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ORIGINAL RESEARCH ARTICLE

CrossMark

Effect of rice residue on weed suppression and yield performance of *boro* rice

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ABSTRACT

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from December 2017 through May 2018 to study the effect of rice residue on weed suppression and yield of *boro* rice. The experiment consisted of four different rice residue treatments such as no rice residue, 2.5, 5 and 7.5t ha^{-1}rice residue, and five different herbicidal treatments such as no herbicide (H_0), 25% of the recommended dose (RD), 50% RD, 75% RD and 100% of RD. The experiment was laid out in a randomized complete block design with three replications. Seven weed species belonging to five families infested the experimental plots. Weed density and weed dry weight were significantly affected by incorporation of rice residue and herbicidal treatment. The maximum weed growth was noticed with no rice residue incorporation and application of no herbicide. The minimum weed density and dry weight were found in incorporation of 5 t rice residue ha^{-1} and application of 100% of RD of herbicide treatment. Rice residue exerted significant effect on yield and yield contributing characters like plant height, number of total tillers $hill^{-1}$, number of effective tillers $hill^{-1}$ and grain yield. The highest grain yield (4.89 t ha^{-1}) was recorded with the incorporation of 2.5 t ha^{-1} rice residue which was statistically identical with5 and 7.5 t ha^{-1} rice residues. The grain yield (5.70 t ha^{-1}) produced by 75% of RD of herbicide was the highest among the other herbicidal treatments. The highest number of effective tillers $hill^{-1}$ (12.80), 1000-grain weight (21.07), grain yield (5.87 t ha^{-1}) and straw yield (7.21 t ha^{-1}) were observed with the incorporation of 5 t rice residue ha^{-1} and 75% of the RD of herbicide treatment. Results of this study indicate that rice residue showed potentiality to inhibit the growth of weed and exerted significant effect on the yield of *boro* rice. Rice residue @ 5 t ha^{-1} with application of herbicide of 75% RD might be suggested to use for effective weed management and better grain yield of *boro* rice.

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INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population (Kumar *et al*., 2016a). It provides 27 percent dietary energy and 20 percent dietary protein for the developing world (Kumar *et al*., 2016b). It is the most extensively cultivated crop in Bangladesh and the staple food for her people. Bangladesh has three rice growing seasons. Annual production of rice is 36.28 million tons from 11.62 million ha of land (BBS, 2019). *Boro* rice comprises about 4.86 million ha of land with a production of 19.58 million tons (BBS, 2019). Average yield of rice is low compared with other rice producing countries like China, India, Korea and Japan. This is due to use of traditional local varieties, high weed infestation, proper crop management, etc. Among these reasons high weed infestation is most serious problems for low production of *boro* rice (Chowdhury *et al*., 1995).

In Bangladesh, weed infestation reduces the grain yield by

70–80% in *aus* rice, 30-40% for transplanted *aman* rice and 22–36% for modern *boro*rice (Mamun, 1990; BRRI, 2008). Weeds not only cause huge reduction in yield but also increase the cost of cultivation and reduce the input use efficiency. Manual weed control is labor intensive and weed control is often imperfect or delayed due to unavailability of labour in the peak season. In present condition herbicide application has become the most widely adopted method for controlling weeds for successful crop production, but their non-judicious use also registers ill effects on soil, water, air, humans and animal health. Moreover, application same herbicide year after year in a particular soil might cause herbicide resistance in weed. In view of the numerous problems arising from the chemical weed control, questions have been raised about the continuous use of herbicides. Alternative approaches needs to be considered which is free from such problems (Ferrell *et al*., 2008).

Use of crop allelopathy and allelochemicals for weed control is a sound alternative of chemical herbicide. Allelopathy may be defined as both inhibitory and stimulatory roles in plant processes such as on seed germination, overall growth, development, reproduction, disease/weed management, cell division, or biosynthesis of photosynthetic pigments of other plants by releasing some allelochemicals, mainly secondary metabolites (Bachheti *et al*., 2020). Chemicals released from plants and imposing allelopathic influences are termed as allelochemicals. Allelochemicals are released into the environment by root exudation, leaching from aboveground parts and volatilization and/or by decomposition of plant material (Rice, 1984; Reigosa *et al*., 1999).

Soil incorporation or surface application, such as mulch of allelopathic crop residues, affects weed dynamics by reducing/ delaying seed germination and establishment, in addition to suppressing individual plant growth resulting in an overall decline in the density and vigor of the weed community (Gallandt *et al*., 1999). Decomposition of allelopathic crop residue produces a variety of allelochemicals in the soil causing adverse effects on other plants (Nelson, 1996) and have the potential to sustain a chemical as well as physical effect on the growth and development of subsequent crops and weeds (Reddy, 2001). Allelopathic crop residues can be exploited for weed suppression, and can thus be helpful in reducing reliance on herbicides (Weston, 1996). Because, incorporation of crop residues inhibits weed germination and growth due to release of allelochemicals in the rhizosphere (Farooq *et al*., 2020). Rice has been extensively studied with respect to its allelopathy and many rice varieties were observed to inhibit the growth of several weed species (Dilday *et al*., 1998; Olofsdotter *et al*., 1999; Azmi *et al*., 2000; Salam and Kato-Noguchi, 2009). Chung *et al*. (2001) identified p-hydroxy benzoic acid, p-coumeic acid, ferulic acid and p-hydroxybenzoic acid from straw extract of four rice cultivars. Kato-Noguchi *et al*. (2002) identified momilactoneb from Japanese rice cultivar Koshihikari and Salam *et al*. (2009), Salam and Kato-Naguchi (2011) and Kato-Naguchi *et al*. (2011) identified 9-hydroxy-b-ionone and 3-oxo-a-ionol from Bangladeshi rice cultivar BR17 and Kartikshail. These compounds inhibited the growth of the barnyard grass at lower concentration. Therefore, rice plant exhibited growth inhibitory effect on other plant species.

In Bangladesh *boro* rice is cultivated during winter season and it is cultivated here through irrigation. During early stage a little depth of water is kept on *boro* rice field for seedling establishment. But after 10-15 days the field remains wet which encourage the weed growth from the soil bank. At this stage the weeds must be controlled by manual or chemical methods. Incorporation of crop residue is one of the environmental friendly options for controlling weed through suppression or by its allelopathic effects. Considering the above points, the present study was carried out to evaluate the effect of BRRI dhan29 rice residue on weed suppression and yield performance of *boro* rice, to find out the effect of different doses of herbicide on weed suppression and yield performance of *boro* rice and to determine the interaction effect of BRRI dhan29 rice residue and herbicide on weed suppression and yield performance of *boro* rice, to establish an effective weed control method with integration of rice residue and herbicide.

MATERIALS AND METHODS

Experimental site

An experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh from December 2017 to May 2018 to study the effect of rice residue on weed suppression and on the performance of *boro* rice.

Soil

The experimental area belongs to Non Calcareous Dark Grey Floodplain soil under the Sonatola soil series of Old Brahmaputra Flood plain in Agro Ecological Zone (AEZ- 9). The soils of this series are pre- dominantly silty loam, dark grey in color having pH value 6.5, low in organic matter and its general fertility level is low.

Treatments and design

The experiment consisted of four different rice residue treatments such as no rice residue (R_0), 2.5(R_1), 5(R_2) and 7.5 t rice residue ha^{-1} (R_3) and five different herbicidal treatments such as no herbicide (H_0), 25% of the recommended dose (RD) (H_1), 50% of RD (H_2), 75% of RD (H_3) and 100% of RD of herbicide (H_4). The experiment was laid out in a randomized complete block design with three replications. Thus the total numbers of unit plots were 60 and each plot size was 2.5 m × 2 m.

Agronomic management

Seed of BRRI dhan29 was collected from the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. The sprouted seeds were sown in the nursery bed on 19 December 2017. Proper care was taken to raise the healthy seedlings in the nursery bed. The field was prepared by a power tiller and followed by laddering. Weeds and stubbles were removed and cleaned from individual plots. Rice residues were applied 7 days before transplanting. Rice straw was cut into pieces before application to the plots. The land was fertilized with urea, triple superphosphate, muriate of potash, gypsum and zinc sulphate as per recommendation of BRRI for BRRI dhan29 (BRRI, 2018). The experimental plots were fertilized with urea, TSP, MoP, gypsum and $ZnSO_4$ @300-100-120-100-10 kg ha^{-1}, respectively. The entire amount of triple super phosphate, muriate of potash, gypsum and zinc sulphate was applied at the time of final land preparation. Urea was top dressed in three equal installments at 15, 30 and 45 days after transplanting (DAT). Thirty two days old seedlings were transplanted in the well prepared puddle field on 20 January 2017 at the rate of three seedlings $hill^{-1}$, maintained row and hill distance of 25 cm and 15 cm, respectively. Pre-emergence herbicide Superhit 500 EC (Pretilachlor) was applied as per treatment one day after transplanting by a hand sprayer.

Data collection

Data were collected at different growth stages and finally at harvest stage. Before harvesting rice five hills were collected randomly from each plot excluding border plants and uprooted carefully for data recording of different yield components. The grains were cleaned and finally the weight was adjusted to a moisture content of 14%.The straw was sun dried and the yields of grain and straw $plot^{-1}$ were converted to t ha^{-1}. Data were recorded on weed density and weed dry weight and yield and yield contributing characters of rice.

Statistical analysis

The recorded data were compiled and tabulated for statistical analysis. All the collected data were analyzed following the analysis of variance (ANOVA) technique and mean differences were adjusted by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of rice residue on weed density and weed dry weight

Rice residue exerted significant effect on weed density and dry weight at 25, 50 and 75 days after transplanting (DAT). At all the sampling dates, the highest weed density was observed in no rice residue, showing the highest values of 46.93, 52.00, 60.00 m^{-2} at 25, 50 and 75 DAT, respectively and the lowest weed density was found in incorporation of 5 t rice residue ha^{-1}, showing the lowest value of 22.67, 36.00, 43.80 m^{-2} at 25, 50 and 75 DAT, respectively (Table 1). The highest weed dry weight was found in no rice residue incorporation and the values were 5.47, 16.72, 63.31 gm^{-2} at 25, 50, 75 DAT, respectively and the lowest one was found in incorporation of 7.5 t rice residue ha^{-1} treatment where the values were 1.41 and 34.70 gm^{-2} at 25, 50 and 75 DAT, respectively (Table 1). This might be due to the fact that after incorporation of rice residue in rice field some allelopathic compounds were released into the soil which inhibited the growth of weed and finally weed dry weight was reduced. Similar research findings were also reported by other researchers. Rahman et al. (2005) reported that application of rice straw mulch at the rate of 4.0 t ha^{-1}suppressed the weed growth in wheat. Sidhu et al. (2007) reported that rice straw mulch reduced weed biomass by 60% in wheat field. Zhu et al. (2020) pointed out that the biomass of *Echinochloa crus-galli* (L.) P. Beauv. was reduced by 65.74%, 80.18%, 81.15%, 70.99%, 55.65%, and 27.22%, respectively, when mulched with powder, and 1, 3, 5, 7, and 9-cm long oilseed rape straw.

Effect of herbicide on weed density and dry weight

Weed population $m^{-2}$and weed dry weight (g m^{-2}) were influenced by different doses of herbicide (Table 2). The highest weed density was found in no herbicide applied plots, showing the highest weed population values of 72.6, 84.58, 93.33m^{-2} at 25, 50, 75 DAT, respectively and the lowest weed density was found in application of 100% of the recommended dose of herbicide when the values were 14.75, 24.00, 32.50 m^{-2} at 25, 50, 75 DAT, respectively (Table 2). The highest weed dry weight (g m^{-2}) was also found in no herbicide application, showing the highest weed dry weight values of 7.63, 16.72, 105.9 g m^{-2} at 25, 50 and 75 DAT, respectively. The lowest weed dry weight was found in application of 100% of the recommended dose of herbicide, when the values were 1.57, 1.41 and 23.81 g m^{-2} at 25, 50 and 75 DAT, respectively (Table 2). Application of herbicide at recommended dose inhibited seed germination process thus reducing weed density and weed dry weight. Similar research findings were also reported by Bhuiyan et al. (2010) who reported that pre emergence application of Oxadiargyl 400 SC @ 75 g a.i. ha^{-1} had minimum weed density and dry weight of weeds which resulted satisfactory weed control than other treatments. The probable cause of lowest weed dry weight in pre-emergence herbicide applied plots was due to suppression of weed growth which was the result of lower photosynthates in herbicide applied plots.

Interaction effect of rice residue and herbicide on weed density and weed dry weight

Significant variation was found in weed density and weed dry weight due to interaction between rice residue and herbicide management at 25 and 50 DAT but non-significant variation was found in 75 DAT. The highest weed population (m^{-2}) was found in R_0H_0 (no rice residue with no herbicide) treatment, showing the highest values 106.67, 97.33, 114.70m^{-2} at 25, 50, 75 DAT, respectively and the lowest values 10.67, 16.00, 28.33 $m^{-2}$was found in R_2H_4 (5 t ha^{-1}rice residue with 100% of the recommended dose of herbicide) treatment of at 25, 50 and 75 DAT, respectively (Table 3). The highest weed dry weight was found in R_0H_0 (no rice residue with no herbicide) treatment, showing the highest values of 10.53, 33.00, 140.80 g m^{-2} at 25, 50, 75 DAT, respectively and the lowest one was found in R_3H_4 (7.5 t ha^{-1} rice residue with 100% of the recommended dose of herbicide) treatment, showing the lowest values of 1.37, 1.82, 16.23 g m^{-2} at 25, 50, and 75 DAT, respectively (Table 3).

Table 1. Effect of rice residue on weed growth at different days of transplanting.

Rice residue	Weed density (no. m^{-2})			Weed dry matter (g m^{-2})		
	25 DAT	50 DAT	75 DAT	25 DAT	50 DAT	75 DAT
0 (No rice residue)	46.93a*	52.00a	60.00a	5.47a	13.66a	63.31a
2.5 t ha^{-1}	30.60b	38.87b	46.93b	4.62b	16.72a	49.52b
5 t ha^{-1}	22.67b	36.00b	43.80b	2.43c	12.20a	48.47b
7.5 t ha^{-1}	31. 60b	41.87ab	54.20ab	2.97c	1.41b	34.70c
CV (%)	45.07	39.07	26.54	27.37	44.33	34.81
Level of significance	0.01	0.05	0.05	0.01	0.01	0.01

*In a column, values having the same letters or without letters do not differ significantly whereas values with dissimilar letters differ significantly as per Duncan's Multiple Range Test (DMRT).

Table 2. Effect of herbicide on weed growth at different days of transplanting.

Herbicide application	Weed density (no. m^{-2})			Weed dry matter (g m^{-2})		
	25 DAT	50 DAT	75 DAT	25 DAT	50 DAT	75 DAT
No herbicide	72.67a*	84.58a	93.33a	7.63a	13.66a	105.9a
25% of RD	34.00b	39.67b	40.67bc	4.10b	16.72a	49.87b
50% of RD	26.08bc	33.00bc	44.33b	3.69b	12.20a	36.45bc
75% of RD	17.25c	29.67bc	45.33b	2.36c	1.41b	28.97c
100% of RD	14.75c	24.00c	32.50c	1.57c	16.45a	23.81c
CV (%)	45.07	39.07	26.54	27.37	44.33	34.81
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01

*In a column, values having the same letters or without letters do not differ significantly whereas values with dissimilar letters differ significantly as per Duncan's Multiple Range Test (DMRT); RD = Recommended dose.

These findings partially corroborate the findings of Alsaadawi and Sarbout (2015) who observed that combination of 50% of the recommended dose of trifluralin herbicide and sunflower residues at 6 t ha^{-1} significantly reduced weed density and weed dry weight by 79 and 90% over control, respectively while combination of lower rate of herbicide (50% of the recommended dose) and residue rate at 3 t ha^{-1} provide 68% higher weed biomass suppression over the control.

Effect of rice residue on yield and yield contributing characters of *boro* rice

Plant height, total tillers $hill^{-1}$ and effective tillers $hill^{-1}$ were significantly influenced by rice residue (Table 4). The tallest plant (89.01 cm) was recorded from the incorporation of 5 t rice residueha^{-1}and the shortest one (84.55 cm) was obtained from the incorporation of 7.5 t rice residue ha^{-1}.The highest number of total tillers $hill^{-1}$(12.74) was recorded from incorporation of 5 t rice residue ha^{-1}. Similar research finding was also reported by Nahar *et al.* (2017) who observed statistically identical total tillers $hill^{-1}$ with the incorporation of 5 t ha^{-1} of sorghum soybean or mung bean residue or rice straw. The lowest number of total tillers $hill^{-1}$(9.64) was found in no rice residue incorporation (Table 4). Incorporation of rice residue added organic matter to the soil and suppress the growth of weed which facilitates vigorous growth of rice. Thus tillering was increased in rice residue incorporated plots. The highest number of effective tillers $hill^{-1}$(11.47) was recorded from the incorporation of 5.0 t ha^{-1} rice residue and the lowest one(7.82) was found in no rice residue incorporation (Table 4). Probably rice crop residues suppressed weed growth which encouraged vigorous rice growth and ultimately effective tillers were increased. Panicle length, number of grains $panicle^{-1}$and 1000-grain weight were not significantly influenced by rice residue. However, numerically the longest panicle (22.24 cm) was recorded in no rice residue incorporation and the shortest one (22.06 cm) was produced by 2.5 t ha^{-1} rice residue incorporation. The highest number of grains $panicle^{-1}$ (102.98) was observed in incorporation of 5 t ha^{-1} rice residue and the lowest one was found (98.07) in no rice residue incorporation. Apparently the highest 1000-grain weight (21.29 g) was obtained from no rice residue incorporation and the lowest 1000-grain weight (21.05 g) was obtained from incorporation of 2.5 t ha^{-1} rice residue (Table 4). Grain yield was significantly affected by the application of rice residue. The highest grain yield (4.89 t ha^{-1}) was recorded from the incorporation of 2.5 t ha^{-1} rice residues which was statistically identical to incorporation of 5.0 t ha^{-1} rice residues and 7.5 t ha^{-1} rice residues. The highest grain yield was obtained from the application of different amounts of rice residue due to highest number of total and effective tillers $hill^{-1}$and highest number of grains $panicle^{-1}$. Application of rice residue probably enhanced the growth of rice due to add of organic matter to the soil which enhanced soil health. Moreover, rice residue suppressed the weed growth resulted less crop weed competition and ultimately increased grain yield. The lowest grain yield (4.22 t ha^{-1}) was found in no rice residue incorporation treatment (Table 4). Straw yield and harvest index were not significantly influenced by rice residue incorporation. Numerically the highest straw yield (6.48 t ha^{-1}) was found in 5 t ha^{-1}rice residue and the lowest one (6.16 t ha^{-1}) was found in no rice residue incorporation (Table 4). Apparently the highest harvest index (43.03%) was obtained from 2.5 t ha^{-1} rice residue while the lowest harvest index (40.39 %) was obtained from no rice residue application treatment (Table 4).

Table 3. Interaction effect of rice residue and herbicide on weed growth.

Interaction (Rice residue × Herbicide)	Weed density (no. m^{-2})			Weed dry matter (g m^{-2})		
	25 DAT	50 DAT	75 DAT	25 DAT	50 DAT	75 DAT
R_0H_0	106.67*	97.33	114.7a	10.53a	33.00a	140.8a
R_0H_1	40.00	56.00	40.00ef	5.467b	12.20bc	58.93cd
R_0H_2	40.00	42.67	52.00c-f	6.53b	1.41c	37.87c-g
R_0H_3	25.33	37.33	54.67c-f	2.73de	16.45b	42.40c-g
R_0H_4	22.67	26.67	38.67ef	2.07e	11.63bc	36.53c-g
R_1H_0	70.67	73.00	73.33bc	8.80a	14.39b	104.5b
R_1H_1	32.00	32.00	42.67def	5.07bc	1.63c	53.40cde
R_1H_2	22.67	32.00	28.00f	4.60bcd	13.18bc	34.67c-g
R_1H_3	15.67	30.67	57.33cde	2.97de	12.41bc	32.33d-g
R_1H_4	12.00	26.67	33.33ef	1.67e	10.05bc	22.67efg
R_2H_0	44.00	89.33	94.67ab	5.07bc	9.31bc	110.7b
R_2H_1	28.00	29.33	30.67f	2.67de	12.20bc	50.03c-f
R_2H_2	17.33	22.67	30.67f	1.47e	14.27b	37.53c-g
R_2H_3	13.33	22.67	34.67ef	1.77e	12.70bc	24.90efg
R_2H_4	10.67	16.00	28.33f	1.17e	10.67bc	19.17fg
R_3H_0	13.67	78.67	90.67b	6.13b	8.17bc	67.57c
R_3H_1	13.33	41.33	49.33c-f	3.20cde	16.72b	37.10c-f
R_3H_2	69.33	34.67	66.67cd	1.87e	10.93bc	35.73c-g
R_3H_3	36.00	28.00	34.67ef	2.27e	15.20b	16.87fg
R_3H_4	24.33	26.67	29.67f	1.37e	1.82c	16.23g
CV (%)	34.81	39.07	26.54	27.37	44.33	34.81
Level of significance	0.05	0.05	0.05	0.05	0.05	0.05

*In a column, values having the same letters or without letters do not differ significantly whereas values with dissimilar letters differ significantly as per Duncan's Multiple Range Test (DMRT); R_0 = No rice residue, R_1 = 2.5ton rice residue ha^{-1}, R_2 = 5 ton rice residue ha^{-1}, R= 7.5 ton rice residue ha^{-1}; H_0 = No Herbicide, H_1 = 25% of the recommended dose of herbicide, H_2 = 50% of the recommended dose of herbicide, H_3 = 75% of the recommended dose of herbicide, H_4 = 100% of the recommended dose of herbicide.

Effect of herbicide on yield and yield contributing characters of *boro* rice

Plant height was not significantly influenced by different doses of herbicide. Numerically the tallest plant (87.48 cm) was found in 50% of the recommended dose of herbicide and the shortest one (84.68 cm) was found in no herbicide application (Table 5). Number of total tillers $hill^{-1}$ and number of effective tillers $hill^{-1}$ was significantly influenced by different herbicidal treatments. The highest number (12.54) of total tillers $hill^{-1}$ was produced when 75% of the recommended dose of herbicide was applied, while the lowest one (8.50) was produced by no herbicide application treatment (Table 5). The highest number of effective tillers $hill^{-1}$ (11.77) was produced by 75% of the recommended dose of herbicide treatment, while the lowest one (7.32) was produced no herbicide application treatment. Different herbicidal treatments enhanced tiller production $hill^{-1}$ by reducing the growth of weed.

Effect of herbicide was not significant for panicle length and number of grains $panicle^{-1}$. Numerically the longest panicle (22.67 cm) was observed in 50% of the recommended dose of herbicide treatment and the shortest one (21.80 cm) was observed in 25% of the recommended dose of herbicide treatment (Table 5). The highest number of grains $panicle^{-1}$ (106.00) was found in 25% of the recommended dose of herbicide treatment, while the lowest one (86.36) was produced in no herbicide application treatment (Table 5). Wayaan *et al.* (1982) and Gogoi *et al.* (2000) reported that plants were affected by weed competition resulting reduce the number of grains $panicle^{-1}$ in no herbicide applied plots. Weight of 1000-grain was significantly affected by different herbicidal doses. The heaviest 1000-grain weight (21.70 g) was recorded from 100% of the recommended dose of herbicide treatment and the lowest one (20.44 g) was obtained from no herbicide applied plots (Table 5). Grain yield, straw yield and harvest index of *boro* rice was significantly influenced by different doses of herbicide. The highest grain yield (5.70 t ha^{-1}) was obtained from 75% of the recommended dose of herbicide while the lowest grain yield (2.89 t ha^{-1}) was produced by no herbicide application treatment (Table 5). The weeds compete with the crop for nutrient, water, air, sunlight and space and decreased crop yield. The increased yield was contributed in low weedy condition by higher number of effective tillers $hill^{-1}$, higher number of grains $panicle^{-1}$ over weedy condition which ultimately increased grain yield. Similar result was also reported by Attala and Kholosy (2002), Singh and Ram (1991) and Gogoi *et al.* (2000). The highest straw yield (6.72 t ha^{-1}) was observed from 75% of the recommended dose of herbicide treatment and the lower straw yield (5.92 t ha^{-1}) was observed in 25% of the recommended dose of herbicide (Table 5). The highest harvest index (45.86%) was observed in 75% of the recommended dose of herbicide treatment and the lowest harvest index (31.51%) was observed in no herbicide application treatment (Table 5).

Table 4. Effect of rice residue on yield and yield contributing characters of *boro* rice.

Rice residue (t ha^{-1})	Plant height (cm)	Total tillers $hill^{-1}$ (no)	Effective tillers $hill^{-1}$(no.)	Length of panicle (cm)	Grains $panicle^{-1}$ (no.)	1000- grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
0 (no rice residue)	86.15b*	9.64c	7.82c*	22.24	98.07	21.29	4.22b	6.16	40.39
2.5	85.99b	10.97b	10.04b	22.06	101.75	21.059	4.89a	6.42	43.03
5.0	89.01a	12.74a	11.47a	22.12	102.98	21.23	4.68a	6.48	41.61
7.5	84.55b	12.25a	11.09a	22.10	102.61	21.10	4.64a	6.23	41.31
CV (%)	3.63	10.00	10.19	4.33	12.85	2.10	9.40	16.17	10.89
Level of significance	0.01	0.01	0.01	NS	NS	NS	0.01	NS	NS

*In a column, values having the same letters or without letters do not differ significantly whereas values with dissimilar letters differ significantly as per Duncan's Multiple Range Test (DMRT); NS= Not significant.

Table 5. Effect of herbicide on yield and yield contributing characters of *boro* rice.

Application of herbicide	Plant height (cm)	Total tillers $hill^{-1}$ (no)	Effective tillers $hill^{-1}$ (no.)	Length of panicle (cm)	Grains $panicle^{-1}$ (no.)	1000- grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
No herbicide	84.68*	8.50c	7.32d	21.92	86.36b	20.44c	2.89d	6.32	31.51b
25% of RD	87.03	11.29b	10.07c	21.80	106.0a	21.23b	4.47c	5.92	43.32a
50% of RD	87.48	12.25a	11.07ab	22.67	104.9a	21.31b	4.85b	6.08	43.30a
75% of RD	87.02	12.54a	11.77a	21.99	104.7a	21.17b	5.70a	6.72	45.86a
100% of RD	85.92	12.42a	10.30bc	22.27	104.8a	21.70a	5.13b	6.56	43.94a
CV (%)	3.63	10.00	10.19	4.33	12.85	2.10	9.40	16.17	10.89
Level of significance	NS	0.01	0.01	NS	0.01	0.01	0.01	NS	0.01

*In a column, values having the same letters or without letters do not differ significantly whereas values with dissimilar letters differ significantly as per Duncan's Multiple Range Test (DMRT); ** = Significant at 1% level of probability, NS = Not significant, RD = Recommended dose.

Interaction effect of rice residue and herbicide on yield and yield contributing characters of *boro* rice

The effect of interaction between rice residue and herbicide was not significant for plant height, non-effective tillers $hill^{-1}$, panicle length and sterile spikelets $panicle^{-1}$. Numerically the tallest plant (90.33 cm) was obtained incorporation of 5 t ha^{-1}rice residue with 50% of the recommended dose of herbicide and the shortest plant (81.93 cm) was found with no rice residue and no herbicide application (Table 6). Numerically the longest panicle (23.27 cm) was produced by incorporation of 5 t ha^{-1}rice residue with 50% of the recommended dose of herbicide and the shortest one (21.47 cm) was found in incorporation of 5 t ha^{-1}rice residue with 75% of the recommended dose of herbicide treatment (Table 6).

Significant variation was found in number of total tillers $hill^{-1}$, effective tillers $hill^{-1}$, number of grains $panicle^{-1}$ and weight of 1000-grain due to interaction between rice residue and herbicide. The highest number of total tillers $hill^{-1}$ (13.80) was produced in incorporation of 5.0 t ha^{-1}rice residue with 75% of the recommended dose of herbicide, while the lowest number of total tillers $hill^{-1}$ (6.17) was produced in no rice residue incorporation with no herbicide application treatment (Table 6). The highest number of effective tillers $hill^{-1}$ (12.80) was produced in 5 t ha^{-1}rice residue with 75% of the recommended dose of herbicide treatment, while the lowest number of effective tillers $hill^{-1}$ (5.43) was produced in no rice residue incorporation with no herbicide application treatment (Table 6). The highest number of grains $panicle^{-1}$(113.07) was produced by incorporation of 7.5 t ha^{-1}rice residue with 25% of the recommended dose of herbicide treatment and the shortest one (75.64) was found in no rice residue incorporation with no herbicide application treatment (Table 6). The heaviest 1000 grain weight (22.12 g) was recorded in no rice residue incorporation with 100% of the recommended dose of herbicide treatment and the lowest one (20.02 g) was produced by incorporation of 7.5 t ha^{-1}rice residue with no herbicide application treatment (Table 6).Grain yield was significantly influenced by the interaction between rice residue and herbicide. The highest grain yield (5.87 t ha^{-1}) was produced incorporation of 3HHHhhh5 t ha^{-1}rice residue with 75% of the recommended dose of herbicide. The highest grain yield in incorporation of 3HHHhhh5 t ha^{-1}rice residue with 75% of the recommended dose of herbicide might be due to highest number of effective tillers in this treatment. The lowest grain yield (2.74 t ha^{-1}) was produced by no rice residue incorporation with no herbicide application treatment (Table 6). This was because crop weed competition was higher for nutrient, moisture and sunlight in this treatment thus reducing grain yield. Similar research finding was also reported by Nahar *et al.* (2017) who obtained the lowest grain yield in no residue incorporation and no herbicide applied plot due to lowest performance of yield and yield contributing characters in this treatment. Straw yield was not significantly influenced by interaction between rice residue and herbicide. The highest straw yield (7.21 t ha^{-1}) was produced by incorporation of 5 t ha^{-1} rice residue with 75% of the recommended dose of herbicide treatment, while the lowest one (5.65 t ha^{-1}) was produced by incorporation of 5 t ha^{-1}rice residue with 25% of the recommended dose of herbicide treatment (Table 6). Harvest index was not significantly influenced by the interaction of rice residue and herbicide. The highest harvest index (48.09%) was observed in R_1H_2 (2.5 t ha^{-1} rice residue with 50% of the recommended dose of herbicide) treatment while the lowest harvest index (30.32%) was observed in incorporation of 5 t ha^{-1}rice residue with no herbicide application treatment (Table 6).

Table 6. Interaction effect of rice residue and herbicide on the performance of *boro* rice.

Interaction (Rice residue × Herbicide)	Plant height (cm)	Total tillers hill^{-1}(no.)	Effective tillers hill^{-1}(no.)	Length of panicle (cm)	Grains panicle^{-1} (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
R_0H_0	81.93	6.17h*	5.43i	21.85	75.64	20.60ef	2.74f	5.78	32.45
R_0H_1	87.93	9.90ef	8.433fg	22.03	101.92	21.08b-e	4.05e	6.11	40.55
R_0H_2	88.77	10.07def	9.133efg	22.65	107.44	21.30a-e	4.05e	5.99	40.39
R_0H_3	87.00	10.93cde	10.03def	22.07	98.00	21.33a-e	5.41a-d	6.35	45.15
R_0H_4	85.13	11.13b-e	6.067hi	22.60	107.37	22.12a	4.85cd	6.55	42.58
R_1H_0	84.53	7.267gh	6.267hi	21.93	87.07	20.09f	3.09f	6.71	31.51
R_1H_1	87.67	11.23b-e	10.03def	21.75	103.53	20.98cde	4.63de	6.01	44.09
R_1H_2	86.80	12.20a-d	11.23a-d	22.49	108.52	21.30a-e	5.37a-d	5.84	48.09
R_1H_3	85.93	12.43abc	12.00abc	21.83	99.42	21.33a-e	5.84a	6.84	46.31
R_1H_4	85.00	11.73a-e	10.67b-e	22.28	110.21	21.58a-d	5.51abc	**6.70**	46.00
R_2H_0	90.13	12.17a-d	9.97def	21.79	93.88	21.07b-e	2.76f	6.42	30.32
R_2H_1	86.47	11.20b-e	10.37cde	21.84	101.08	21.67abc	4.58de	5.65	44.80
R_2H_2	90.33	13.50a	12.63ab	23.27	112.15	20.75def	5.08a-d	6.59	43.51
R_2H_3	84.20	13.80a	12.80a	21.47	102.88	21.07b-e	5.87a	7.21	44.04
R_2H_4	89.33	13.03abc	11.83a-d	22.23	104.93	21.60a-d	5.13a-d	6.55	43.99
R_3H_0	81.93	8.40fg	7.60gh	22.11	88.84	20.02f	2.97f	6.39	45.42
R_3H_1	86.06	12.83abc	11.43a-d	21.60	113.07	21.17b-e	4.61de	5.93	43.82
R_3H_2	84.20	13.23ab	11.50a-d	22.26	104.86	21.87ab	4.91bcd	5.90	41.22
R_3H_3	86.33	13.00abc	12.27abc	22.57	109.51	20.97cde	5.69ab	6.47	45.71
R_3H_4	88.80	13.77a	12.40ab	21.97	96.79	21.50a-d	5.01bcd	6.44	31.77
CV %)	3.63	10.00	10.19	4.33	12.85	2.10	9.40	16.17	10.89
Level of significance	NS	0.05	0.01	NS	NS	0.05	0.01	NS	NS

*In a column, values having the same letters or without letters do not differ significantly whereas values with dissimilar letters differ significantly as per Duncan's Multiple Range Test (DMRT); NS = Not significant; R_0= No rice residue, R_1= 2.5ton rice residue ha^{-1}, R_2= 5 ton rice residue ha^{-1}, R_3= 7.5 ton rice residue ha^{-1}, H_0= No Herbicide, H_1= 25% of the recommended dose of herbicide, H_2= 50% of the recommended dose of herbicide, H_3= 75% of the recommended dose of herbicide, H_4 = 100% of the recommended dose of herbicide.

Conclusion

From the above results it is found that 5.0 t ha^{-1}rice residue with 75% of the recommended dose of herbicide treatment exhibited the superior effect. It may be concluded that 5.0 t ha^{-1} rice residue with 75% of the recommended dose of herbicide is effective for weed suppression and for obtaining highest grain yield. But further researches are needed using residue of different crops to draw a concrete conclusion.

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