Bangladesh J. Weed Sci. 8(1&2): 65-71; 2025 ISSN 2078 – 130X

WEED CONTROL EFFICACY OF PRE-EMERGENCE HERBICIDES IN PUDDLE TRANSPLANTED RICE

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ABSTRACT

Pre-emergence herbicides inhibit weed emergence and reduces the weed growth at early phase of the crop growth in transplanted lowland rice. Selection of pre-emergence herbicides of different mode of action and their rotational use reduces risk of herbicide resistance development in weeds. The experiment included thirteen herbicides for pre-emergence application, Pyrazosulfuran ethyl as early post emergence (EP) application along with a weed free and a weedy check as control. The experiment was laid out in a randomized complete block design with three replications. The results revealed that Pretilachlor, Pendimethalin, Butachlor, Penoxulam, and Carfentrazon ethyl provided best weed control (73-79%), while Pyrazosulfuran both as pre-emergence and early post emergence, Oxadiargyl, Metamiphop, Metribuzin, and Oxadiazone gave moderate (50-63%) weed control in transplanted rice. Among the herbicides, Triasulfuran gave only 30% weed control and exerted toxic effects on rice plant and reduced yield of crop. Different pre-emergence herbicides gave similar yield such as Butachlor (5.81 t ha^{-1}), Pretilachor (5.66 t ha^{-1}), Carfentrazol ethyl (5.58 t ha^{-1}), Orthosulfamuron (5.53 t ha^{-1}), and Ethoxysulfuron (5.46 t ha^{-1}) to that of weed free plots (5.98 t ha^{-1}). From the present study it appeared that pre-emergence herbicides of any of the four groups such as (i) Butachlor or (ii) Pretilachlor or (iii) Carfentrazon ethyl or (iv) Orthosulfamuron, Penoxulum, and Ethoxysulfuron could be used for successful weed control in puddle transplanted rice and the alternate use of these herbicides could be an effective tool for avoiding herbicide resistance development in weeds.

Keywords: Weed dry matter, phyto-toxicity, herbicide resistance, growth, grain yield

INTRODUCTION

Weeds compete with rice plants for space, nutrient, light, air, and water exert a serious negative effect on crop production causing significant losses in crop yield ranging from 20 to 60% in land low rice (Mondal *et al*., 2005; Singh and Singh, 2007; Manhas *et al*., 2012). The extent of yield losses due to weed infestation is highly variable and it depends on the type of weed species, time of weed association with crops and the management practices (mechanical and chemical) that are used to control the weeds (Mitra *et al*., 2005). The maximum yield of a crop can be achieved if competition from weed in the field is minimized. Weeds grow in the rice field and the delay in weed control leads to increased weed biomass which has negative correlation with yield. Hand weeding is the traditional method of weed control. Generally, two to three hand weeding is required for wet season rice to achieve the satisfactory yield performance. Hand weeding is environmentally friendly but it is cumbersome, uneconomical and becoming more difficult day-by-day due to the scarcity of labour and also due to increased wage rates. Chemical weed control is the economical method of weed control and it has advantages over cultural weed control as it is quick, cost effective and saves labour, time, and money (Al-Mamun *et al*., 2011.). A number of pre-emergence and post-emergence herbicides are used successfully to control weeds in transplanted wet season rice (Ahmed *et al*., 2005; Talgre *et al*., 2008). Pre-emergence herbicides checks weed emergence and reduces the weed growth at early phase of the crop growth. It offers the most practical, effective, and economical method of weed control for increasing grain yield of transplanted rice. The extensive and promiscuous use of herbicides induces weed resistance, alters weed population dynamics and dominance pattern, weed population shifts, and serious implications to soil micro-biota.

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Herbicides can suppress weeds effectively and may provide a weed free environment if applied at proper stage and time (Gitsopoulos and Froud-Williams, 2004). Sometimes, phytotoxicity of herbicide is observed which eventually disappear without causing much adverse effect on yield performance (Zahan *et al*., 2014). Herbicides may cause serious agro-ecological and environmental complications that imbalance the plant-soil-environmental relationships (Chauhan, 2012). The efficacy of a number of pre-emergence herbicides needs to be evaluated to select the most promising ones having different mode of actions for using in the puddle transplanted wet season rice to help avoid herbicide resistance problems and related adverse effects. With respect to the above discussion, the present study was therefore, undertaken with a view to find out the effect of different pre-emergence herbicides on weed suppression, growth, and yield performance of rainy season rice.

MATERIALS AND METHODS

Site and soil

An experiment was conducted in wet (*aman*) season (July to November) of 2015 at the Agronomy Field laboratory of Bangladesh Agricultural University, Mymensingh. The experimental field was a medium high land having silt loam soil (sand-24%, silt-62%, and clay-14%) with particle density of 2.30, pH value of 7.19, and electrical conductivity of 162 µS 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 is under sub-tropical climate which is characterized by high temperature, humidity and rainfall with occasional gusty wind in the wet season (April–September), and moderately low temperature, humidity and scanty rainfall during the dry season (October–March).

Experimental treatment and design

The experiment included thirteen herbicides for pre-emergence application along with a weed free control, a weedy check, and also Pyrazosulfuran ethyl for early post emergence (EP) application as control. The experiment used a randomized complete block design (RCBD) with three replications. The unit plot size was 4.0 m × 2.5 m. The chemical name, trade name, mode of actions, and the application rates of these herbicides are listed in Table 1.

Table 1. List of herbicides used in the trial along with their mode of action and dose of application.

Chemical name	Trade name	Mode of action	Dose ha^{-1}
Pretilachlor (T_1)	Rifit 500 EC	Inhibitor of very long-chain fatty acid synthesis	1.0 L
Pyrazosulfuran ethyl PRE (T_2)	Laser10WP	Inhibitor of ALS	125.0 g
Trisulfuran (T_3)	Logran75WG	Inhibitor of ALS	10.0 g
Pendimethalin (T_4)	Panida33EC	Inhibitor of microtubule assembly	2.5 L
Oxadiazon (T_5)	Supercare250EC	PPO inhibitor	1.0 kg
Ethoxysulfuron (T_6)	Sunrice150WG	Inhibitor of ALS	100.0 g
Butachlor (T_7)	AimChlor5G	Inhibitor of microtubule assembly or cell division	25.0 kg
Orthosulfamuron (T_8)	Kelion50WP	Inhibitor of ALS	150.0 mg
Oxadiargyl (T_9)	Topstar400SC	PPO inhibitor	187.5 ml
Penoxulam (T_{10})	Granite240SC	Inhibitor of ALS	93.7 ml
Metamifop (T_{11})	Pyzero	Inhibition of ACCs	750.0 ml
Carfentrazon ethyl (T_{12})	Affinity50.75WP	PPO inhibitor	1.5 kg
Metribuzin (T_{13})	Neon70WG	Photosystem II inhibitor	750.0 g
Pyrazosulfuran ethyl EP (T_{14})	Laser10WP	Inhibitor of ALS	125.0 g
Weed free check (T_{15})	-	-	-
Weedy check (T_{16})	-	-	-

PPO = Protoporphyrinogen oxidase; ACCs = Acetyl-coenzyme-A carboxyl transferase, ALS = Acetolacte synthase; EP = Early post-emergence, PRE = Pre-emergence

Pyrazosulfuran ethyl is generally used as EP herbicide but some reports showed the good performance of this herbicide as pre-emergence application in rice. The weed free conditions of the plots were maintained by hand weeding at 15, 25, and 35 days after transplanting (DAT). All pre-emergence herbicides were applied at 4 DAT and early post-emergence application of Pyrazosulfuran ethyl was done at 20 DAT at their recommended dose (Table 1).

Crop husbandry

Twenty-five-day old seedling of rice variety BRRI dhan49 was transplanted on the well puddled land on 27 July 2015 at 25 cm × 15 cm spacing using two seedlings per hill. Urea, TSP, MoP, gypsum, zinc sulphate, and boron fertilizers were applied @ 200, 50, 70, 70, 5, and 5 kg hectare^{-1} respectively. All non-urea fertilizers were applied as basal dose while urea fertilizer was applied at three installments at 15, 30, and 45 DAT. All the agronomic management practices were done as and when needed. The crop was harvested at full maturity on 03 November 2015 from central 3 m^2 area of each plot.

Data recording

A 25 cm × 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 h and the weed biomass were expressed as g m^{-2}. The weed control efficacy (WCE) of different herbicides was calculated as follows:

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

Five rice hills were randomly selected from each unit plot and uprooted before harvesting for recording necessary data on growth and yield attributes. After sampling, harvesting was done from central 3.0 m × 1.0 m area to record the grain yield. The harvested crop from each plot were separately bundled, properly tagged and then threshed by pedal thresher and the fresh weight of grain was recorded plot-wise. The grains were cleaned and sun dried 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 RCBD with the help of computer package "Statistix 10". Significant differences among means were adjudged by LSD test at $p \leq 0.05$ using the same statistical package programme.

RESULTS AND DISCUSSION

Weed dry matter and weed control efficacy

The pre-emergence herbicide treatments had significant influence on weed dry matter. Weedy plots produced the highest weed dry matter (145 g m^{-2}) while Butachlor applied plots showed the lowest weed dry matter (30 g m^{-2}). Pretilachlor and Carfentrazon ethyl treated plots showed statistically similar values to that obtained from Butachlor applied plots (Table 2). Pendimethalin and Ethoxysulfuron treated plots also gave similar values to those of pretilachlor applied plots (Table 2). The second highest weed dry matter (102 g m^{-2}) found in plots applied with trisulfuran. The fourth highest weed dry matter was found with oxadiazone which was statistically similar with those received Orthosulfomuron, Oxadiargyl, Metamiphop, Metribuzin, and Pyrazosulfuron ethyl as pre and early post. The present study clearly revealed that Pretilachlor, Pendimethalin, Butachlor, Penoxulam, and Carfentrazon ethyl are more effective herbicides, which exerted similar weed suppression in transplanted lowland rice field. Butachlor provided 79% weed control while pretilachlor, Carfentrazon ethyl, Pendimethalin gave 76%, 77%, and 73% weed control. Pyrazosulfuran as pre-emergence (T_2)

and post-emergence (T_{14}) application exhibited 63% and 50% weed control, respectively. Oxadiazone and Oxadiargyl showed 50 and 60% weed control. The lowest weed control efficacy (30%) was evident from Trisulfuran applied plot. The present study showed highest weed control with Butachlor which was closely followed by Pretilachlor and Carfentrazon ethyl. Oxadiazone showed the moderate weed control while Trisulfuran showed the lowest effect. Several experiments showed that Ronstar 25 EC (Oxadiazon) gave effective weed control in transplanted rice (Zahan *et al*., 2014; Hasan *et al*., 2003). Shultana *et al*., (2011) showed that Pretilachlor, Butachlor, and Oxadiazon are very effective pre-emergence herbicides in controlling weeds in transplanted dry season rice.

Growth attributes

Plant height, tiller production, grain number panicle^{-1} and grain yield of rice were significantly affected by pre-emergence herbicides. The pre-emergence herbicide did not show any significant effect on thousand seed weight. The tallest plant (111 cm) was found with Orthosulfamuron treated plots which was similar with both weed free and weedy plots. The lowest plant height (92 cm) was found with Triasulfuran (Table 2).

Table 2. Effect of different pre-emergence herbicides on weed biomass, weed control efficacy, plant height and tiller production of transplanted rice

Treatment	Weed dry matter (g m^{-2})	WCE (%)	Plant height at harvest (cm)	No. of total tillers hill^{-1}	No. of total tillers m^{-2}
Pretilachlor (T_1)	34.90 f	75.99	106.40 abcd	13.83 bcd	452.61 bc
Pyrazosulfuran ethyl-PRE (T_2)	54.21 cde	62.71	103.20 d	14.40 bcd	389.88 bcde
Trisulfuran (T_3)	101.5 b	30.17	91.62 e	11.93 d	348.94
Pendimethalin (T_4)	40.04 ef	72.45	108.07 abcd	13.20 cd	450.91 bc
Oxadiazon (T_5)	73.06 c	49.74	104.91 abcd	15.73 bc	425.88 bcd
Ethoxysulfuron (T_6)	46.47d ef	68.03	105.10 abcd	14.97 bcd	404.91 bcd
Butachlor (T_7)	29.99 f	79.37	107.81 abcd	14.40 bcd	464.27 b
Orthosulfamuron (T_8)	61.30 cd	57.83	111.33 a	15.50 bc	419.85 bcd
Oxadiargyl (T_9)	58.18 cde	59.98	108.14 abcd	14.20 bcd	352.94
Penoxulam (T_{10})	46.96 def	67.69	107.53 abcd	17.20 b	390.55 bcde
Metamifop (T_{11})	59.84 cd	58.83	110.93 ab	15.17 bcd	386.61 bcde
Carfentrazon ethyl (T_{12})	33.23 f	77.14	110.65 abc	16.87 b	419.21 bcd
Metribuzin (T_{13})	72.28 c	50.28	104.16 cd	23.67 a	371.52
Pyrazosulfuran ethyl -EP (T_{14})	72.56 c	50.08	104.53 bcd	14.17 bcd	380.88 bcde
Weed free check (T_{15})	0.00 g	100.00	110.34 abc	16.97 b	577.00 a
Weedy check (T_{16})	145.36 a	0.00	105.49 abcd	12.53 cd	313.82 e
Level of significance	***	-	***	***	***
CV (%)	19.72	-	3.74	13.42	12.91
$S\bar{x}$	6.61	-	2.29	1.18	30.55

In a column, figures having the same or similar letters do not differ significantly as per DMRT, *** = significant at 0.1% level of probability, CV = Coefficient of variation, $S\bar{x}$ = Standard error of means, PRE = preemergence application, EP = Early post application

The highest number of tillers hill^{-1} (24) was obtained with Metribuzin while the lowest (12) was found with Triasulfuran treated plots. The total numbers of tillers hill^{-1} found with weed free check plots were 17.0, which was lower than many other pre-emergence herbicides treated plots (Table 2). The number of total tillers m^{-2} was highest (577) with the weed free plots while the lowest (313) was found with weedy plots. Among the herbicide treated plots, Butachlor gave the highest total tillers m^{-2} (464) which was closely followed by Pretilachlor (453). Triasulfuran exerted severe toxic effect on rice plants and it ultimately did not recover. Although slight effect was found in case of Butachlor but it recovered very soon. Thapa (2012) found that Butachlor exerted slight toxic effect in term of leaf chlorosis on rice plant at seedling stage at 21 DAT but the effect disappeared soon and produced satisfactory grain yield. Oxyfluorfen also showed slight toxic effect on rice plants as manifested by chlorosis and vein clearing at initial growth stages which recovered later on and did not show any significant impact on yield performance (Priya *et al.* 2017). Abraham *et al.* (2010) also found that rice seedlings recovered from the phytotoxicity effect of Oxyfluorfen within 10 days of application. Das *et al*. (2024) reported that herbicide selectively plays a critical role in rice weed control. They also reported that rice plants may suffer no more than 30% initial injuries through chlorosis and stunting which disappeared within 2 to 4 weeks with most of those herbicides.

Grain yield and related attributes

The highest grain yield was found with weed free plots (5.98 t ha^{-1}) which was statistically similar to that of Butachlor (5.81 t ha^{-1}), Pretilachor (5.66 t ha^{-1}), Carfentrazol ethyl (5.58 t ha^{-1}), Orthosulfamuron (5.53 t ha^{-1}), and Ethoxysulfuron (5.46 t ha^{-1}) treated plots. The lowest grain yield was found with weedy check plots (2.34 t ha^{-1}) which is statistically similar with that (2.74 t ha^{-1}) of Triasulfuran treated plots (Table 3).

Table 3. Effect of different pre-emergence herbicides on grain yield and related attributes of transplanted rice

Treatment	No. of effective tillers hill^{-1}	No. of grains panicle^{-1}	Thousand seed weight (g)	Grain yield (t ha^{-1})
Pretilachlor (T_1)	416.61 bc	114.33 ab	22.58	5.66 abc
Pyrazosulfuran ethyl as pre (T_2)	361.21 bcde	88.00 bcde	22.63	4.54 ef
Trisulfuran (T_3)	312.94	74.33 de	22.63	2.74 g
Pendimethalin (T_4)	421.58 bc	103.67 abcd	22.38	5.36 bcd
Oxadiazon (T_5)	391.21 bcd	91.33 bcde	22.53	4.93 de
Ethoxysulfuron (T_6)	375.58 bcd	109.33 abc	22.71	5.46 abcd
Butachlor (T_7)	440.94 b	117.33 ab	22.60	5.81 ab
Orthosulfamuron (T_8)	379.85 bcd	93.67 bcd	22.47	5.53 abc
Oxadiargyl (T_9)	327.61 bcde	80.33 cde	22.52	4.20 f
Penoxulam (T_{10})	366.55 bcde	95.67 bcd	22.53	5.64 abc
Metamifop (T_{11})	358.61	91.00 bcde	22.65	4.73 ef
Carfentrazon ethyl (T_{12})	379.88 bcd	114.33 ab	22.51	5.58 abc
Metribuzin (T_{13})	338.85 cde	81.00 cde	22.53	4.63 ef
Pyrazosulfuran ethyl EP (T_{14})	353.55 cde	95.67 bcd	22.48	5.09 cde
Weed free check (T_{15})	539.67 a	136.00 a	22.62	5.98 a
Weedy check (T_{16})	287.82 e	60.67 e	22.43	2.34 g
Level of significance	***	**	ns	***
CV (%)	13.73	20.30	0.74	6.98
S$\bar{x}$	29.94	11.32	0.09	0.19

In a column, figures having the same or similar letters do not differ significantly as per DMRT, *** = significant at 0.1% level of probability, CV = Coefficient of variation, S$\bar{x}$= Standard error of means, PRE = preemergence application, EP = Early post application.

The Pyrazosulfuran ethyl as pre-emergence and early post emergence herbicide gave 4.54 and 5.09 t ha^{-1}, respectively. This yield was much lower than that obtained from many pre-emergence herbicides. The highest number of effective tiller m^{-2} was found with weed free plots (540). The second highest value was found with Butachlor which was similar with those found with Pretilachlor, Oxadiargyl, Oxadiazon, Carfentrazon ethyl, Pendimethyl, and Pyrazosulfuran ethyl as pre-emergence.

The highest number of filled grains panicle^{-1} (136.0) was found with weed free check plots. The lowest number of filled grains panicle^{-1} (60.7) was found with weedy plots. The second highest number of filled grains panicle^{-1} (117) was found with Butachlor treated plots which is similar to those of Pretilachlor (114), Carfentrazon ethyl (114), and Ethoxysulfuron (109). The second highest number of total spikelet panicle^{-1} was found with Pretilachlor (136.0), Carfentrazon-ethyl (134.7), Butachlor (133.7), Ethoxysulfuron (128.3), and Pendimethalin (123.0). All these yield contributing characters were lowest with Triasulfuran treated crop (Table 3). Bhowmick *et al*. (2000) found that Pretilachlor effectively controlled the weeds in transplanted rice and recorded the maximum grain and straw yields which were at par with hand weeding. Hossain and Rahman (2013) found that Pretilachlor (Rifit 500 EC) and Butachlor (Machete 5G) were equally effective in controlling weeds and increasing grain yield of lowland transplanted rice variety BR11.

Rice productivity is mainly decided by the weed control efficiency of weed management methods (Abraham *et al*., 2010). It was evident from the study that the herbicides those have higher weed control efficacy gave higher yield indicating that these herbicides not only controlled weeds but also give higher yield by improving the yield contributing characters of rice. In the present study the best performing pre-emergence herbicides Butachlor, Pretilachlor, Carfentrazon ethyl, Orthosulfamuron, Penoxulum, and Ethoxysulfuron. In relation to the mode of action of these herbicides, Butachlor is a microtubule assembly or cell division inhibitor, pretilachlor is a very long-chain fatty acid synthesis inhibitor, Carfentrazon ethyl is a Protoporphyrinogen oxidase (PPO) inhibitor while Orthosulfamuron, Penoxulum, and Ethoxysulfuron are acetolactate synthase (ALS) inhibitors. It is obvious that continuous application of the herbicides having same mode of action helps in developing herbicide resistance in weeds. Therefore, the alternate use of herbicides of different mode of action group could help in avoiding herbicide resistance problem in weeds.

CONCLUSION

The study revealed that Triasulfuran had high phytotoxicity and it considerably reduced plant height, tiller number, and yield of rice cv. BRRI dhan49. Some other herbicides showed slight toxicity in rice plant but recovered very shortly and did not pose any adverse effect on rice growth and yield. The study concludes that pre-emergence application of Butachlor, Pretilachlor, Carfentrazon ethyl, Orthosulfamuron, Penoxulum, and Ethoxysulfuron provides satisfactory weed control and gives high gain yield of wet season rice cv. BRRI dhan49. Thus, these pre-emergence herbicides could be considered as an alternative to hand weeding for controlling weeds in transplanted lowland wet season rice. The present study concludes that use of any herbicide from the selected four mode of action groups (i) Butachlor or (ii) Pretilachlor or (iii) Carfentrazon ethyl or (iv) Orthosulfamuron, Penoxulum and Ethoxysulfuron could be effective for weed control and their alternate use for avoiding herbicide resistance development in weeds.

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