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WEED COMPOSITION AND YIELD PERFORMANCE OF *BORO* RICE INFLUENCED BY TILLAGE METHODS AND WEEDING REGIME

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ABSTRACT

Ahmed I, Begum M, Sultana A, Monira S, Ali MD, Limu GN (2023) Weed composition and yield performance of *boro* rice influenced by tillage methods and weeding regime. *Int. J. Expt. Agric*. 13(2), 19-29.

Tillage has an important role in reducing crop weed competition and increasing crop yield. Therefore, an experiment was designed using split plot design to investigate the effect of tillage and weeding regimes on weed dynamics and yield of *boro* rice and repeated for three times. The experiment included four tillage methods *viz.* conventional tillage, false seedbed, stale seedbed and conservation tillage, assigned in the main plots and seven weeding regimes viz. no weeding, two hand weedings (HW) at 25 DAT and 50 DAT, super power as early post-emergence herbicide + HW at 25 DAT, granite as post-emergence herbicide + HW at 50 DAT, super power followed by (fb) granite, super power fb granite + HW at 50 DAT and weed free, assigned in sub plots. Total number of infested weeds were 29 belonging to 11 families of which Poaceae family was dominant. Irrespective of sampling dates, the plots under conventional tillage, false seedbed, stale seedbed and conservation tillage were infested with 24, 25, 22 and 27 weeds, respectively. Conventional tillage produced the highest yield (6.31 t ha^{-1}) along with other yield contributing characters and the lowest yield (5.59 t ha^{-1}) was obtained from conservation tillage. Besides, Super power fb Granite + HW at 50 DAT produced the highest yield (6.34 t ha^{-1}). Considering interaction effect, combination of conventional tillage with Super power followed by Granite + HW at 50 DAT gave the best performance in terms of yield attributes and yield (6.5 t ha^{-1}). Therefore, it may be concluded that conventional tillage with Super power fb Granite + hand weeding at 50 DAT could be the promising technology to manage weeds effectively and also to obtain higher yield of *boro* rice. However, further studies in different agro-ecological zones are needed to draw any concrete conclusions.

Key words: *benefit cost ratio, conservation tillage, weed dynamics, weed management, herbicide*

INTRODUCTION

Agriculture is one of the most important economic sectors of Bangladesh. This sector plays a key role in increasing productivity, ensuring sustainable food security and creating employment opportunities. The BBS estimates that, the contribution of agriculture to the GDP in FY 2021-22 is about 11.50% (BER 2022). Bangladesh has three rice growing seasons among which *boro* rice covers about 48.14 lakh hectares of total rice area and average yield of *boro* rice (4.19 t ha^{-1}) (BBS 2022). But yield is much lower than that of other rice producing countries like China, and India. This is due to high weed infestation and poor crop management such as lack of optimum seed rate, nutrient & water management, traditional weed management and natural calamities.

Weeds are harmful agricultural pests because they affect plant growth and development by competing for water, nutrients, light and space. In aerobic paddy fields, uncontrolled weed growth can reduce yields by up to 96% (Chauhan and Johnson, 2011). According to Sarker (1996) and BRRI (2006), weed infestation causes the grain yield reduction by 70-80% in *aus* rice (early summer), 30-40% for transplanted *aman* rice (late summer) and 22-36% for modern *boro* rice cultivars. Weed competition affects most of the plant parameters including plant height, number of tillers, number of panicles, grain yield etc. Production cost increases due to investment in different weed management operations.

To minimize production cost and to increase yield, tillage operations can be used to control weeds. Tillage is the agricultural preparation of land for growing crops. Through tillage operation, weed infestation in rice can be reduced. Tillage operation cuts and uproots the weeds and buries them deep enough also causes moving there seeds both vertically and horizontally and so promoting or inhibiting the weed germination and establishment (Jorgensen 2018). Several tillage operations may be practiced in Bangladesh such as conservation, stale seedbed, and false seedbed technique in *boro* rice. Modifications in tillage practices can cause shifts in weed species. Long-term cultivation and differing tillage systems produce critical adjustments within the composition and density of weed. A number one difference among the tillage treatments may be weed production, specifically if there is no earlier experience on-farm with the use of herbicides in reduced tillage situations. If weeds emerge before the crop, they will get competitive advantage in the use of different resources like light, water and nutrients and crop yield will be reduced.

Applying herbicides is another cheap method for controlling weeds. Herbicidal weed control is gaining popularity now a day's due to labor crisis during peak growing season and its lower cost. Ahmed *et al*. (2000) also confirmed that, weed control with herbicides is an efficient and cheap method. Pre-emergence herbicides can play a vital role in eliminating weed competition at early growth stages and at later crop growth stage, post-emergence herbicides can be used to control weeds. In some cases, pre- and post-emergence herbicide along with both combination of hand weeding may be more effective for efficient weed control.

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It has been seen that integration of strategies are constantly better than any single approach that is only hand weeding or only chemical weed control (Islam 2012). Furthermore, when any single method is used repeatedly an uncommon weed may become an abundant one. The replacement of manual weeding by herbicides or herbicides in combination with hand weeding would help to obtain higher crop productivity with less efforts and cost. A number of studies (Mandal *et al*. 1995; Panwar *et al.* 1992) showed that weed control through both conventional and chemical methods influence the growth and yield attributes of rice. Thus, to reduce weed infestation and maximizing rice yield appropriate weed management practices need to be adopted by the farmers. Keeping the above facts in view, the present study was undertaken to evaluate the effect of different types of tillage on weed diversity and density, and yield of *boro* rice and to identify potential combination of tillage with weeding regime for reducing weed infestation and maximizing yield of *boro* rice.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh from January 2018 to June 2018 belonging to the Old Brahmaputra Floodplain (AEZ-9) (UNDP and FAO 1988) and Sonatala series of dark grey floodplain soil. BRRI dhan28 was utilized as planting material. Monthly weather data on average maximum and minimum temperature, relative humidity and total precipitation throughout the experimental period were recorded from Weather Yard, Department of Irrigation and Water Management, BAU, Mymensingh which has been summarized in Fig. 1. Prior to conducting the investigation, soil of the study area was analyzed and the physicochemical properties were documented in Table 1.

Table 1. The physico-chemical attributes of soil of study area

Morphological characteristics	Characteristics
Land type	Medium high land
Bulk density (g/cc)	1.35
Porosity (%)	46.67
pH	6.80
Organic matter (%)	1.29
Total nitrogen (%)	0.101
Available phosphorous (ppm)	26.00
Exchangeable potassium (me %)	0.14

Source: Results obtained from chemical analysis of the initial soil sample done in the Department of Soil Science, Bangladesh Agricultural University, Mymensingh.

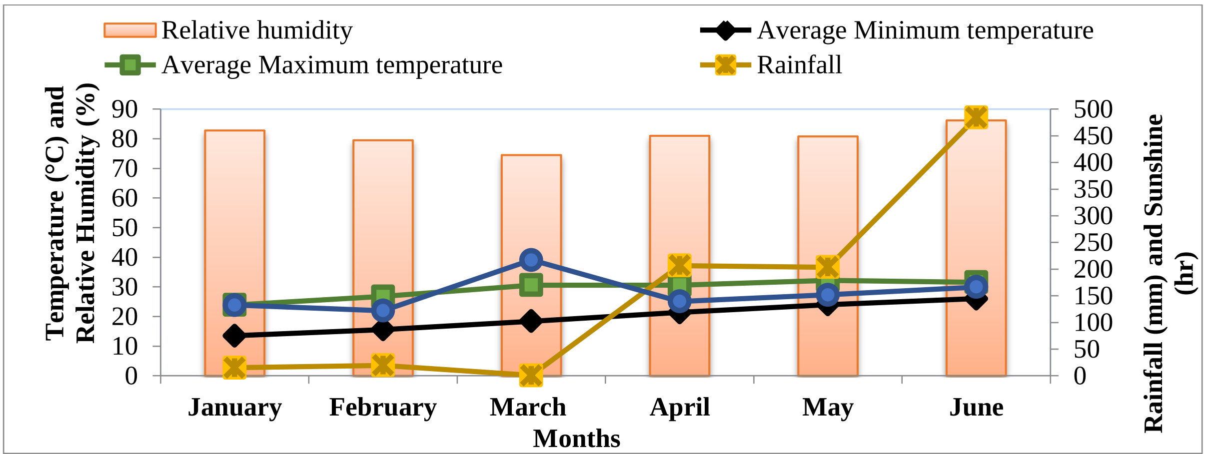

Fig. 1. Monthly average temperature, relative humidity, total rainfall and sunshine during the crop growing season.

Experimental Treatments and design

The trial consisted of two factors; factor A: four tillage systems *i.e.*, conventional tillage (CT), false seedbed (FS), stale seedbed (ST) and conservation tillage (CS); factor B: seven weeding regimes *i.e.*, No weeding (W_0), two times hand weeding (HW) at 25 DAT and 50 DAT (W_1), super power as early post-emergence herbicide + HW at 25 DAT (W_2), granite as post-emergence herbicide + HW at 50 DAT (W_3), super power followed by (fb) granite (W_4), super power followed by (fb) granite + HW at 50 DAT (W_5) and weed free (W_f). The research work was organized in split plot design with 3 replications. The size of the unit plot was 10 m^2 (4.0 m x 2.5 m) and main plots were separated by 1 m and sub plots by 0.5 m and total number of plots were 84. A short description of herbicides was given in Table 2.

Table 2. A short description of the herbicides used in the experiment

Trade name	Generic name	Mode of action	Recommended dose	Target weeds	Field condition
Parakrone	Paraquat dichloride salt	Contact herbicide	150 g ha^{-1}	Annual grass, sedge, broad leaved weeds	1-2 cm standing water must be present in soil
Super power	Pyrazosulfuronethyle	Systemic	150 g ha^{-1}	Annual grass, sedge, broad leaved weeds	1-2 cm standing water must be present in soil
Granite	Penoxsulam	Systemic (cell division inhibitor)	93.7 ml ha^{-1}	Annual grass, sedge, broad leaved weeds	2-3 cm standing water must be present in soil

Crop Husbandry

Healthy and good quality seeds of BRRI dhan28 were collected from Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. The sprouted seeds were sown through broadcast method in wet seedbed on 10 December 2017 and raised with proper care. Conventional tillage consisted of two passes primary tillage by two wheeler power tiller (2WPT). In stale seedbed and false seedbed plot, 1^{st} tillage operation was done at 5 January 2018 with 2WPT and one light irrigation was given to allow the germination of weed seeds. About seven days later shallow tillage was done in false seedbed and stale seedbed method to kill the emerged weeds and again the land was lightly irrigated to allow more weeds to emerge for next one week. Then another shallow tillage operation for false seedbed was done on 18 January 2018 along with conventional method, while glyphosate was used to kill the weeds in stale seedbed. The field layout was made as per design and seedlings were transplanted in the main fields on 18 January 2018 @ three seedlings $hill^{-1}$ following 25 cm x 15 cm spacing. The experimental plot was fertilized with 150, 100, 70, 60 and 10 kg ha^{-1} of urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate, respectively. The entire amounts of TSP, MoP, gypsum, zinc sulphate and 1/3 urea were broadcasted and incorporated with the soil during final land preparation. The rest amount of the urea was top dressed in two installments at 30 DAT and 50 DAT. Weeding was done as per treatment. In plots some hills were died off and gap filling was done within 10 DAT where it was required. The plots were irrigated for six times.

Harvesting and Processing

Crops were harvested at maturity (when 90% of the grains became golden yellow in color) on 25 April 2018, just before harvesting five hills excluding the border plant and the harvest area 1 m^2 of each plot were selected at random and uprooted for collecting data on yield component. Central 1 m^2 from each plot was cut manually at the ground level to record grain and straw yields. The harvested crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. The harvested crop was threshed by paddle thresher. Grains were cleaned and dried to a moisture content of 14%. Straws were dried properly by sun drying method. Grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}.

Data Collection

Data on weeds density were collected from each plot of rice field by using 0.5 m^{-2} quadrate at 25 DAT, 50 DAT and at harvest as per method described by Cruz *et al.* (1998). The quadrate was placed twice at random in each plot and all weeds inside the quadrate were uprooted and separated species-wise and counted and their average values were converted to number m^{-2}. Afterwards, weeds were washed and oven dried for 72 hours at 65^0C and weighed and expressed in g m^{-2}. Five hills were randomly selected from each plot excluding boarder rows prior to harvest for recording data on yield contributing characters. Experimental data on yield and yield contributing characters were recorded on the following parameters: number of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$, thousand grain weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}) and biological yield. Harvest index was calculated by following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Economic analysis

The cost of individual head of expenditure was recorded and partial budget analysis was done. Benefit Cost Ratio was calculated by the equation mentioned below-

$$\text{BCR} = \frac{\text{Gross income}}{\text{Total cost of production}}$$

Statistical Analysis

The recorded data were compiled and tabulated for statistical analysis. Data were subjected to ANOVA using MSTAT-C and means were separated by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Weed infestation in *boro* rice

Conditions suitable for growing *boro* rice are also suitable for many weed species that compete with the crop. The intensity of this competition increases when the nature and the weed growth are relatively abundant and faster than growth of the desired crop plants. If not timely controlled, different types of weeds like aquatic, semi-aquatic, broadleaved, grasses and a few types of sedges which can withstand water logging are able to suppress the rice plants and depress crop yield significantly. The experimental plots were overrun by 29 weed species from 11 different family members, of which eight from the family Poaceae, five from the family Cyperaceae, three each from the families of Amaranthaceae and Polygonaceae, two each from the families of Commelinaceae, Compositae, and Scrophulariaceae, one each from the families of Convolvulaceae, Marsileaceae, Onagraceae and Euphorbiaceae (Table 3). Monira *et al.* (2020) identified 19 weed species under nine families at the same location of which six were grasses, five were sedge and eight were broadleaves.

Regarding tillage, the experimental plots under conventional tillage, false seedbed, stale seedbed and conservation tillage were infested with 24, 25, 22 and 27 weed species, respectively (Table 3). In case of 25 DAT, a total of 16 weeds were observed in four tillage methods and 11 weed species were commonly found among the four tillage methods. The weed species *Parapholis incurva* was absent in false seed bed technique and conservation tillage but present in other two tillage system. The weed species *Commelina benghalensis* and *Cyanotis axillaris* were absent from the false seed bed technique but present in the other three treatments, whereas the weed species *Fimbristylis miliaceae* was absent from the stale seed bed technique but present in the other three treatments (Table 3).

In case of 50 DAT, total number of weeds 20, were observed in four tillage methods and 12 weed species were commonly found among the four tillage methods. The *Scirpus juncoides* was only present in conservation tillage, while *Ludwigia hyssopifolia* and *Rumex maritimus* were absent in conservation tillage but present in other three tillage methods. *Commelina benghalensis* and *Spilanthes acmella* were absent only in false seed bed technique, while *Lindernia hysopioides* was absent only in conventional tillage. In addition, *Hedyotis corymbosa* was present in false seedbed and conservation tillage but absent in other two tillage methods (Table 3).

In case of harvesting, total number weeds 24, were observed in four tillage methods and seven weed species were commonly found among the four tillage methods. *Leersia hexandra*, *Eleucine indica*, and *Ludwigia hyssopifolia* were absent exclusively in the stale seedbed technique, while *Parapholis incurua* was absent solely in conservation tillage. Both conventional and conservation tillage were devoid of the weed *Cyperus esculentus*, while stale seedbed and conservation tillage were devoid of *Cyperus rotundus*. Besides, weed species *Cyperus iria* was absent in stale seedbed and conservation tillage system but present in other two tillage system. In addition, *Monochoria vaginalis* was present only in false seed bed technique, while *Amaranthus viridis* and *Commelina benghalensis* were absent in false seedbed technique. *Ipomoea indica* was absent from the conservation and false seed bed tillage systems, in contrast to *Lindernia hysopioides*, which was absent from the conventional and conservation tillage systems. Weed species *Scirpus juncoides* was present only in stale seed bed technique, while *Rumex maritimus* was present in both conventional and stale seed bed tillage systems (Table 3).

Table 3. Floristic composition of weeds in the experimental field of *boro* rice

Scientific name	Family Name	Morphology and Life cycle	Weeds at different tillage system											
			Conventional tillage			Stale seed bed technique			False seed bed technique			Conservation tillage		
			At 25 DAT	At 50 DAT	At Harvest	At 25 DAT	AT 50 DAT	At Harvest	At 25 DAT	At 50 DAT	At Harvest	At 25 DAT	At 50 DAT	At Harvest
Echinochloa crusgalli	Poaceae	GA	+	+	+	+	+	+	+	+	+	+	+	+
Digitaria sanguinalis	Poaceae	GA	+	-	+	+	-	+	+	-	+	+	-	+
Panicum distichum	Poaceae	GP	+	-	+	+	-	+	+	-	+	+	-	+
Parapholis incurua	Poaceae	GA	+	+	-	+	+	+	-	+	+	-	+	-
Leersia hexandra	Poaceae	GP	+	+	+	+	+	-	+	+	+	+	+	+
Cynodon dactylon	Poaceae	GP	+	+	+	+	+	+	+	+	+	+	+	+
Eleusine indica	Poaceae	GA	-	-	+	-	-	-	-	-	+	-	-	+
Cyperus esculentus	Poaceae	SA	-	-	-	-	-	+	-	-	+	-	-	-
Fimbristylis miliaceae	Cyperaceae	SA	+	+	+	-	+	+	+	+	+	+	+	+
Cyperus difformis	Cyperaceae	SA	+	+	-	+	+	+	+	+	+	+	+	+
Cyperus rotundus	Cyperaceae	SA	+	+	+	+	+	-	+	+	+	+	+	-
Scirpus juncoides	Cyperaceae	SA	+	-	-	+	-	+	+	-	-	+	+	-
Cyperus iria	Cyperaceae	SA	-	-	+	-	-	-	-	-	-	-	-	+
Amaranthus viridis	Amaranthaceae	BA	-	-	+	-	-	+	-	-	-	-	-	+
Amaranthus spinosus	Amaranthaceae	BA	-	-	-	-	-	-	-	-	-	-	-	+
Alternanthera sessile	Amaranthaceae	BA	+	+	+	+	+	+	+	+	+	+	+	+
Commelina benghalensis	Commelinaceae	BA	+	+	-	+	+	+	-	-	-	+	+	+
Cyanotis axillaris	Commelinaceae	BA	+	-	-	+	-	-	-	-	-	+	-	-
Eclipta alba	Compositae	BA	+	+	+	+	+	-	+	+	-	+	+	-
Spilanthes acmella	Compositae	BA	-	+	-	-	+	-	-	-	-	-	+	-
Ipomoea indica	Convolvulaceae	BA	-	-	-	-	-	+	-	-	-	-	-	+
Phylanthus niruri	Euphorbiaceae	BA	-	+	-	-	+	-	-	+	-	-	+	-
Hedyotis corymbosa	Marsileaceae	BA	-	-	-	-	-	-	+	+	-	-	+	-
Ludwigia hyssopifolia	Onagraceae	BA	-	+	+	-	+	-	-	+	+	-	-	+
Polygonum hydropiper	Polygonaceae	BA	-	+	+	-	+	+	-	+	+	-	+	+
Monocoria vaginalis	Polygonaceae	BP	-	+	-	-	+	-	-	+	+	-	+	-
Rumex maritimus	Polygonaceae	BP	-	+	+	-	+	+	-	+	-	-	-	-
Lindernia hysopioides	Scrophulariaceae	BA	-	-	-	-	+	+	-	+	+	-	+	-
Lindernia antipoda	Scrophulariaceae	BA	+	+	-	+	+	25-	+	+	22-	+	+	27-

+ = Present; - = Absent; G-Grass; S-Sedge; B-Broadleaf; A-Annual; P-Perennial

Effect of tillage methods on weed density and weed dry weight

Effect of tillage methods had significant influence on weed density at 25 DAT, 50 DAT and at harvest (Table 4). At 25 and 50 DATs, the highest weed density 19.72 m^{-2} and 47.61 m^{-2} was found in conservation tillage which was statistically identical to false and stale seedbed technique. At harvest, the highest weed density 57.22 m^{-2} was also found in conservation tillage. The lowest weed density 16.94 m^{-2}, 40.78 m^{-2} and 49.78 m^{-2} was obtained from conventional tillage method at all sampling dates (Table 4). In the conventional tillage method, ploughing caused cutting and deep burial of weed plants and seeds which may reduce the weed density, while in conservation tillage method, weed seed germination and growth was not disturbed and ultimately weed density was high. Carr *et al.* (2012) also found higher weed density in conservation tillage system. In addition, conservation tillage method is believed to worsen weed problems by higher weed emergence promoted by concentration of seed in soil and shifts of the weed community towards increased abundance of troublesome species, e.g. grasses and perennials (Bhowmick *et al.* 2000).

Weed dry weight was also significantly influenced by tillage methods only at 50 DAT. The highest weed dry weight (17.95 g m^{-2}) was found in conservation tillage followed by stale and false seedbed technique and the lowest weed dry weight (13.73 g m^{-2}) was obtained from conventional tillage method (Table 4). Reduced weed density in the conventional tillage method might be the reason of the lowest weed dry weight in this treatment.

Table 4. Effect of tillage on weed density and dry weight at different days after transplanting of *boro* rice

Method	**Weed density (m^{-2})**			**Weed dry weight (g)**
	25 DAT	**50 DAT**	**At harvest**	**50 DAT**
Conventional	16.94 b	40.78 b	49.78 c	13.73 c
False seedbed	17.67 ab	43.11 b	53.22 b	15.90 b
Stale seedbed	18.61 ab	47.17 a	54.94 b	17.54 ab
Conservation	19.72 a	47.61 a	57.22 a	17.95 a
Level of Significance	**	**	*	**
CV (%)	15.32	12.79	14.82	10.23

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, CV= Co-efficient of variation

Effect of weeding regimes on weed density and weed dry weight

Effect of weeding regimes had significant influence on weed density and weed dry weight at 25, 50 DAT and at harvest (Table 5). The highest weed density (24.83 m^{-2} at 25 DAT, 60.42 m^{-2} at 50 DAT and 78.58 m^{-2} at harvest) and dry weight (7.57, 24.99 and 42.22 g m^{-2} at 25 DAT, 50 DAT and at harvest, respectively) was obtained from W_0 (No weeding) treatment followed by W_1 (two hand weeding at 25 DAT and 50 DAT) and W_2 (Super power as early post-emergence herbicide + HW at 25 DAT) treatments. The lowest weed density (10.01 m^{-2} at 25 DAT, 16.25 m^{-2} at 50 DAT and 25.25 m^{-2} at harvest) and dry weight (4.5, 10.75 and 30.55 g m^{-2} at 25 DAT, 50 DAT and at harvest, respectively) was found from weed free treatment followed by W_5 (Super power followed by Granite + HW at 50 DAT) treatment and W_4 (Super power followed by Granite) treatment (Table 5). Weed density increased with time and became maximum at harvest. Weed density was the highest in the no weeding treatment and lowest in the weed free treatment when early post emergence herbicide followed by post-emergence herbicide + one hand weeding was done at 50 DAT. Using herbicides, weed seed germination and emergence was checked and through hand weeding established weeds were removed and ultimately weed density was reduced. Paul *et al*. (2019) also found the lowest weed density using herbicides during early crop growth stages followed by hand weeding at later stages. In addition, the weeds in the unweeded plots increased tremendously and the dry weight of the weeds became high. Early post followed by post emergence herbicide along with one hand weeding caused lowest weed dry weight due to successful reduction of weeds during early and later stages from the plots. Paul *et al*. (2019) also found similar results.

The interaction effect of tillage and weeding regime was not significant on weed density and dry weight at 25, 50 DAT and at harvest (data not given).

Table 5. Effect of weeding regimes on weed density and dry weight at different days after transplanting of *boro* rice

Weed management	Weed density (m^{-2})			Weed dry weight (g)		
	25 DAT	50 DAT	At harvest	25 DAT	50 DAT	At harvest
W_0	24.83 a	60.42 a	78.58 a	7.573 a	24.99 a	42.22 a
W_1	20.08 b	49.33 b	63.00 b	7.070 b	17.16 b	38.13 b
W_2	17.42 bc	45.33 c	55.42 c	6.528 c	15.50 bc	36.69 bc
W_3	16.50 c	41.50 c	46.42 d	6.213 cd	13.86 cd	35.16 bcd
W_4	15.42 c	36.42 d	43.25 d	5.758 de	13.29 cd	33.50 cd
W_5	15.17 c	35.00 d	36.08 e	5.421 e	12.88 d	32.75 d
W_f	10.1 d	16.25 e	25.52 f	4.5 f	10.75 e	30. 55 e
Level of Significance	**	**	**	**	**	**
CV (%)	9.21	10.81	12.02	20.51	10.73	9.75

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). **= Significant at 1% level of probability, CV= Co-efficient of variation, W_0= No weeding, W_1= Two hand weedings (HW) at 20 DAT and 50 DAT, W_2= Super power as early post-emergence herbicide + HW at 25 DAT, W_3= Granite as post-emergence herbicide + HW at 50 DAT, W_4= Super followed by Granite, W_5= Super power followed by Granite + HW at 50 DAT, W_f = Weed free

Effect of tillage methods on the yield and yield characters of *boro* rice

Different tillage systems exerted significant effect on all the yield characters and yield of BRRI dhan28 (Table 6). The highest number of effective tillers hill^{-1} (9.35), grains panicle^{-1} (95.25), 1000-grain weight (21.88 g), grain yield (6.31 t ha^{-1}) and harvest index (47.15%) were obtained from conventional tillage, whereas the second highest of the above mentioned parameters were observed in false seedbed except harvest index. So, next to conventional tillage, the second highest value of harvest index was found in conservation tillage which was statistically identical to stale seedbed. Regarding biological yield, the highest value (13.50 t ha^{-1}) was recorded in false seedbed followed by conventional. The lowest number of effective tillers hill^{-1} (8.34), grains panicle^{-1} (89.22), 1000-grain weight (21.25 g) and grain yield (5.59 t ha^{-1}) were obtained from conservation tillage, while the minimum value of harvest index (43.48%) were observed in false seedbed (Table 6). In the conservation tillage method soil was not disturbed and slower nitrogen mineralization and high weed pressure might cause the lowest number of effective tillers hill^{-1} and grains panicle^{-1}, 1000-grain weight and ultimately the lower the grain yield. Sitthaphanit *et al.* (2018) also found the lowest rice yield in the conservation tillage method compared to conventional tillage.

Table 6. Effect of tillage practice on the yield attributes and yields of *boro* rice

Tillage methods	Effective tillers hill^{-1}	Number of grains panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest index (%)
Conventional	9.35 a	95.29 a	21.88 a	6.31 a	13.38 b	47.15 a
False seedbed	8.86 b	93.29 a	21.74 ab	5.87 b	13.50 a	43.48 c
Stale seedbed	8.63 c	90.42 b	21.46 b	5.71 c	12.97 c	43.94 b
Conservation	8.34 d	89.22 b	21.25 bc	5.59 d	12.72 d	43.95 b
Level of Significance	**	**	*	**	**	**
CV (%)	2.38	3.77	2.18	1.73	0.80	1.27

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, CV = Co-efficient variation

Effect of weeding regime on the yield attributes and yields of *boro* rice

From the result it was observed that weeding regimes had significant effect on all the yield contributing parameters and yield of BRRI dhan28 (Table 7). The highest number of effective tillers hill^{-1} (9.78), grains panicle^{-1} (94.50), 1000 grain weight (22.33 g), grain yield (6.34 t ha^{-1}) and harvest index (45.31%) was produced by weed free treatment, whereas the second highest values of these above mentioned parameters were recorded in W_5 (Super power followed by Granite + HW at 50 DAT) (Table 7). Regarding straw yield and biological yield, the highest value of straw yield (8.01 t ha^{-1}) and biological yield (14.20 t ha^{-1}) were documented in W_5 (Super power followed by Granite + HW at 50 DAT) followed by weed free treatment. The lowest value of yield contributing parameters and yield was noted in W_0 (No weeding) (Table 7). Similar results were reported by Parvez *et al.* (2013) that the maximum effective tillers hill^{-1}, number of grains panicle^{-1} and 1000-grain weight were recorded from weed free condition and the lowest value was observed under no weeding treatment. Again, similar results were reported by Rashed (2011) and Rahman (2014) who observed that all the yield contributing parameters were affected by weed competition and the lowest values of these parameters were found in no weeding treatment. Parvez *et al.* (2013) also reported that the highest harvest index (41.73%) was observed in weed free treatment which was identical to application of Pretilachlor herbicide + one hand weeding at 21 DAT (40.89%) treatment. In addition, Rahman (2014) also found that the highest harvest index (50.11%) was observed in weed free treatment which was statistically identical to application of Rifit 500 EC @ 1 L ha^{-1} and the lowest harvest index (42.53%) was observed in no weeding treatment.

The result proved that effective weed management is important for production of rice. The highest grain yield was obtained because of the field was weed free or less weed infested. As a result, there was no scope for competition between rice and weeds for nutrients, air, water and light and the rice plant produced more number yield contributing parameters. In addition, higher number of growing leaves might have enhanced the photosynthetic activity due to reduced crop-weed competition, which also contributes in generating higher yield in the treated plots. Monira *et al.* (2020) also found the similar results.

Table 7. Effect of weeding regime on the yield attributes and yields of *boro* rice

Weeding regime	**Effective tillers hill^{-1}**	**Number of grains panicle^{-1}**	**1000 grain weight (g)**	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**	**Biological yield (t ha^{-1})**	**Harvest index (%)**
W_0	8.05 f	85.54 c	20.41 c	3.09 f	6.57 f	9.66 g	31.97 b
W_1	8.37 e	90.71 b	21.29 b	4.31 e	6.73 e	11.04 f	39.04 b
W_2	8.84 c	89.61 b	21.35 b	4.34 d	7.16 d	11.50 e	37.74 b
W_3	8.89 c	89.64 b	21.86 a	4.85 c	7.46 c	12.31 d	39.37 b
W_4	8.52 d	92.61 a	21.91 a	5.14 b	7.42 c	13.01 b	39.50 b
W_5	9.13 b	93.79 a	21.93 a	6.19 b	8.01 a	14.20 a	43.59 b
W_f	9.78 a	94.50 a	22.33 a	6.34 a	7.65 b	13.99 c	45.31 a
Level of Significance	**	**	**	**	**	**	**
CV (%)	1.69	2.36	2.44	1.50	1.42	0.95	1.26

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, CV = Co-efficient variation; W_0= No weeding, W_1= Two hand weedings (HW) at 20 DAT and 50 DAT, W_2= Super power as early post-emergence herbicide + HW at 25 DAT, W_3= Granite as post-emergence herbicide + HW at 50 DAT, W_4= Super followed by Granite, W_5= Super power followed by Granite + HW at 50 DAT, W_f = Weed free

Interaction effect of tillage and weeding regimes on the yield attributes and yields of *boro* rice

Interaction among the treatments exerted significant effect on all of the yield and yield contributing characters of BRRI dhan28 (Table 8). The highest number of effective tillers hill^{-1} (11.01) was obtained conventional tillage with W_5 treatment (Super power followed by Granite + HW at 50 DAT). The lowest number of total tillers hill^{-1} (7.26) was obtained from stale seed bed technique with W_f (weed free) treatment which was statistically identical to conservation tillage with W_0 (no weeding) treatment (Table 8).

Apparently the highest weight of 1000 grains (23.39 g) was recorded of Conservation tillage with W_3 (Granite as post-emergence herbicide + HW at 50 DAT) treatment and lowest (20.15 g) was obtained from conventional tillage method with W_0 (No weeding) treatment (Table 8).

It was observed that maximum grain yield (6.50 t ha^{-1}), straw yield (8.69 t ha^{-1}) and biological yield (15.20 t ha^{-1}) were obtained from conventional tillage with W_5 (Super power followed by Granite + HW at 50 DAT) treatment. The lowest grain yield (3.87 t ha^{-1}) and biological yield (11.29 t ha^{-1}) were observed from conservation tillage method with W_0 (No weeding) treatment, while the lowest straw yield (6.28 t ha^{-1}) was observed in conventional tillage method with no weeding treatment which was statistically identical to conservation tillage method with no weeding treatment (Table 8).

The highest harvest index (46.31%) was obtained from conservation tillage method with weed free condition which was statistically identical to conventional tillage method with weed free treatment. The lowest harvest index (42.51%) was obtained from false seedbed technique with W_3 (Granite as post-emergence herbicide + HW at 50 DAT) treatment which was statistically identical to conservation tillage method with W_1 (two hand weedings at 25 DAT and 50 DAT) treatment (Table 8).

Table 8. Interaction effect of tillage and weeding regimes on yield attributes and yields of *boro* rice

Interaction	Effective tillers hill^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
CTW_0	8.48 hij	20.15 i	4.24 n	6.28 n	11.53 o	45.49 abc
CTW_1	8.96 ef	20.64 hi	4.47 m	6.42 n	11.90 mn	46.03 ab
CTW_2	8.99 ef	20.88 ghi	4.86 k	6.88 lm	12.74 k	46.00 ab
CTW_3	8.93 ef	21.13 fghi	5.15 j	7.23 ij	13.38 gh	45.95 ab
CTW_4	9.66 bc	21.92 defg	5.43 hi	8.39 b	14.83 b	43.40 fghij
CTW_5	11.01 a	20.95 ghi	6.50 a	8.69 a	15.20 a	42.78 hij
CTW_f	9.42 cd	23.11 abc	6.38 abc	7.45 fgh	13.84 de	46.13 a
FSW_0	7.92 k	20.95 ghi	4.06 o	6.81 m	12.01 m	43.32 fghij
FSW_1	8.43 hij	21.99 def	4.41 m	6.95 klm	12.37 l	43.77 efgh
FSW_2	8.99 ef	22.19 cde	4.76 kl	7.56 f	13.34 gh	43.21 ghij
FSW_3	9.02 ef	21.83 defg	4.81 k	7.86 de	13.67 ef	42.51 j
FSW_4	9.14 e	23.23 ab	5.17 j	8.04 c	14.21 c	43.43 fghij
FSW_5	9.74 b	20.93 ghi	6.42 ab	8.33 b	14.75 b	43.51 fghij
FSW_f	8.76 fg	21.02 fghi	6.32 bcd	7.86 cde	14.18 c	44.61 cde
STW_0	8.45 hij	20.27 i	4.033 o	6.76 m	11.79 n	42.68 ij
STW_1	8.24 j	21.49 efgh	5.32 i	6.78 m	12.10 m	43.98 efg
STW_2	9.02 ef	22.32 bcde	5.56 h	7.13 jk	12.69 k	43.82 efgh
STW_3	9.05 e	21.08 fghi	5.77 g	7.43 fgh	13.20 hi	43.73 efghi
STW_4	9.04 ef	21.56 efgh	5.98 f	7.52 fgh	13.50 fg	44.31 def
STW_5	9.38 d	21.80 defg	6.25 cd	7.94 cd	14.20 c	44.02 defg
STW_f	7.26 l	21.73 defg	6.02 f	7.34 ghi	13.37 gh	45.05 bcd
CSW_0	7.34 l	20.26 i	3.87 p	6.42 n	11.29 p	43.15 ghij
CSW_1	7.86 k	21.06 fghi	4.02 o	6.76 m	11.79 n	42.64 j
CSW_2	8.35 ij	22.26 cde	4.35 mn	7.05 kl	12.40 l	43.15 ghij
CSW_3	8.55 ghi	23.39 a	4.65 l	7.33 hi	12.99 j	43.53 fghij
CSW_4	8.67 gh	22.60 abcd	5.96 f	7.53 fg	13.50 fg	44.21 defg
CSW_5	8.99 ef	21.74 defg	6.17 de	7.75 e	13.93 d	44.35 def
CSW_f	8.63 gh	21.86 defg	6.06 ef	7.03 kl	13.09 ij	46.31 a
Level of Significance	**	**	**	**	**	**
CV (%)	1.69	2.44	1.73	1.42	0.95	1.26

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, CV = Co-efficient variation; Conventional tillage (CT), False seedbed (FS), Stale seedbed (ST) and Conservation tillage (CS). W_0= No weeding, W_1= Two hand weedings (HW) at 20 DAT and 50 DAT, W_2= Super power as early post-emergence herbicide + HW at 25 DAT, W_3= Granite as post-emergence herbicide + HW at 50 DAT, W_4= Super followed by Granite, W_5= Super power followed by Granite + HW at 50 DAT, W_f = Weed free

BCR value in relation to different tillage systems and weeding regime treatment

There were four tillage system and seven weed control treatments in the experiment to evaluate their economic performance, the cost of production and return of BRRI dhan28. In case of control (No weeding), there was no involvement of cost for weed control. It was observed from the data that net returns from *boro* rice were influenced to a great extent by different weed control treatments. Conventional tillage with W_5 (Super power followed by Granite + HW at 50 DAT) treatment provided the highest net return of BDT 67976 ha^{-1}, that excelled rest of the treatments. Stale seedbed technique with no weeding (W_0) treatment provided lowest net return of BDT 18703 ha^{-1}. Without above two treatments, rest of the treatments provided intermediate net return of BDT ha^{-1} (Table 9).

Regarding B:C ratio, the treatments like conservation tillage with W_4 (Super power followed by Granite) as well as conventional tillage, false seedbed and stale seedbed with each of W_4 (Super power followed by Granite) and W_5 (Super power followed by Granite + HW at 50 DAT) produced the B:C ratio greater than 1.5 (Table 9). But, the highest mean B:C ratio of 1.67 was recorded from conventional tillage system with W_5 (Super power followed by Granite + HW at 50 DAT) due to minimum weed infestation and low labor cost involvement, whereas the lowest mean B:C ratio of 1.22 was recorded from both conservation tillage system with W_0 (no weeding) and stale seedbed technique with W_0 (no weeding) treatment (Table 9).

From this experiment, it can be concluded that conventional tillage with W_5 (Super power followed by Granite + HW at 50 DAT) might be considered as the best treatment in terms of economic returns and B:C ratio for controlling weeds and having considerable yield increase in *boro* rice.

Table 9. BCR value in relation to different tillage systems and weeding regime treatment in *boro* rice

Weeding regime	Conventional tillage		False seedbed		Stale seedbed		Conservation tillage	
	Net income	BCR	Net income	BCR	Net income	BCR	Net income	BCR
W_0	21223	1.28	23433	1.26	18703	1.22	19503	1.22
W_1	30168	1.34	29138	1.32	29768	1.35	22651	1.26
W_2	31343	1.33	28033	1.35	34241	1.25	27923	1.31
W_3	34081	1.33	39991	1.44	41441	1.37	32697	1.35
W_4	50536	1.53	43266	1.61	57706	1.61	52616	1.52
W_5	67976	1.67	59106	1.53	59726	1.58	50896	1.47
W_F	45815	1.39	30996	1.35	40866	1.35	40192	1.34

Here, W_0= No weeding, W_1= Two hand weedings (HW) at 20 DAT and 50 DAT, W_2= Super power as early post-emergence herbicide + HW at 25 DAT, W_3= Granite as post-emergence herbicide + HW at 50 DAT, W_4= Super power followed by Granite, W_5 = Super power followed by Granite + HW at 50 DAT, W_f = Weed free

CONCLUSION

The treatments like conservation tillage with W_4 (Super power followed by Granite) as well as conventional tillage, false seedbed and stale seedbed with each of W_4 (Super power followed by Granite) and W_5 (Super power followed by Granite + HW at 50 DAT) could be used by the farmers based on resource availability as they revealed as profitable treatment. But, conventional tillage system with W_5 (Super power followed by Granite + HW at 50 DAT) treatment gave the most favorable effects yield attributes and yields of *boro* rice. Therefore, it may be concluded that conventional tillage system with W_5 (Super power followed by Granite + HW at 50 DAT) treatment could be used as the best tillage and weed control practice in *boro* rice cv. BRRI dhan28.

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