ISSN: 2518-2021 (Print), 2415-4474 (Online) Fundam Appl Agric 2017, 2(3): 303-310

Fundamental and Applied Agriculture

Journal homepage:www.f2ffoundation.org/faa

Agronomy

ORIGINAL ARTICLE

Response of transplanted *aman* rice varieties to herbicides in strip-tilled non-puddled soil

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A R T I C L E I N F O

Article history:

Received: 20 August 2017

Received in revised form: 27 September 2017

Accepted: 07 October 2017

Available online: 20 October 2017

doi: 10.5455/faa.275840

Academic Editor: Md. Shafiqul Islam

Keywords:

Crop growth

Herbicide

Non-puddled transplanting

Rice

Weed control

A B S T R A C T

Sensitivity of crop cultivars may vary to commonly used herbicides resulting in potential yield loss and reduce farm profit. Transplanting of rice seedlings in strip-tilled non-puddled field is a new practice for which herbicide tolerant varieties need to select. Therefore, a study was executed at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh during 2013 to evaluate the response of some popular transplanted *aman* rice varieties to different herbicides at their recommended rate and to select most tolerant *aman* rice variety or varieties for strip-tilled non-puddled transplanting. Twelve *aman* rice varieties (BR11, BRRI dhan33, BRRI dhan39, BRRI dhan44, BRRI dhan46, BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan56, BRRI dhan57, BRRI hybrid dhan-4 and BINA dhan7) were examined in the study against six herbicides (2 pre-emergence: pyrazosulfuron-ethyl and butachlor; 1 early post-emergence: orthosulfamuron and 3 late post-emergence: acetochlor + bensulfuron methyl, butachlor + propanil and 2,4-D amine) along with one untreated manually weed-free control. The study revealed that *aman* rice varieties responded differentially to different herbicides. All rice varieties performed better in pyrazosulfuron-ethyl treated plots relative to the other herbicide treated plots and even than the control plots. Pyrazosulfuron-ethyl increased grain yield of all *aman* rice varieties by 0.6-32.6% over control and butachlor + propanil provided increased grain yield in all rice varieties by 2.0-25.5% except BRRI hybrid dhan-4. The study also disclosed that BRRI dhan57 and BRRI hybrid dhan-4 gone through the yield loss by application of 2,4-D amine and BRRI dhan56 by application of butachlor and orthosulfamuron. Moreover, acetochlor + bensulfuron methyl made plants shorter and caused yield loss by 7.8-27.1% in all *aman* rice varieties and BRRI dhan39 was the most susceptible variety to this herbicide. Therefore, the study concluded that all transplanted *aman* rice varieties were tolerant to the recommended rate of pyrazosulfuron-ethyl. BRRI dhan33, BRRI dhan46, BRRI dhan51 and Binadhan-7 were the tolerant *aman* rice varieties for strip-tilled non-puddled transplanting. All over, this study demands that breeder should undergo the herbicide sensitivity test before release of rice varieties.

INTRODUCTION

Use of herbicide in minimum tillage system is common and effective means of weed control. Day-by-day, using frequency of herbicide is rapidly increasing in Bangladesh (Hossain 2015) since herbicide provides more cost-effective and labour-saving weed control than manual weeding (Ahmed and Chauhan 2014). In Bangladesh, 52 registered herbicides are in the market at present, among which 36 are used for rice (BCPA 2016). But, these rice herbicides are being used by farmers frequently without any assessment of their possible phytotoxic effects on the existing rice varieties.

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Herbicides are usually applied in transplanted *aman* rice under puddled field condition. In puddle soil herbicides can easily be mixed with the loose soil sediments and additionally standing water of the field help herbicides to go through the contamination of germinating weed seeds. On the other hand, strip-tilled non-puddled transplanting is a new but promising rice establishment technique in our country, but the behaviour of applied herbicide in the less muddy soil of the strip-tilled non-puddled field is unknown. Hence, the effectiveness of herbicides in this reduced tillage rice cultivation technique might not be the same as the conventionally tilled puddle system. Moreover, all the registered herbicides have recommended rate for application in puddled transplanted *aman* rice, but not have any recommendation for strip-tilled non-puddled transplanted *aman* rice. The recommendation of herbicide application rate for non-puddled transplanted rice might be varied from the puddled transplanting or not. Additionally, some previous studies reported that rice varieties response differentially to different herbicides, even if herbicides are applied at the recommended rate and the reason is related to the morphological difference, genetic difference or the difference of their seedling age (Bond and Walker 2012; Moore and Kröger 2010). Furthermore, some crop cultivars might have sensitivity to particular herbicides (Li et al. 2000; Swantek et al. 1998). Therefore, a study had done to evaluate the growth and yield response of some selected transplanted *aman* rice varieties to the recommended rate of some available rice herbicides and to find out the most tolerant *aman* rice variety or varieties to herbicides under strip-tilled non-puddled field condition.

METHODOLOGY

Experimental site and season

The experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh (24° 75′ N latitude and 90° 50′ E longitude at an altitude of 18 m above the sea level) during July to November 2013. The experimental site was a medium high land with sandy clay loam soil (50% sand, 23.4% silt, 26.6% clay) having pH 7.1 and moderate soil fertility with 1.65% organic matter content. Weather information regarding air and soil temperature, rainfall and relative humidity prevailed at the experimental site during the study period is presented in Table 1.

Table 1. Monthly record of air temperature, soil temperature, rainfall and relative humidity of the experimental site during July December 2013

Months	Average air temperature (°C)			Average soil temperature (°C)			Total rainfall (mm)	Average relative humidity (%)
	Max.	Min.	Mean	5 cm	10 cm	20 cm		
July	32.3	26.8	29.5	31.4	31.9	30.6	338.8	84.1
August	31.7	26.2	29.0	31.1	31.5	31.3	317.4	85.7
September	32.4	26.2	29.3	31.4	31.8	31.6	131.6	85.5
October	30.5	23.7	27.1	29.2	29.8	29.8	262.6	86.9
November	29.6	16.6	23.1	24.3	25.2	25.7	0.6	81.6
December	25.1	13.6	19.4	20.7	21.6	22.1	0.6	82.5

Source: Weather Yard, Department of Irrigation and Water management, BAU, Mymensingh

Treatment and design

The study consisted of two factors: variety and herbicide. Twelve transplanted *aman* rice varieties (BR11, BRRI dhan33, BRRI dhan39, BRRI dhan44, BRRI dhan46, BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan56, BRRI dhan57, BRRI hybrid dhan-4 and Binadhan-7) were tested against six herbicide (2 pre-emergence: pyrazosulfuron-ethyl and butachlor; 1 early post-emergence: orthosulfamuron and 3 late post-emergence: acetochlor + bensulfuron, butachlor + propanil and 2,4-D amine) at the recommended rate. Among the late post-emergence herbicides, two herbicides named acetochlor + bensulfuron and butachlor + propanil were the proprietary mixture of two chemicals. Trade names of all herbicides have given in Table 2 along with their chemical group, active ingredient and application time and rate. The experiment was set up in a strip-plot design (variety was in vertical plots and herbicide was in horizontal plots) with three replications. Unit plot size was 13 m × 4 m (1 m for each variety × 4 m).

Table 2. Type, Chemical group and rate, active ingredient and time of application of herbicides in all transplanted *aman* rice varieties during 2013

Name of herbicide	Trade name	Chemical group	Rate of application	Active ingredient	Time of application
Pyrazosulfuron-ethyl	Manage 10WP	Sulfonylurea	150 g ha^{-1}	100g kg^{-1}	3 DAT
Butachlor	M-chlor 5G	Chloroacetamide	25 kg ha^{-1}	50 g kg^{-1}	3 DAT
Orthosulfamuron	Kelion 50WP	Sulfonylurea	150 g ha^{-1}	500 g kg^{-1}	15 DAT
Acetochlor + bensulfuron methyl	Changer 18WP	Chloroacetamide + Sulfonylurea	0.74 kg ha^{-1}	100 g kg^{-1}	22 DAT
Butachlor + propanil	Prepona 700EC	Chloroacetamide + Amide	1.0 L ha^{-1}	700 mL L^{-1}	22 DAT
2,4-D amine	2,4-D	Phenoxy-carboxylic-acid	2.25 L ha^{-1}	720g L^{-1}	22 DAT

DAT = days after transplanting

Application of herbicide

Before setting up the experiment, pre-plant non-selective herbicide, Roundup® (glyphosate 41% SL- IPA salt), was applied @ 2.25 L ha^{-1} at 20 days and 5 days before strip till the land at 20 cm apart by Versatile Multi-Crop Planter (VMP). Just before strip tillage, the land was fertilized as per recommended practice and then the land was inundated to 3-5 cm depth of standing water for 48 hours (Haque et al. 2016). Twenty five-day-old rice seedlings of all the rice varieties were transplanted on 03 August 2013 at 15 cm spacing between hills allocating three seedlings per hill. Commercial formulation of all herbicides was used in the study and spray solutions according

to the recommendation of the associated companies were applied by locally made knapsack hand sprayer having flat-pan nozzle at the rate of 180 L ha-1 and 140 kPa.

Data recording and statistical analysis

Crop phytotoxicity was visually assessed from the day of herbicide application up to 25 days. Data on growth parameters were recorded from randomly selected 10 hills per plot at different days after transplanting (DAT). Leaf chlorophyll content of each rice varieties was measured from the average value of randomly selected 10 fresh leaves at vegetative stage and from 10 flag leaves at heading stage by using SPAD-502 plus meter (Konica Minolta Optics, inc., Japan). Rice varieties were harvested at maturity (BRRI dhan57 and BRRI hybrid dhan-4 were harvested at 94 DAT on 05 November 2013; BRRI dhan56, Binadhan-7 and BRRI dhan33 at 96 DAT on 07 November 2013; BRRI dhan39 and BRRI dhan49 at 105 DAT on 16 November 2013; BR11 and BRRI dhan52 at 113 DAT on 24 November 2013; BRRI dhan51 and BRRI dhan44 at 121 DAT on 02 December 2013 and BRRI dhan46 was harvested at 131 DAT on 12 December 2013) and data on yield and related attributes were recorded before harvesting of all rice varieties. Data were subjected to analysis of variance and means were compared by Tukey's Honest Significance Difference (HSD) test using 'STAR nebula' developed by IRRI (version 2.0.1, January 2014).

RESULT AND DISCUSSION

Plant height

Application of herbicides at their recommended rate significantly affected plant heights of twelve transplanted *aman* rice varieties at different days after transplanting (DAT) and even at harvest (Figure 1-3 and Table 3). In case of pre-emergence herbicides, pyrazosulfuron-ethyl treated plots had taller plants in all *aman* rice varieties in comparison to control plots at 10 DAT (7 days after pre-emergence herbicide application-DAHA) and 20 DAT (17 DAHA) and even at harvest, however exception was observed in case of BRRI dhan57 at 20 DAT and BRRI dhan49 at harvest (Figure 1). Moreover, the tallest plants of BRRI dhan33 and BRRI dhan56 at harvest were recorded from pyrazosulfuron-ethyl treated plots (Table 3). On the other hand, compared to control plots and pyrazosulfuron-ethyl treated plots, plants of BRRI dhan51 were taller in butachlor treated plots at both 10 DAT and 20 DAT. Additionally, the tallest plants of BRRI hybrid dhan-4 were in butachlor treated plots at harvest (Table 3).

Table 3. Interaction effect of variety and herbicides on plant height (cm) of twelve *aman* rice varieties at harvest under strip-tilled non-puddled transplanting system during 2013

Herbicide	Variety					
	V_1	V_2	V_3	V_4	V_5	V_6
Control	104.6	107.0	108.3	114.4	130.6	107.8
Pyrazosulfuron-ethyl	105.2	114.9	111.2	118.1	131.9	106.5
Butachlor	105.1	105.0	105.9	117.7	131.6	104.7
Acetochlor + bensulfuron methyl	99.9	105.7	103.1	108.5	124.9	100.8
Orthosulfamuron	100.3	107.3	111.0	118.5	130.9	102.6
Butachlor + propanil	105.7	111.7	112.8	117.8	135.1	104.8
2,4-D amine	106.1	110.3	109.6	119.4	132.3	109.3
	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}
Control	90.1	114.1	117.8	102.3	106.2	101.2
Pyrazosulfuron-ethyl	94.4	117.2	120.5	106.8	107.1	105.1
Butachlor	92.5	118.9	111.3	106.6	111.1	102.7
Acetochlor + bensulfuron methyl	85.9	113.7	109.6	97.9	101.5	94.7
Orthosulfamuron	90.3	120.1	115.9	107.1	110.2	107.9
Butachlor + propanil	96.1	111.8	117.3	108.0	109.1	105.0
2,4-D amine	97.1	117.2	117.3	104.1	107.9	98.5
$HSD_{0.05}$	4.63 for variety, 4.93 for herbicide					
Level of significance	*** for variety, *** for herbicide, *** for variety × herbicide					
CV (%)	1.86 for variety, 1.58 for herbicide, 1.51 for variety × herbicide					

Here, CV = co-efficient of variance, *** = 0.01% level of significance

V_1 = BR11, V_2 = BRRI dhan33, V_3 = BRRI dhan39, V_4 = BRRI dhan44, V_5 = BRRI dhan46, V_6 = BRRI dhan49, V_7 = BRRI dhan51, V_8 = BRRI dhan52, V_9 = BRRI dhan56, V_{10} = BRRI dhan57, V_{11} = BRRI hybrid dhan-4, V_{12} = Binadhan-7

In case of early post-emergence herbicide, all *aman* rice varieties had similar plant heights in orthosulfamuron treated plots as control plots both at 20 DAT (5 DAHA) and 30 DAT (15 DAHA) (Figure 2). Moreover, plants of BRRI dhan39 were taller in orthosulfamuron treated plots than control plots at both 20 and 30 DAT. Furthermore, the tallest plants of BRRI dhan52 and Binadhan-7 were observed in orthosulfamuron treated plots at harvest (Table 3).

Among the late post-emergence herbicides, results demonstrated that plants of all *aman* rice varieties in acetochlor + bensulfuron methyl treated plots were significantly shorter at both 30 DAT (8 DAHA) and 40 DAT (18 DAHA) in comparison to the untreated control plots (Figure 3). Besides, the shortest plants of all *aman* rice varieties at harvest were also recorded from acetochlor + bensulfuron methyl treated plots (Table 3). Similar effect of acetochlor + bensulfuron methyl on plant height of transplanted *aman* rice was also documented by Zahan et al. 2017. The adverse effect of acetochlor + bensulfuron methyl on plant height of all transplanted *aman* rice varieties might be related to its application rate which was relatively higher to the currently revised recommended rate by the authorized company of this herbicide. The previously recommended rate of acetochlor + bensulfuron methyl according to the company was much higher for transplanted puddled rice to tolerate (Rahman and Zahan 2017). On the other hand, the tallest plants of BRRI dhan39, BRRI dhan46 and BRRI dhan56 were recorded from butachlor + propanil treated plots and the tallest plants of BRRI dhan44, BRRI dhan49 and BRRI dhan51 were from 2,4-D amine treated plots at harvest.

Additionally, butachlor + propanil treated plots of all *aman* rice varieties had taller plants both at 30 DAT (8 DAHA) and 40 DAT (18 DAHA) than other late post-emergence herbicide treated

plots and even had taller plants than control plots except BR11 and BRRI dhan49 at 30 DAT and BRRI dhan49, BRRI dhan51 and BRRI dhan52 at 40 DAT (Figure 3). Furthermore, in BRRI dhan49, 2,4-D amine treated plots had taller plants than rest of the late post-emergence herbicide treated plots and even than the control plots. The present study results were also supported by Nimanthika and Weerakoon (2012) who examined the tolerance of five improved and three traditional varieties of *Oryza sativa* and five wild rice spp. against post-emergence herbicide in Sri Lanka and found significant effect of post-emergence herbicides on plant height of rice cultivars at their mature stage. Zhang and Webster (2002) reported that rice tolerance to herbicide varied both with cultivar and growth stage of rice. The differential response in plant height of transplanted *aman* rice varieties to herbicides might be related to their genotypic variability that may vary the level of herbicide tolerance at different growth stage of rice. However, no literature related to the effect of pre-emergence herbicide on plant height of rice was found.

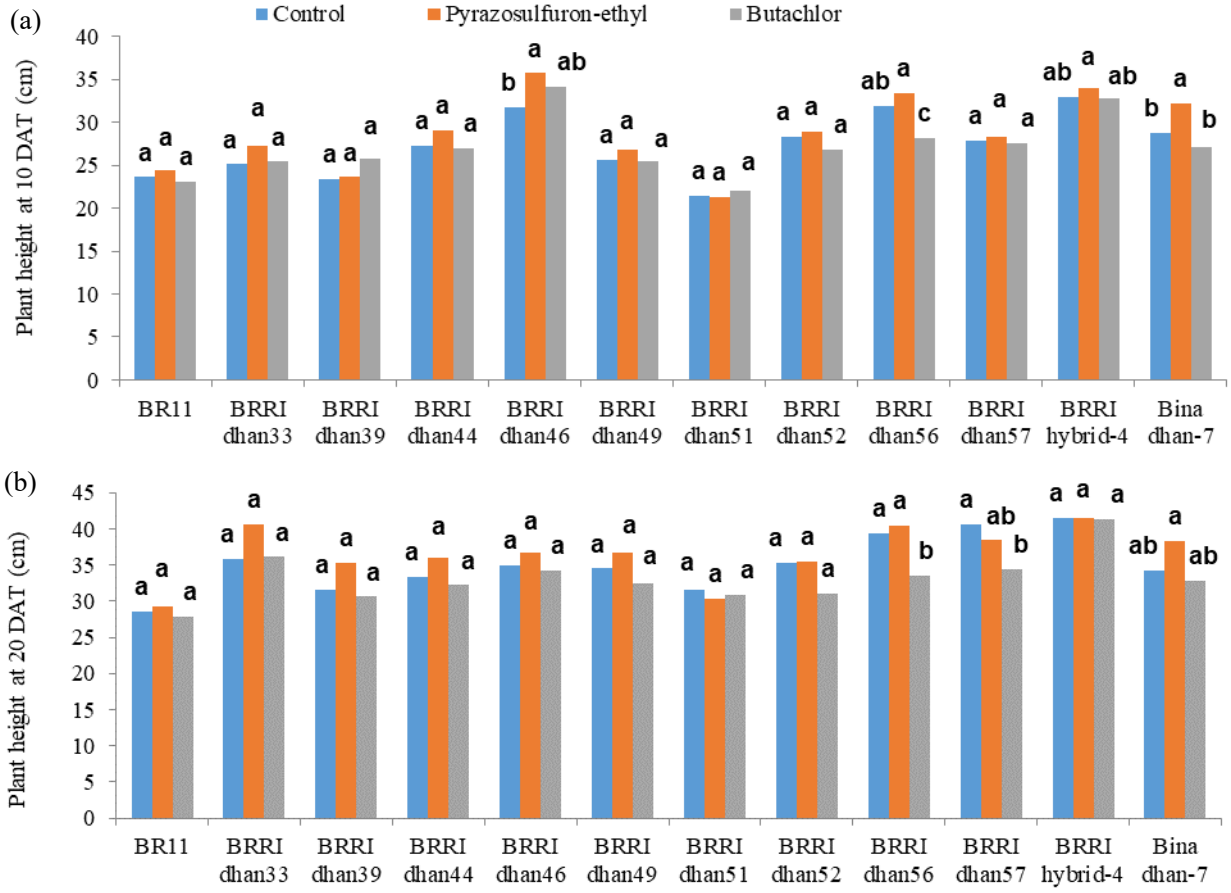
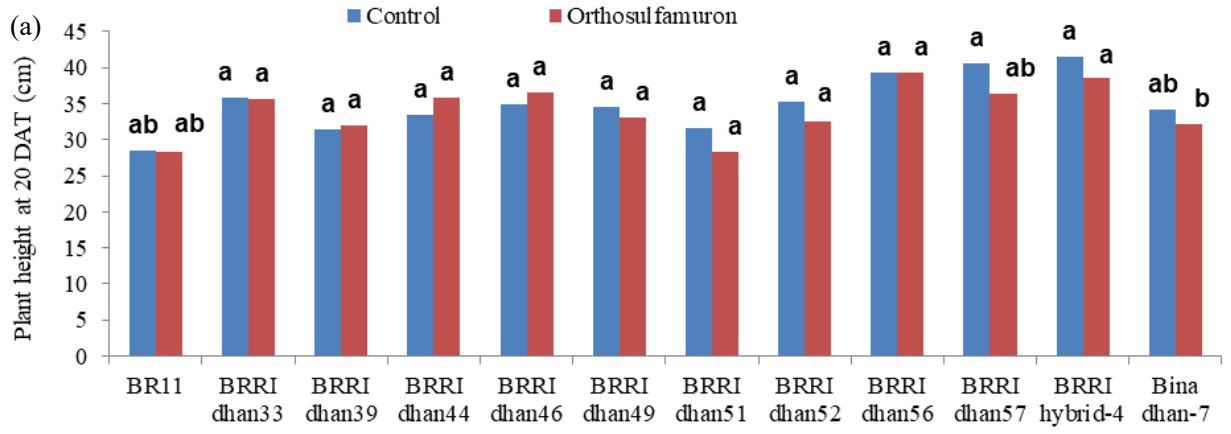


Figure 1. Effect of pre-emergence herbicides (pyrazosulfuron-ethyl and butachlor) on plant height of twelve transplanted *aman* rice varieties at (a) 10 days after transplanting (7 days after herbicide application-DAHA) and (b) 20 DAT (17 DAHA) in strip-tilled non-puddled field during 2013



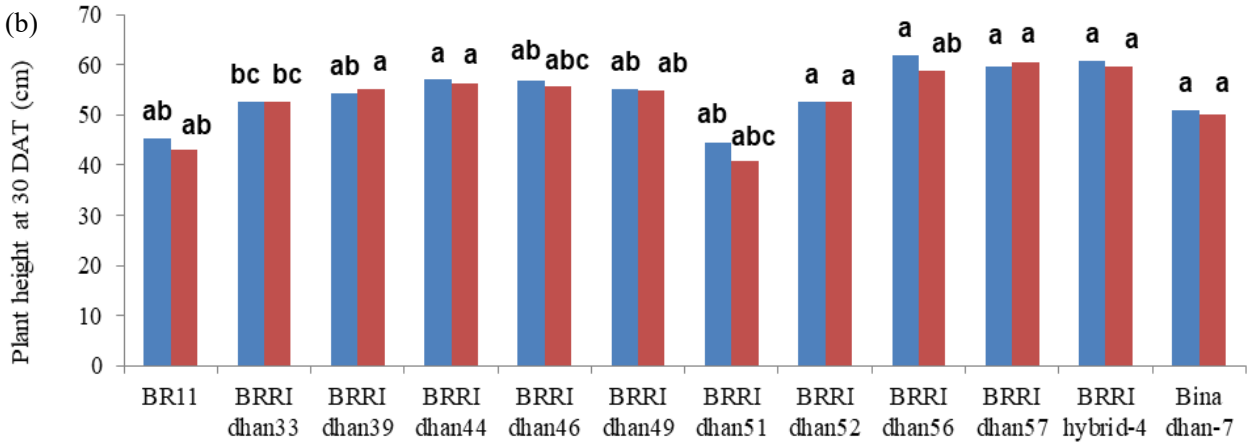


Figure 2. Effect of early post-emergence herbicide (orthosulfamuron) on plant height of twelve transplanted *aman* rice varieties at (a) 20 days after transplanting (5 days after herbicide application-DAHA) and (b) 30 DAT (15 DAHA) in strip-tilled non-puddled field during 2013

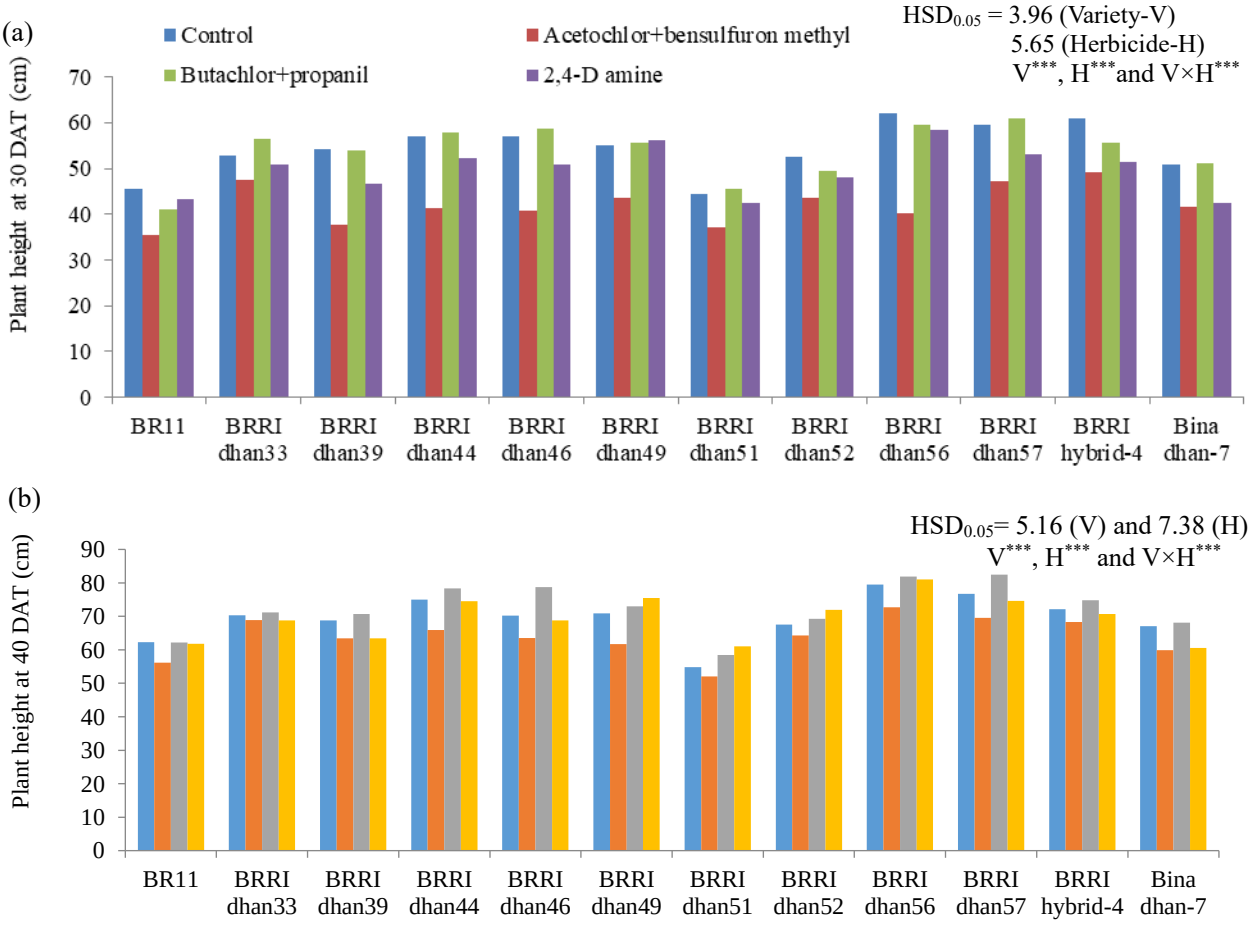


Figure 3. Effect of late post-emergence herbicide (acetochlor + bensulfuron methyl, butachlor + propanil and 2,4-D amine) on plant height of twelve transplanted *aman* rice varieties at (a) 30 days after transplanting (8 days after herbicide application-DAHA) and (b) 40 DAT (18 DAHA) in strip-tilled non-puddled field during 2013

Leaf chlorophyll content

Leaf chlorophyll contents (SPAD values) of all *aman* rice varieties were significantly varied against the recommended rate of herbicides (Table 4). Results showed that all *aman* rice varieties except BRRI dhan44 had the highest SPAD values in herbicide treated plots. In case of BR11 and BRRI dhan51, the highest values were recorded from butachlor + propanil treated plots; in BRRI dhan33 and BRRI dhan39, the highest values were obtained from 2,4-D amine treated plots; in BRRI dhan46 and Binadhan-7, the highest values were measured from pyrazosulfuron-ethyl treated plots; in BRRI dhan49 and BRRI

dhan56, acetochlor + bensulfuron methyl treated plots had the highest values; and in BRRI dhan52, BRRI dhan57 and BRRI hybrid dhan-4, the highest SPAD values were taken from butachlor treated plots.

On the other hand, the lowest SPAD values of BR11, BRRI dhan39 and BRRI dhan57 were in orthosulfamuron treated plots, the lowest values of BRRI dhan33, BRRI dhan52, BRRI hybrid dhan-4 and Binadhan-7 were in acetochlor + bensulfuron methyl treated plots, BRRI dhan44, BRRI dhan49 and BRRI dhan56 had the lowest values in butachlor + propanil treated plots, the lowest values of BRRI dhan46 was in 2,4-D amine treated plots and leaves of BRRI dhan51 had the lowest SPAD value in untreated control plots. This differential behaviour in leaf chlorophyll content of rice varieties to herbicide has not documented earlier and therefore the specific reason for the differential response in leaf chlorophyll content of rice varieties to herbicide is unknown. However, in another study Gilreath et al. (2000) observed the phytotoxic effects of glyphosate on pepper (*Capsicum annuum*) and found that glyphosate injury was ranged from non-detectable to chlorosis of the terminal bud and extended to the foliage. In some cases, leaves of pepper became more pointed and darker green, however leaves turned to pale green with increasing rate of glyphosate application.

Shoot dry matter of rice plants

Results revealed that pyrazosulfuron-ethyl increased shoot dry matter of all *aman* rice varieties at 35 days after transplanting (DAT) by 2.9-33.8% over control (Table 5) and the highest percentage of increase observed in BRRI dhan33 whereas the lowest increase was in BRRI dhan52. Shoot dry matters of BR11, BRRI dhan57 and Binadhan-7 were also increased at 35 DAT in butachlor treated plots. Application of orthosulfamuron increased shoot dry matters of BRRI dhan33, BRRI dhan39, BRRI dhan44, BRRI dhan52, BRRI hybrid dhan-4 and Binadhan-7 by 1.4-24.1%. Moreover, 2,4-D amine treated plots had 2.2-10.6% higher shoot dry matters in BR11, BRRI dhan33, BRRI dhan44, BRRI dhan49 and BRRI dhan56 than the control plots. Furthermore, application of butachlor + propanil increased shoot dry matters of BRRI dhan39, BRRI dhan44, BRRI dhan49, BRRI dhan52, BRRI dhan56 and Binadhan-7 by 6.6-27.1% in comparison to untreated control. The increased shoot dry matter of rice varieties with herbicides might be related to the increased plant height, leaf chlorophyll content and production of increased number of tillers (data have not shown). On the contrary, acetochlor + bensulfuron methyl treated plots reduced shoot dry matter of all rice varieties by 8.3-37.0% compare to the control plots which might be happened due to the phytotoxic effect of this herbicide on plant height and leaf chlorophyll content of rice varieties. Several previous studies on other herbicides also reported significant increase in rice shoot dry matter by herbicide application (Bond and Walker 2012; Moore and Kröger 2010). But, some studies found reduction in rice shoot dry matter through application of herbicides (Chauhan and Johnson 2011) and they also revealed greater reduction in rice shoot dry matter by applied herbicides was in saturated soil condition compared to the aerobic soil condition.

Table 4. Interaction effect of variety and herbicide on leaf chlorophyll content of transplanted *aman* rice varieties at 35 days after transplanting under strip-tilled non-puddled field condition during 2013

Herbicide	Variety					
	V_1	V_2	V_3	V_4	V_5	V_6
Control	38.40	39.63	40.87	43.50	40.53	40.53
Pyrazosulfuron-ethyl	40.03	40.27	40.13	40.10	43.80	43.67
Butachlor	39.80	40.30	43.67	41.10	41.63	38.63
Acetochlor + bensulfuron methyl	39.73	37.53	41.00	39.97	38.40	44.60
Orthosulfamuron	37.23	42.00	40.07	41.63	39.67	42.60
Butachlor + propanil	40.60	41.27	43.40	39.60	40.00	37.67
2,4-D amine	38.98	46.50	45.53	41.57	37.83	39.13
	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}
Control	41.37	42.87	40.87	38.23	44.87	37.57
Pyrazosulfuron-ethyl	43.67	42.33	41.43	41.30	43.57	40.33
Butachlor	44.17	45.40	40.30	44.57	50.40	39.60
Acetochlor + bensulfuron methyl	43.57	36.27	43.33	39.80	41.33	36.20
Orthosulfamuron	44.47	44.73	39.40	36.93	44.93	39.37
Butachlor + propanil	45.20	40.70	37.40	39.03	43.27	38.93
2,4-D amine	44.60	38.57	37.80	40.50	41.93	37.53
$HSD_{0.05}$	5.11 for variety, 5.49 for herbicide					
Level of significance	*** for variety, ** for herbicide, *** for variety × herbicide					
CV (%)	4.82 for variety, 4.68 for herbicide, 4.55 for variety × herbicide					

Here, CV = co-efficient of variance, *** = 0.01% level of significance, ** = 1% level of significance
V_1 = BR11, V_2 = BRRI dhan33, V_3 = BRRI dhan39, V_4 = BRRI dhan44, V_5 = BRRI dhan46, V_6 = BRRI dhan49, V_7 = BRRI dhan51, V_8 = BRRI dhan52, V_9 = BRRI dhan56, V_{10} = BRRI dhan57, V_{11} = BRRI hybrid dhan-4, V_{12} = Binadhan-7

Grain yield

Grain yields of all transplanted *aman* rice varieties were significantly influenced by application of herbicides at their recommended rate (Table 6). Results demonstrated that application of pyrazosulfuron-ethyl increased grain yields of all rice varieties by 0.6-32.6% compared to control. Application of butachlor + propanil also provided higher grain yields in all rice varieties over control by 2.0-25.5% except BRRI hybrid dhan-4 that had lower yield by 4.3% than the control. Results also revealed that the highest grain yield of BRRI dhan33, BRRI dhan44, BRRI dhan46 and BRRI dhan51 was obtained from pyrazosulfuron-ethyl, BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and Binadhan-7 had the highest yield in butachlor + propanil, BRRI dhan39 had in orthosulfamuron, BRRI hybrid dhan-4 had in butachlor and BR11 had the highest grain yield in 2,4-D amine treated plots. The increase in grain yield of all *aman* rice varieties by applied herbicides is related to their increased dry matter production. Moreover, results clearly expressed the increased grain yield production of rice varieties in herbicide treated plots over control plots reflected the tolerance of rice varieties to the above mentioned specific

herbicides. On the other hand, the study also demonstrated that plots treated with acetochlor + bensulfuron methyl gave the lowest grain yield in all *aman* rice varieties (Table 6) and this is due to the phytotoxic effect of acetochlor + bensulfuron methyl on shoot dry matter of *aman* rice varieties. Previous research with post application of sulfentrazone in soybean also reported severe yield reduction due to the stunting and reduction of canopy development (Walker, 1994). In another study, Grey *et al*. (2000) examined the response of seven peanut (*Arachis hypogaea*) cultivars to two early post-emergence herbicides (imazapic and paraquat) and they revealed that one cultivar exhibited early-season injury up to 29%, however this injury did not affect yield. On the other hand, Grichar *et al*. (2000) reported that application of CGA-152005, a sulfonylurea herbicide injured peanut up to 37% and reduced yield up to 94%.

Table 5. Percent change of shoot dry matter of transplanted *aman* rice varieties at 35 days after transplanting as affected by herbicides under strip-tilled non-puddled field condition during 2013

Herbicide	% increase or decrease over control					
	V_1	V_2	V_3	V_4	V_5	V_6
Pyrazosulfuron-ethyl	+5.0	+33.8	+6.5	+3.8	+10.6	+6.0
Butachlor	+2.2	-7.3	-2.3	-12.7	-23.8	-1.1
Acetochlor + bensulfuron methyl	-37.0	-21.7	-17.2	-20.6	-36.8	-34.4
Orthosulfamuron	-17.5	+24.1	+16.9	+1.4	-34.7	-10.5
Butachlor + propanil	-18.7	-17.7	+9.5	+6.3	-2.5	+8.6
2,4-D amine	+4.4	+10.6	-2.2	+2.2	-12.9	+2.3
	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}
Pyrazosulfuron-ethyl	+15.4	+2.9	+7.1	+16.4	+13.5	+26.9
Butachlor	-4.4	-3.5	-5.4	+9.6	-4.8	+19.7
Acetochlor + bensulfuron methyl	-23.9	-18.3	-9.9	-34.9	-14.9	-8.3
Orthosulfamuron	-4.5	+21.4	-1.7	-4.0	+6.5	+11.5
Butachlor + propanil	-1.8	+27.1	+7.8	-36.3	-3.5	+6.6
2,4-D amine	-8.0	-1.0	+3.7	-21.8	-4.2	-34.7

V_1 = BR11, V_2 = BRRI dhan33, V_3 = BRRI dhan39, V_4 = BRRI dhan44, V_5 = BRRI dhan46, V_6 = BRRI dhan49, V_7 = BRRI dhan51, V_8 = BRRI dhan52, V_9 = BRRI dhan56, V_{10} = BRRI dhan57, V_{11} = BRRI hybrid dhan-4, V_{12} = Binadhan-7

Table 6. Grain yield (t ha^{-1}) and percent change in yield of twelve transplanted *aman* rice varieties as influenced by herbicide under strip-tilled non-puddled field condition during 2013

Herbicide	V_1		V_2		V_3		V_4	
	GY	% change	GY	% change	GY	% change	GY	% change
Control	3.83	-	4.79	-	4.94	-	3.98	-
Pyrazosulfuron-ethyl	4.02	+ 4.9	5.40	+ 12.7	5.08	+ 2.8	5.12	+ 28.5
Butachlor	3.71	- 3.1	4.84	+1.0	4.78	- 3.1	3.79	- 4.9
Acetochlor + bensulfuron methyl	3.08	- 19.5	4.42	- 7.9	3.60	- 27.1	3.63	- 9.0
Orthosulfamuron	3.52	- 8.2	4.95	+ 3.3	5.81	+ 17.8	4.81	+ 20.8
Butachlor + propanil	4.15	+ 8.4	5.13	+ 7.0	5.03	+ 2.0	4.57	+ 14.7
2,4-D amine	4.30	+ 12.3	4.52	- 5.8	5.35	+ 8.4	4.20	+ 5.4
	V_5		V_6		V_7		V_8	
	GY	% change	GY	% change	GY	% change	GY	% change
Control	4.40	-	3.59	-	3.54	-	3.68	-
Pyrazosulfuron-ethyl	5.21	+ 18.3	4.32	+ 20.3	4.69	+ 32.6	3.89	+ 5.7
Butachlor	4.77	+ 8.4	4.15	+ 15.5	4.27	+ 20.7	3.49	- 5.2
Acetochlor + bensulfuron methyl	3.67	- 16.7	3.09	- 13.9	3.26	- 7.8	3.07	- 16.7
Orthosulfamuron	4.63	+ 5.2	3.54	- 1.5	3.78	+ 6.9	3.73	+ 1.3
Butachlor + propanil	4.39	- 0.2	4.51	+ 25.5	4.35	+ 23.1	4.15	+ 12.6
2,4-D amine	5.10	+ 15.9	4.82	+ 34.0	3.59	+ 1.4	3.90	+ 6.0
	V_9		V_{10}		V_{11}		V_{12}	
	GY	% change	GY	% change	GY	% change	GY	% change
Control	5.18	-	3.68	-	4.65	-	4.68	-
Pyrazosulfuron-ethyl	5.78	+ 11.6	4.01	+ 8.9	4.68	+ 0.6	5.02	+ 7.3
Butachlor	4.71	- 9.1	3.49	- 5.3	5.09	+ 9.5	4.93	+ 5.3
Acetochlor + bensulfuron methyl	4.24	- 18.1	3.14	- 14.8	4.25	- 8.6	4.08	- 12.9
Orthosulfamuron	4.86	- 6.1	3.98	+ 8.1	4.84	+ 3.9	4.72	+ 0.9
Butachlor + propanil	5.92	+ 14.2	4.85	+ 32.8	4.45	- 4.3	5.51	+ 17.7
2,4-D amine	5.19	+ 0.2	3.23	- 12.3	3.68	- 20.9	4.66	- 0.4
$HSD_{0.05}$	0.49 for variety, 0.32 for herbicide							
Level of significance	*** for variety, *** for herbicide, *** for variety × herbicide							
CV (%)	4.33 for variety, 2.58 for herbicide, 4.09 for variety × herbicide							

Here, GY = Grain yield, CV = co-efficient of variance, *** = 0.01% level of significance, ** = 1% level of significance
V_1 = BR11, V_2 = BRRI dhan33, V_3 = BRRI dhan39, V_4 = BRRI dhan44, V_5 = BRRI dhan46, V_6 = BRRI dhan49, V_7 = BRRI dhan51, V_8 = BRRI dhan52, V_9 = BRRI dhan56, V_{10} = BRRI dhan57, V_{11} = BRRI hybrid dhan-4, V_{12} = Binadhan-7

CONCLUSION

The study concluded that all transplanted *aman* rice varieties were tolerant to the recommended rate of pyrazosulfuron-ethyl and butachlor + propanil. Additionally, BRRI dhan33, BRRI dhan46, BRRI dhan51 and Binadhan-7 were tolerant to butachlor and orthosulfamuron. Moreover, the most tolerant *aman* rice variety under strip-tilled non-puddled field condition was BRRI dhan51 that provided higher grain yield at the recommended rate of all herbicides over control except

acetochlor + bensulfuron methyl. Additionally, all rice varieties were susceptible to acetochlor + bensulfuron methyl. This preliminary study highlights the variation in varietal tolerance of rice to the existing herbicides suggesting that routine screening of herbicide phytotoxicity needs to be incorporated in rice breeding programs in Bangladesh.

ACKNOWLEDGEMENTS

This study was funded by the research project LWR/2010/080 and the principal author would like to acknowledge ACIAR (Australian Centre for International Agricultural Research) for funding this project.

CONFLICTS OF INTEREST

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

REFERENCES

Ahmed S, Chauhan BS. 2014. Performance of different herbicides in dry–seeded rice in Bangladesh. Sci. World J. DOI:10.1155/2013/729418

BCPA (Bangladesh Crop Protection Association). 2016. List of registered agricultural pesticides, bio pesticides and public health pesticides in Bangladesh. Bangladesh Crop Prot. Assoc., Plant Protection Wing, Ministry of Commerce, Govt. of the People's Republic of Bangladesh. pp. 125-157.

Bond JA, Walker TW. 2012. Effect of postflood quinclorac applications on commercial rice cultivars. Weed Technol, 26: 183-188.

Chauhan BS, Johnson DE. 2011. Growth response of direct-seeded rice to oxadiazon and bispyribac-sodium in aerobic and saturated soils. Weed Sci, 59(1): 119-122. DOI: 10.1614/WS-D-10-00075.1

Gilreath JP, Chase CA, Locascio SJ. 2000. Phytotoxic effects of glyphosate on pepper (*Capsicum annuum*). Weed Technol, 14: 488-494.

Grey TL, Bridges DC, Brecke BJ. 2000. Response of seven peanut (*Arachis hypogaea*) cultivars to sulfentrazone. Weed Technol, 14: 51-56.

Grichar WJ, Sestak DC, Brewer K, Minton B. 2000 Weed control with CGA-152005 and peanut (*Arachis hypogaea*) response. Weed Technol, 14: 218-222.

Haque ME, Bell RW, Islam MA, Rahman MA. 2016. Minimum tillage unpuddled transplanting: an alternative crop establishment strategy for rice in conservation agriculture cropping systems. Field Crops Res, 185: 31-39.

Hossain MM. 2015. Recent perspective of herbicide: review of demand and adoption in world agriculture. J. Bangladesh Agril Univ, 13(1): 19-30.

Li Z, Wehtje GR, Walker RH. 2000. Physiological basis for the differential tolerance of Glycine max to sulfentrazone during seed germination. Weed Sci, 48: 281-285.

Moore MT, Kröger R. 2010. Effect of three insecticides and two herbicides on rice (*Oryza sativa*) seedling germination and growth. Arch Environ Contam Toxicol, 59: 574-581.

Nimanthika WJ, Weerakoon SR. 2012. Impact of pre- and post-planting herbicides on growth performance and yield of oryza genotypes in Sri Lanka. Pakistan J. Weed Sci Res, 18: 469-475.

Rahman MM, Zahan T. 2017. Tolerance of rice varieties to higher rates of two post-emergence herbicides under strip tilled non-puddled transplanted establishment. In: Proceedings of 2nd Conference on Conservation Agriculture for Smallholders (CASH-II), 14-16 February, 2017, Mymensingh, Bangladesh. pp. 46-47.

Swantek JM, Sneller CH, Oliver LR. 1998. Evaluation of soybean injury from sulfentrazone and inheritance of tolerance. Weed Sci, 46: 271-277.

Walker RH. 1994. F-6285 applied postemergence in soybean. Proc. South Weed Sci Soc, 47: 64.

Zahan T, Rahman MM, Hashem A. 2017. Growth and yield response of transplanted *aman* rice varieties to herbicides in strip tilled unpuddled soil. In: Proceedings of 2nd Conference on Conservation Agriculture for Smallholders (CASH-II), 14-16 February, 2017, Mymensingh, Bangladesh. pp. 48-49.

Zhang W, Webster EP. 2002. Shoot and root growth of rice (*Oryza Sativa*) in response to V-10029. Weed Technol, 16: 768-772.