58 SL @ 0.2% (pre-emergence) (T_5). The interaction between variety and weed management did not have a notable impact on the quantity of non-effective tillers hill^{-1} (Table 6). BRRI dhan28 with three HW at 15, 35 and 55 DAT ($V_1 \times T_4$) treatment recorded highest result (1.18) while BRRI dhan29 along with rice residues ($V_2 \times T_7$) calculated lowest one (0.30).

Panicle length

Panicle length was notably influenced by variety, weed management and their interaction effect (Table5, 6). The longest panicle (22.10 cm) was resulted in BRRI dhan29 and the shorter one (21.33) was calculated in BRRI dhan28 (Table 5). The longest panicle (22.16 cm) was found in three HW at 15, 35 and 55 DAT (T_4) while the shortest panicle (20.59 cm) was obtained in control treatment (T_1) (Table 5). The longest panicle (22.61 cm) was found in BRRI dhan29 with application of livina 18 WP @1.5 g/L water (post-emergence) ($V_2 \times T_6$) and the shortest panicle (20.55cm) was found in BRRI dhan29 with control condition ($V_2 \times T_1$) (Table 6).

Number of grains panicle^{-1}

Various varieties significantly affected the number of grains panicle^{-1} (Table 5). The highest grains panicle^{-1} (126.75) was calculated in BRRI dhan29 and the lower one was found (97.09) in BRRI dhan28. Various weed management approaches had a notable impact on the quantity of grains panicle^{-1} (Table 5). The highest grains panicle^{-1} (118.56) was resulted by three HW at 15, 35 and 55 DAT (T_4) and the lowest one (102.59) was resulted by rice residues (T_7). Various varieties and methods of weed control had a notable impact on the quantity of grains panicle^{-1} (Table 6). The highest grains panicle^{-1} (132.46) was calculated by BRRI dhan29 with three HW at 15,35 and 55 DAT ($V_2 \times T_4$) and the lowest one (90.86) was produced by BRRI dhan28 with rice residues ($V_1 \times T_7$).

Number of sterile spikelet's panicle^{-1}

Various varieties, weeding strategies and their interaction significantly impacted the quantity of sterile spikelets panicle^{-1}. BRRI dhan29 produced the highest sterile spikelet panicle^{-1} (16.46) while the lowest one (8.35) was attained by BRRI dhan28 (Table 5). The highest sterile spikelet panicle^{-1} (14.00) was produced by control condition (T_1), while the lowest one (11.47) was produced with rice residues (T_7) (Table 5). At interaction, the highest sterile spikelet panicle^{-1} (19.12) was obtained from BRRI dhan29 with control condition ($V_2 \times T_1$) and the lowest one (7.06) was found from BRRI dhan28 with application of superhit 58 SL @ 0.2% (pre-emergence) ($V_1 \times T_5$) (Table 6).

1000-grain weight

The 1000-grain weight of *Boro* rice was notably impacted by different varieties, weeding practices and their interactions (Table 5, 6). The heaviest result (24.62) was found in variety BRRI dhan28 and the lowest one (21.19) was found in variety BRRI dhan29 (Table 5). Numerically the heaviest result (23.132 g) was found in rice residues (T_7) and the lowest one (22.687 g) was observed in two HW at 15 and 35 DAT (T_3) (Table 5). While interacts, the heaviest result (24.877 g) was calculated from BRRI dhan28 with rice residues ($V_1 \times T_7$) and the lowest one (20.853 g) was resulted from BRRI dhan29 with two HW at 15 and 35 DAT ($V_2 \times T_3$) (Table 6).

Table 5: Effect of variety and weed management on the yield components of *Boro* rice

Treatments	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	Sterile spikelet (no.)	1000-grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
Variety										
BRRI dhan28	90.32a	9.57	8.80	0.77	21.33b	97.09b	8.35b	24.62a	10.055	43.85b
BRRI dhan29	86.95b	9.61	9.00	0.60	22.10a	126.75a	16.46a	21.19b	9.978	47.09a
Sig. level	**	NS	NS	NS	**	**	**	**	NS	**
CV%	2.83	5.48	6.03	6.56	3.88	3.59	13.94	5.33	2.50	2.49
Weed Management										
T_1	86.58b	8.95c	8.33b	0.62ab	20.59c	110.48b	14.00a	22.873	7.41e	44.33d
T_2	87.52ab	9.68b	8.82ab	0.86ab	21.91ab	110.27b	11.92b	23.042	9.62d	45.00cd
T_3	86.77b	9.96ab	9.15a	0.80ab	21.61b	113.95ab	12.48ab	22.687	10.79b	44.32d
T_4	90.25a	10.50a	9.40a	1.09a	22.16a	118.56a	12.81ab	22.857	11.65a	46.36b
T_5	90.05a	9.63b	9.20a	0.42b	22.04ab	111.38b	11.95b	22.992	10.70b	48.38a
T_6	90.39a	9.63b	9.07a	0.55b	21.98ab	116.20a	12.21ab	22.790	10.22c	46.24bc
T_7	88.88ab	8.78c	8.31b	0.46b	21.68ab	102.59c	11.47b	23.132	9.70d	43.66d
Sig. level	**	**	**	**	**	**	**	**	**	**
CV%	2.83	5.48	6.03	6.56	3.88	3.59	13.94	5.33	2.50	2.49

Means with the same letters or without letters within the same column do not differ significantly. ** = Significant at 1% level of probability. Here, V_1 = BRRI dhan28, V_2 = BRRI dhan29; T_1= No weeding, T_2 = one hand weeding at 15 DAT, T_3 = two hand weeding at 15 and 35 DAT, T_4 = Three hand weeding at 15, 35 and 55 DAT, T_5 = application of pre-emergence herbicide, T_6 = application of post-emergence herbicide, T_7 = rice residues 3 t ha^{-1}.

Table 6: Effect of interaction of variety and weed management on the yield components of *Boro* rice

Interaction	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non effective tillers hill^{-1} (no.)	Panicle length (cm)	Grain panicle^{-1} (no.)	Sterile spikelet (no.)	1000-grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
$V_1 \times T_1$	87.50b	8.77d	8.33de	0.44	20.63f	91.48e	8.89d	24.46	6.68l	49.74a
$V_1 \times T_2$	89.88a	9.87ab	8.88a-e	0.98	21.59cd	92.30e	8.45d	24.48	10.05ghi	48.96ab
$V_1 \times T_3$	89.66a	9.96ab	9.01a-e	0.95	21.03ef	103.23d	8.30d	24.52	11.06bc	47.96ab
$V_1 \times T_4$	92.00a	10.55a	9.37abc	1.18	21.81bc	104.65d	8.17d	24.72	11.95a	47.07bc
$V_1 \times T_5$	91.11a	9.10cd	8.66b-e	0.43	21.65cd	93.32e	7.06d	24.74	10.70cd	47.03cd
$V_1 \times T_6$	91.44a	9.93ab	9.17a-d	0.76	21.34de	103.77d	8.89d	24.59	10.17fgh	46.97cd
$V_1 \times T_7$	90.66a	8.79d	8.16e	0.63	21.23def	90.86e	8.73d	24.87	9.75hi	46.47cd
$V_2 \times T_1$	85.66d	9.13cd	8.33de	0.79	20.55f	129.48a	19.12a	21.28	8.14k	46.21cd
$V_2 \times T_2$	85.16e	9.50bc	8.76b-e	0.73	22.24ab	128.25a	15.38bc	21.60	9.18j	45.41de
$V_2 \times T_3$	83.88f	9.96ab	9.30abc	0.65	22.20ab	124.66b	16.67ab	20.85	10.53def	43.76ef
$V_2 \times T_4$	88.50a	10.44a	9.44ab	1.00	22.51a	132.46a	17.44ab	20.98	11.36b	42.45f
$V_2 \times T_5$	89.00a	10.17a	9.74a	0.42	22.43ab	129.44a	16.84ab	21.24	10.69cde	42.18fg
$V_2 \times T_6$	89.33a	9.33bc	8.98a-e	0.34	22.61a	128.63a	15.54bc	20.98	10.28efg	42.04fg
$V_2 \times T_7$	87.11c	8.77d	8.47cde	0.30	22.13ab	114.32c	14.22c	21.38	9.64i	40.35g
Sig. level	**	**	**	NS	**	**	**	**	**	**
CV%	2.83	5.48	6.03	6.56	3.88	3.59	13.94	5.33	2.50	2.49

Means with the same letters or without letters within the same column do not differ significantly. ** = Significant at 1% level of probability. Here, V_1 = BRRI dhan28, V_2 = BRRI dhan29; T_1= No weeding, T_2 = one hand weeding at 15 DAT, T_3 = two hand weeding at 15 and 35 DAT, T_4 = Three hand weeding at 15, 35 and 55 DAT, T_5 = application of pre-emergence herbicide, T_6 = application of post-emergence herbicide, T_7 = rice residues 3 t ha^{-1}.

Table 7: Effect of variety and weed management on the yield and yield components of *Boro* rice.

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Variety		
BRRI dhan28	4.40b	5.65a
BRRI dhan29	4.71a	5.26b
Sig. level	**	**
CV%	3.05	3.79
Weed Management		
T_1	3.27e	4.14d
T_2	4.31d	5.30c
T_3	4.78c	6.01b
T_4	5.39a	6.26a
T_5	5.17b	5.52c
T_6	4.73c	5.49c
T_7	4.23d	5.46c
Sig. level	**	**
CV%	3.05	3.79

Here, T_1= No weeding, T_2 = one hand weeding at 15 DAT, T_3 = two hand weeding at 15 and 35 DAT, T_4 = Three hand weeding at 15, 35 and 55 DAT, T_5 = application of pre-emergence herbicide, T_6 = application of post-emergence herbicide, T_7 = rice residues 3 t ha^{-1}.

Table 8: Effect of interaction of variety and weed management on the yield and yield components of *Boro* rice.

Interaction	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
$V_1 \times T_1$	3.08l	3.59g
$V_1 \times T_2$	4.22i	5.82b
$V_1 \times T_3$	4.67efg	6.39a
$V_1 \times T_4$	5.23bc	6.72a
$V_1 \times T_5$	5.03cd	5.67bc
$V_1 \times T_6$	4.62fgh	5.55bc
$V_1 \times T_7$	3.93j	5.82b
$V_2 \times T_1$	3.45k	4.68f
$V_2 \times T_2$	4.40hi	4.78ef
$V_2 \times T_3$	4.89de	5.63bc
$V_2 \times T_4$	5.55a	5.80b
$V_2 \times T_5$	5.32b	5.37cd
$V_2 \times T_6$	4.84def	5.44cd
$V_2 \times T_7$	4.53gh	5.11de
Sig. level	**	**
CV%	3.05	3.79

Here, V_1 = BRRI dhan28, V_2 = BRRI dhan29; T_1= No weeding, T_2 = one hand weeding at 15 DAT, T_3 = two hand weeding at 15 and 35 DAT, T_4 = Three hand weeding at 15, 35 and 55 DAT, T_5 = application of pre-emergence herbicide, T_6 = application of post-emergence herbicide, T_7 = rice residues 3 t ha^{-1}.

Grain yield

There was a notable variance among varieties, weeding practices and their interaction concerning the amount of grain produced (Table 7). The highest result (4.71 t ha^{-1}) was calculated in BRRI dhan29. The lowest one (4.40 t ha^{-1}) was resulted in BRRI dhan28. The highest grain yield (5.39 t ha^{-1}) was found with three HW at 15, 35 and 55 DAT (T_4) while the lowest one (3.27 t ha^{-1}) was recorded in control condition (T_1) (Table 7). While interplay, the highest grain yield (5.55 t ha^{-1}) was produced by BRRI dhan29 along with three HW at 15, 35 and 55 DAT ($V_2 \times T_4$). The lowest result (3.08 t ha^{-1}) was calculated in BRRI dhan28 along with no weeding practice ($V_1 \times T_1$) (Table 8).

Straw yield

Straw yield was notably influenced by the variety (Table 7). Numerically, the highest result (5.65 t ha^{-1}) was found in BRRI dhan28 and the lower one (5.26 t ha^{-1}) was found in BRRI dhan29. Various methods of weed control had a notable impact on the quantity of straw harvested (Table 7). The highest result (6.26 t ha^{-1}) was observed in three HW at 15, 35 and 55 DAT (T_4) and the lowest one (4.14 t ha^{-1}) was observed in control condition (T_1). Variety choice and weed control had a notable impact on the straw yield (Table 8). The highest straw yield (6.72 t ha^{-1}) was produced by BRRI dhan28 along with three HW at 15, 35 and 55 DAT ($V_1 \times T_4$). The lowest result (3.59 t ha^{-1}) was obtained in BRRI dhan28 along with control condition ($V_1 \times T_1$) (Table 8).

Biological yield

The variety did not exert a noticeable effect on the biological yield (Table 5). BRRI dhan28 obtained highest biological yield (10.055 t ha^{-1}) compare to BRRI dhan29 (9.978 t ha^{-1}). Various approaches to weed control had a notable impact on the biological yield (Table 5). The highest result (11.65 t ha^{-1}) was observed in three HW at 15, 35 and 55 DAT (T_4) and the lowest straw yield (7.41 t ha^{-1}) was observed in control condition (T_1). Variety and weed control had a notable impact on the biological yield (Table 6). Numerically, the highest biological yield (11.95 t ha^{-1}) was produced by BRRI dhan28 along with three HW at 15, 35 and 55 DAT ($V_1 \times T_4$). The lowest one (6.68 t ha^{-1}) was obtained in BRRI dhan28 along with control condition ($V_1 \times T_1$).

Harvest index

Harvest index was notably affected by variety, weeding strategies and their interaction (Table 5, 6). The highest harvest index (47.09 %) was found in BRRI dhan29 (V_2) and the lowest one (43.85 %) was found in BRRI dhan28 (V_1) (Table 5). The highest result (48.38 %) was observed in application of superhit 58 SL @ 0.2% (pre-emergence) (T_5) and the lowest harvest index (43.66%) were observed in rice residues (T_7) (Table 5). In interaction, the highest result (49.74%) was observed in BRRI dhan28 along with control condition ($V_1 \times T_1$) followed by BRRI dhan28 along with one HW at 15 DAT ($V_1 \times T_2$) while the lowest harvest index (40.35%) was observed with BRRI dhan29 along with rice residues ($V_2 \times T_7$) (Table 6).

DISCUSSION

The current investigation revealed that *Echinochloa crusgalli*, *Leersia hexandra*, *Fimbristylis miliacea* and *Paspalum scrobiculatum* were the most prevalent weed species in the study region. Previous studies conducted in the same area also identified *Echinochloa crusgalli* as the prevailing weed species in rice fields (Afroz *et al.,* 2019; Islam *et al.,* 2018). In this research, we observed that various approaches to weed control exerted a notable influence on both the quantity and mass of weeds present, while the variety of the crop did not show a significant effect. Specifically, the minimum density and weight of dry weeds were observed at 35 and 55 DAT when employing three HW at 15, 35, and 55 DAT, which differed significantly from other methods (Table 3). Additionally, when examining the interaction between variety and treatment, it was found that at 35 and 55 DAT, the lowest weed density was associated with BRRI dhan29 when combined with three HW sessions at 15, 35 and 55 DAT ($V_2 \times T_4$). Regarding dry weight, the lowest result was recorded for BRRI dhan28 combined with three HW at 15, 35 and 55 DAT ($V_1 \times T_4$) at 35 DAT, while at 55 DAT, the smallest amount of weed dry weight was noted with BRRI dhan29 when combined with rice residues ($V_2 \times T_7$) (Table 4).

Weed poses a significant challenge to crops as it competes vigorously with them, thanks to its rapid growth rate, ability to adapt to changing environments and efficient seed production. Studies suggest that there is competition between crops and weeds in the initial growth phase spanning from 15 to 45 days post sowing. When plants are grown without weeding practices, they often have to compete with weeds for essential resources like space, nutrients, water, sunlight and air. None of the weeding methods resulted in a higher weed population compared to various weed control methods (Paul *et al.*, 2019). However, when they are grown in an environment free from such competition, they can exhibit improved growth and development. Rekha *et al.* (2002) noted that various weeding practices resulted in lower weed density compared to plots where no weeding was done. Similarly, Jena *et al.* (2002) found that the herbicide oxadiazon showed enhanced efficiency in controlling weeds when supplemented with one session of HW at 20 DAS in rice fields. However, in control plots overrun with weeds, the weeds were permitted to thrive unchecked, leading to competition with the crop at every stage of its growth. This resulted in diminished crop growth and yield (Roy *et al.,* 2020).

The characteristics influencing *Boro* rice's yield and its contributing factors were significantly influenced by the rice variety and the methods used to manage weeds. BRRI dhan29 showed the highest results for total tillers hill^{-1}, effective tillers hill^{-1}, panicle length, grains panicle^{-1}, grain yield and harvest index. However, the combination of three HW sessions at 15, 35, and 55 days after transplanting resulted in the highest total tillers hill^{-1}, effective tillers hill^{-1}, panicle length, grains panicle^{-1}, grain yield and biological yield (Table 5 & 7). At interaction, the highest total tillers hill^{-1}, grains panicle^{-1} and grain yield were observed when BRRI dhan29 was subjected to three HW at 15, 35 and 55 DAS ($V_2 \times T_4$) (Table 6 & 8).

In the untreated plots where no weeding was done, the weeds competed with the rice crop for essential resources like nutrients, water, air, sunlight and space. This competition led to the suppression of the rice plants, resulting in decreased yields. Conversely, in the weed-free plots where effective weed management was implemented, the yield increased. This increase was attributed to factors such as a higher number of tillers hill^{-1}, more grains panicle^{-1} and fewer sterile spikelets panicle^{-1} compared to the untreated plots (Kabiraj *et al.,* 2020). These improvements in yield can be attributed to the reduced weed population in the rice fields. Those treatments resulted in fewer weeds, which allowed the rice crop to absorb more nutrients and moisture from the soil and receive more solar radiation, ultimately promoting better growth. Proper weeding practices result in reduced the rivalry for nutrients and water resources between rice plants and weeds compared to no weeding, potentially allowing rice plants to obtained more tillers (Walia *et al.,* 2009). These results are consistent with previous studies (Sharma *et al.,* 1994). Reduced competition between rice and weeds may encourage the allocation of resources towards grain production, resulting in a higher number of grains per panicle (Mukhupadhyay and Ghosh, 1981). Weeding not only maintains a weed free environment but also improves soil aeration, facilitating greater absorption of nutrients and moisture by the crop as well as better utilization of solar radiation for enhanced growth (Atalla and Kholosy, 2002).

CONCLUSION

The yield influencing factors such as grains per panicle were notably impacted by the combined effect of variety and weed management techniques. BRRI dhan29 exhibited the highest grain yield when practiced with three HW sessions at 15, 35, and 55 days after transplanting, while BRRI dhan28 yielded the least when there was weeding. Consequently, to efficiently manage weed growth and achieve a substantial grain yield in *Boro* rice, it is suggested to implement three HW sessions at 15, 35 and 55 DAT.

ACKNOWLEDGMENTS

The author would like to acknowledge the Ministry of Science and Technology, People's Republic of Bangladesh for funding this research work.

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