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Post-Emergence Herbicides Selection for Rotational Use in Puddle Transplanted Rice to Avoid Herbicide Resistance in Weeds

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ABSTRACT

Background and Objective: Indiscriminate use of herbicide poses serious concern as it encourages herbicide resistance development in weeds and makes weed control a difficult task. The present study was undertaken with a view to select suitable post-emergence herbicides for puddle-transplanted rice. **Materials and Methods:** The experiment included ten post-emergence herbicides along with a weed-free control and a weedy check in a randomized complete block design with three replications. **Results:** The proprietary mixture of bispyribac sodium+bensulfuron methyl showed the best weed control efficacy (83%) followed by penoxulum (80%), proprietary mixture of bensulfuron methyl+quinchlorac (74%), ethoxysulfuran (63%) and pyrazosulfuran ethyl (54%). Satisfactory grain yields were obtained from proprietary mixture bispyribac sodium+bensulfuron methyl (5.28 t ha^{-1}), ethoxysulfuron (5.06 t ha^{-1}), proprietary mixture of bensulfuron methyl+quinchlorac (5.01 t ha^{-1}), penxosulum (5.0 t ha^{-1}) and 2,4-D amine (4.85 t ha^{-1}) while, pyrazosulfuron ethyl (3.55 t ha^{-1}) and MCPA500 (3.92 t ha^{-1}) showed the worst performance similar to that of the weedy plot (3.40 t ha^{-1}). **Conclusion:** The alternate use of any of the post-emergence herbicides like a proprietary mixture of bispyribac sodium+bensulfuron methyl, bensulfuron methyl+quinchlorac and single herbicide of ethoxysulfuron, pyrazosulfuran ethyl and penoxulum could be used effectively to control weeds in puddle transplanted rice.

KEYWORDS

Weed control efficacy, proprietary mixture, weed biomass, early post emergence herbicide

INTRODUCTION

Weeds compete with rice plants for space, nutrient, light, air and water and exert a serious negative effect on crop production causing significant losses in crop yield ranging from 20 to 60% in land low rice[1,2]. Weed infestation inflicted yield loss vary highly due to variation in weed species, crop weed association and the adopted management practices[3]. The maximum yield of a crop can be achieved if there is no competition from weed in the field. Weeds grow in the rice field where the delay in weed control leads to increased weed biomass and exerts negative impact on yield. Hand weeding is the traditional but most effective method of weed control. In general, rainy season rice requires two to three hand weeding to obtain satisfactory yield performance. Although the hand weeding is environmentally benign, it is

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unmanageable and uneconomical. Moreover, becoming tough day-by-day due to wage rate rise and labour scarcity[4]. Mechanical weed control with the use of simple implements e.g., Japanense rice weeder, harrow etc. is also the practical and economic method for transplanted rice but due to labour shortage and increase wage rates, this method is also becoming costly. Nonetheless, labour unavailability, increased labour costs and the pressing need of increased yield and economic profit has been forced the farmers to alternative weed control measures. The effective weed management practices with low cost can be possible with the use of herbicide. Herbicidal weed control is the economical method of weed control and it has many advantages over cultural weed control as it is quick, cost effective and saves labour, time and money[5,6]. Generally, a pre-emergence herbicide is applied at 1-5 days after transplanting of rice seedling to prevent the emergence of weeds at early growth stage of the crop. The pre-emergence herbicide cannot provide full control over all the weeds and therefore, post-emergence herbicide application is needed to control the subsequent weed flushes. A number of post-emergence herbicides are in use and many new herbicides are coming into the Bangladesh market. Use of post-emergence herbicide gives most pragmatic, effective and economic weed control which ultimately gives higher yield in transplanted rice. However, the ample and indiscriminate use of same herbicide may result in weed resistance development, weed population structural change and dominance pattern, shift in weed population and serious consequences to the soil microbial organisms. Herbicides of different chemical compositions need to be applied in combination and in rotation to reduce the problem of residue buildup, shift in weed flora and development of herbicide resistance in weed. Herbicides applied at proper stage and time can suppress weeds effectively and may provide a weed free environment[7]. Sometimes, phyto-toxicity of herbicide is observed which eventually disappear with time[8]. However, many herbicides affect the agro-ecology and environment which consequently make the soil-plant-environment relationship imbalance[9]. The efficacy of the post-emergence herbicides needs to be evaluated to select the most promising herbicides of different mode of actions for using in the puddle transplanted rice in rotation to help effective weed control, avoiding herbicide resistance development and related adverse effects. The present study was therefore, undertaken with a view to find out some suitable post-emergence herbicides having different mode of actions for puddle transplanted lowland rainy season rice so that they can be used in rotation for effective weed control and also to avoid herbicide resistance development.

MATERIALS AND METHODS

Site and soil: An experiment was conducted during July to November, 2015 in a medium high land with silt loam soil (24% sand, 62% silt and 14% clay). The experimental area is located at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh having 24.75°N latitude and 90.50°E longitude at an altitude of 18 m which belonged under the Old Brahmaputra Floodplain (AEZ-9). The experimental area is located at and belongs to the agro-ecological zone of the Old Brahmaputra Floodplain (AEZ-9). The soil had particle density of 2.30, pH value of 7.19 and electrical conductivity of 162 ms cm^{-1}. The soil contained 1.48% organic matter, 0.08% total N, 4.06 ppm available P, 0.113 mEq 100 g^{-1} available K and 11.98 ppm S. The experimental area experiences sub-tropical climate characterized by high temperature, humidity and rainfall. Occasional gusty wind occurs in the Kharif season during April to September while, moderately low temperature, humidity and scanty rainfall occur during the Rabi season during October to March.

Experimental treatment and design: The experiment included ten herbicides for post-emergence application along with a weed free control and a weedy check control. The experiment used a randomized complete block design with three replications. The unit plot size was 4.0×2.5 m. The chemical name, trade name, mode of actions and the application rates of these herbicides were listed in Table 1. The weed fee conditions of the plots were maintained by hand weeding at 15, 25 and 35 days after transplanting (DAT). The post-emergence herbicides were applied at 10, 15 and 25 DAT at their recommended doses as shown in Table 1.

Table 1: Chemical name, trade name, mode of action, time and dose of application the post-emergence herbicides

Herbicide	Trade name	Mode of action	Time of application	Dose ha^{-1}
2,4-D	Weed kill	Synthetic auxin	25 DAT	2.25 L ha^{-1}
MCPA	MCPA 500	Synthetic auxin	25 DAT	1.00 L ha^{-1}
Bispyribac sodium+bensulfuron methyl	Manin	Inhibitor of ALS	15 DAT	0.15 kg ha^{-1}
Metsulfuron methyl		Inhibitor of ALS	15 DAT	0.06 kg ha^{-1}
Ethoxysulfuron	Sunrice 150WG	Inhibitor of ALS	15 DAT	0.10 kg ha^{-1}
Pyrazosulfuron ethyl	Laser 10 WP	Inhibitor of ALS	15 DAT	0.125 kg ha^{-1}
Acetachlor+bensulfuron methyl		Inhibitor of VLCFA and ALS	25 DAT	0.7 kg ha^{-1}
Penoxulam	Granite 240 SC	Inhibitor of ALS	10 DAT	0.093 kg ha^{-1}
Carfentrazone ethyl	Affinity 50.75 WP	PPO inhibitor	15 DAT	1.5 kg ha^{-1}
Bensulfuronmethyl+quinchlorac	Vacate	Inhibitor of ALS, Group O and monocot	15 DAT	0.60 L ha^{-1}
Weed free check(T15)	-	-		
Weedy check (T16)	-	-		

ALS: Acetolactate synthase and VLCFAs: Very long chain fatty acids

Crop husbandry: Twenty-five days old seedling of rice variety BRRI dhan49 was transplanted in the well puddled land on 27 July, 2015 at 25x15 cm spacing allocating two seedlings per hill. Urea, TSP, MOP, gypsum, zinc sulphate and boron fertilizers were applied at 200, 50, 70, 70, 5 and 5 kg per hectare, respectively. All non-urea fertilizers were applied as basal dose while urea fertilizer was applied at three installments at 15, 30 and 45 DAT. Herbicides were applied during 12th to 24th August, 2015 at recommended rates and times (Table 1). All the agronomic management practices were done as and when needed. The crop was harvested at full maturity on 3rd November, 2015 from central 3 m^2 area of each plot.

Data recording: A 25×25 cm quadrate was randomly placed lengthwise at two spots in each plot for recording of weed data at 40 DAT. Weeds were uprooted within the quadrate, washed, clipped to ground level and were oven dried at 70°C for 72 hrs and the weed biomass were expressed as g m^{-2}. The weed control efficacy (WCE) of different herbicides was calculated as follows[8]:

$$\text{WCE}\,(\%) = \frac{\text{Dry weight of weeds in weedy check}}{\text{Dry weight of weeds in treated plots}} \times 100$$

For recording necessary data on growth and yield attributes, five rice hills were selected and cut from each unit plot at random before harvesting the crops for recording data on grain and straw yield. The crop was harvested from central 3.0x1.0 m area from each unit plot just after collection of sample plants. The harvested crops from each plot were then separately bundled, properly tagged and threshed by a pedal thresher. The fresh weight of both grain and straw from each plot was recorded. The grains were dried in the sun and cleaned properly. Finally, grain yield was recorded in t ha^{-1} at 14% moisture content.

Statistical analysis of data: Data recorded for different parameters were subjected to statistical analysis following "Analysis of variance" technique using "Randomized Complete Block Design" with the help of computer package "Statistix 10". Significant differences among means were adjudged by Tukey's HSD Test at p = 0.05 using the same statistical package program.

RESULTS AND DISCUSSION

Weed biomass and weed control efficiency: Post-emergence herbicides had significant effect on weed dry matter production in transplant rainy season rice cv. BRRI dhan49. The highest weed dry matter was found in plots treated with metsulfuron methyl (84.36 g m^{-2}). This treatment gave statistically similar weed dry matter that was found with weedy check plot (73.58 g m^{-2}). Table 2 shows that bispyribac

Table 2: Effect of different post-emergence herbicides on weed dry matter, weed control efficacy, plant height and tiller production of transplanted rainy season rice

Treatment	Weed dry matter (g m^{-2})	WCE (%)	Plant height at harvest (cm)	Number of total tiller per hill	Number of total tiller m^{-2}
2,4-D Amine (T1)	44.11^{bc}	40.05	109.05	14.77^{abc}	398.88
MCPA500 (T2)	47.04^{abc}	36.07	109.55	14.77^{abc}	398.88
Bispyribac sodium+bensulfuron methyl (T3)	12.35^{cd}	83.21	110.26	15.21^{abc}	410.85
Metsulfuron methyl (T4)	84.36^{a}	-14.65	109.43	14.99^{abc}	404.91
Ethoxysulfuron (T5)	27.02^{cd}	63.28	113.83	15.88^{ab}	428.85
Pyrazosulfuran ethyl (T6)	33.55^{cd}	54.40	109.57	12.33^{cd}	332.91
Acetachlor+bensulfuron methyl (T7)	45.88^{bc}	37.65	112.78	13.55^{bc}	365.94
Penoxulam (T8)	14.80^{cd}	79.88	117.31	15.88^{ab}	428.94
Carfentrazon ethyl (T9)	41.62^{bc}	43.44	111.53	14.99^{abc}	404.91
Bensulfuron methyl+quinchlorac (T10)	18.97^{cd}	74.22	111.37	15.77^{ab}	425.97
Weed free check (T11)	0.00^{d}	100.0	112.24	17.33^{a}	387.00
Weedy check (T12)	73.58^{ab}	0.00	113.25	10.22^{d}	395.82
Level of significance	**	-	ns	**	ns
CV (%)	6.0	-	3.36	12.07	12.94

In a column figures having same or similar letters do not differ significantly while figures having dissimilar letters differ significantly as per DMRT, **Significant at 1% level of probability and ns: Not significant

sodium+bensulfuron methyl applied plots had the lowest weed dry matter (12.35 g m^{-2}) which is similar to those of penoxulum (14.8 g m^{-2}), bensulfuron methyl+quinchlorac (18.97 g m^{-2}) and ethoxysulfuron (27.02 g m^{-2}). The MCPA applied plot had the second highest weed dry matter which was similar with those for 2,4-D amine, acetachlor+bensulfuran methyl and carfentrazon ethyl applied plots (Table 2). The proprietor mixture of bispyribac sodium+bensulfuron methyl showed the highest weed control efficacy (83%) which was followed by penoxulum (80%), bensulfuron methyl+quinchlorac (74%), ethoxysulfuran (63%) and pyrazosulfuran ethyl (54%). All other herbicides showed 36-44% weed control while metsulfuran methyl could not reduce weed growth (Table 2). It has been reported that post-emergence application of bispyribac sodium alone reduced 80% weed dry matter in rice[10]. This herbicide suppresses all types of weeds including broadleaved, grasses and sedges[11]. Zahan *et al.*[12] pointed that proprietary mixture of herbicides i.e., propanil+bentazon, mefenacet+bensulfuron methyl, penoxsulum and azimsufuron+adjuvant are used to control mutha (*Cyperus rotundas*) and barnyard grass (*Echinochloa crus-galli*) effectively in rice. Uses of cyhalofop-butyl and bispyribac sodium were effective in controlling *Leptochloa chinensis* and *Ischaemum rugosum*. Chauhan and Abugho[13] reported that early-post emergence herbicides provided high weed control than post emergence herbicides. They also reported that bispyribac sodium is effective against *Echinochloa colona*. Ali *et al.*[14] showed that bispyribac sodium and ethoxysulfuran showed 90 and 87% weed control efficacy in rice. Bispyribac sodium is most effective against small and actively growing weeds, especially against barnyard grass[15]. Penoxulum is effective against barnyard grass but not effective against broadleaved weeds[16].

Growth parameters: The herbicides used in the study did not show any significant effect on plant height of rice cv. BRRI dhan49. Although, number of tiller per hill at harvest differed significantly but the herbicide did not produce significant variation in number of tiller m^{-2}. The weed free plots produced 17.33 tillers per hill while weedy plots showed 10.22 tillers per hill. Almost all herbicides produced tiller per hill similar to that produced in weed free plots but the crop treated with pyrazosulfuran ethyl produced lowest number of tiller per hill (12.33). The result showed that the post emergence herbicides used in the study did not have any toxic effect on any growth parameter of rice.

Grain yield and related attributes: Post-emergence herbicides had significant effect on grain yield, number of grains per panicle and thousand seed weight but not on number of effective tiller per hill and number of total spikelet per panicle. The weed free plots produced the highest yield (5.40 t ha^{-1}) which was similar to that found with bispyribac sodium+bensulfuron methyl (5.28 t ha^{-1}), ethoxysulfuron

Table 3: Effect of post-emergence herbicides on grain yield and related attributes of transplanted rainy season rice

Treatment	Number of effective tiller per hill	Number of filled grain per panicle	Number of total spikelet per panicle	Thousand seed weight (g)	Grain yield (t ha^{-1})
2,4-D Amine (T1)	363.21	85.00^{de}	97.67	22.85^{c}	4.85^{abc}
MCPA500 (T2)	368.21	82.67^{e}	100.33	22.82^{c}	3.92^{de}
Bispyribac sodium+bensulfuron methyl (T3)	379.52	106.67^{abc}	120.00	22.89^{bc}	5.28^{a}
Metsulfuron methyl (T4)	375.58	105.00^{abc}	124.33	22.93^{bc}	4.53^{bcd}
Ethoxysulfuron (T5)	393.52	114.33^{ab}	126.33	22.93^{bc}	5.06^{ab}
Pyrazosulfuran ethyl (T6)	302.24	105.00^{abc}	120.00	22.94^{bc}	3.55^{e}
Acetachlor+bensulfuron methyl (T7)	316.27	102.00^{bcd}	126.67	22.86^{c}	4.37^{cd}
Penoxulam (T8)	399.27	108.67^{abc}	120.67	22.90^{bc}	5.00^{abc}
Carfentrazon ethyl (T9)	372.58	92.67^{cde}	113.67	22.84^{c}	4.53^{bcd}
Bensulfuron methyl+quinchlorac (T10)	395.64	108.67^{abc}	122.67	23.04^{ab}	5.01^{abc}
Weed free check (T11)	432.33	121.67^{a}	135.67	23.17^{a}	5.40^{a}
Weedy check (T12)	316.88	76.67^{e}	102.00	22.61^{d}	3.40^{e}
Level of sign	ns	***	ns	***	***
CV (%)	13.43	9.97	12.20	0.40	8.41

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(5.06 t ha^{-1}), bensulfuron methyl+quinchlorac (5.01 t ha^{-1}), penxosulum (5.0 t ha^{-1}) and 2,4-D amine (4.85 t ha^{-1}). The lowest grain yield was found with weedy check plot (3.40 t ha^{-1}) which is similar to that of pyrazosulfuron ethyl (3.55 t ha^{-1}) and MCPA500 (3.92 t ha^{-1}) (Table 3). The weed free check plot produced the 121.7 grains per panicle which was similar to that of ethoxysulfuron (114.3 per panicle), bensulfuron methyl+quinclorac (108.7 per panicle), penoxulum (108.7 per panicle) and bispyribac sodium+bensulfuron methyl (106.7 per panicle). The highest thousand seed weight was obtained from weed free check plot (23.17 g) which was similar to that obtained from bensulfuron methyl+quinchlorac (23.04 g). The lowest thousand seed weight was obtained from the weedy check plot (22.61 g). It was noted from the result that the plot that produced lower weed dry matter gave a higher grain yield. Reports from different workers showed that bensulfuron, ethoxysulfuron, bispyribac sodium, penoxsulam and cyhalofop-butyl were highly effective in weed control and gave higher yields in rice[8,17]. This yield improvement was attained mainly due to an increase in the number of filled grain per panicles.

CONCLUSION

The present study concludes that post-emergence herbicides such as ethoxysulfuron, pyrazosulfuran ethyl, penoxulum, 2,4-D, proprietary mixture of bispyribac sodium+bensulfuron methyl and proprietary mixture of bensulfuron methyl+quinchlorac could be used for most effective weed control and achieving higher yield of rainy season rice cv. BRRI dhan49. Among the herbicides tested 2,4-D is a synthetic auxin while others are ALS inhibitors and therefore, 2,4-D and other herbicides should be applied in rotation for herbicide resistance development management. The present study suggested that new herbicide molecules of different mode of actions should be made available for weed control in rice.

SIGNIFICANCE STATEMENT

Application of selected early post-emergence herbicides of a different mode of an action group in the rotation would be helpful in controlling weeds effectively and would help reduce the chance of development of herbicide resistance in weeds.

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