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Efficacy of Different Commercial Product Oxadiazon and Pyrazosulfuron-Ethyl on Rice and Associated Weeds in Dry Season Rice Cultivation

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Abstract: Due to shortage of labor using herbicides is an alternative, effective and economic system of weed management. An experiment was conducted on dry season at Bangladesh Rice Research Institute farm Gazipur (92°41′ E longitude and 20°34′ N latitude), Bangladesh during January-May, 2009 to find out the efficacy of different post emergence herbicide and select cost effective herbicide as weed control option. There were ten different weed control treatments viz. T_1=Zealus 10 WP at 125 g ha^{-1}, T_2=Amaraj 10 WP at 150 g ha^{-1}, T_3=Siniron 10WP at 187 g ha^{-1}, T_4=Herbikill 10 WP at 150 g ha^{-1}, T_5=Res Q 25 EC at 1.2 L ha^{-1}, T_6=Remover 10 WP at 187 g ha^{-1}, T_7=Safety 10 WP at 200g ha^{-1}, T_8=Laser 10 WP at125 g ha^{-1}, T_9=Three hand weeding at 15, 30 and 45 DAT and T_{10}=Weedy check. There were 8 different weed species infested the field among which *Scirpus maritimsu* followed by *Echinochloa crusgalli* was the most dominated weed in terms of weed density and importance value. Among the treatments T_6 gave the lowest weed population, weed dry weight and weed index and highest weed control efficiency. The yield and the yield contributing characters (no. of panicles m^{-2}, no. of grains $panicle^{-1}$, grain and straw yield) were influenced according to the effectiveness of the treatments. Herbicidal treatment T_6 produced similar yield as hand weeding (T_9) but weeding cost of T_6 was almost one-sixth of T_9. Maximum marginal return rate with T_6 suggested that this herbicidal treatment could be used as an alternative tool when labor is a limiting factor in dry season rice cultivation.

Key words: Efficacy · Post emergence herbicide · Manual weeding · Dry season · Rice

INTRODUCTION

Rice (*Oryza sativa* L.) is the vital food for more than two billion people in Asia and four hundreds of millions of people in Africa and Latin America [1]. The people in Bangladesh depend on rice as staple food and have tremendous influence on agrarian economy of Bangladesh. Rice alone constitute of 95% of the food grain production in Bangladesh [2]. Among different groups of rice dry season (Boro) rice cover about 43.6% of total rice area and it contributes to 61.3% of the total rice production in Bangladesh [3]. Boro covers the second largest area of 4.61 million hectare with a production of 17.72 million metric ton and average yield is about 3.84 t ha^{-1} [3]. The average yield of rice in Bangladesh is 2.73 t ha^{-1} [4], which is approximately 50% of the world average rice grain yield/ha. Weed infestation is one problem that causes low yield of rice. In Bangladesh, weed infestation reduces the grain yield by 70-80% in *Aus* rice (early summer), 30-40% for transplanted (T) *Aman* rice (late summer) and 22-36% for modern *Boro* rice cultivars (winter rice) [4, 5]. Production cost of rice increased due to increases in weed control cost. The prevailing climatic and edaphic conditions are highly favorable for numerous species of weeds that strongly compete with the rice crop. In Bangladesh the traditional methods of weed control practices include preparatory land tillage, hand weeding by hand pulling. Usually two or three hand weeding is normally done for growing rice season depending upon the nature of weeds, their intensity of infestation and the vigor of rice plants. Mechanical and cultural weed control methods in transplant *Boro* rice are expensive. Especially at periods of labor crisis late weeding can cause drastic losses in grain yield while chemical weed control is efficient, easy and available. Now a days the use of herbicides is gaining popularity in rice fields due to their rapid effects and lower costs compared to traditional methods [6]. The available herbicides for controlling rice weeds are of overseas origin. The country depends on foreign multinational companies for the supply of herbicides and the companies do not supply the same brand of

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herbicides for long time. So, continuous evaluation is necessary for the benefit of the farmers of this country. Therefore, the study was undertaken to examine the performance of different post emergence herbicides in comparison with manual weeding for controlling weeds of *Boro* rice.

MATERIALS AND METHODS

An experiment was conducted at Bangladesh Rice Research Institute, Bangladesh during on *Boro* season rice (January-May) of 2009. The soil of the experimental site was clay loam with a pH of 5.47-5.63. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 3 replications. Ten different weed control treatments were: T_1=Zealus 10 WP at 125 g ha^{-1}, T_2=Amaraj 10 WP at 150 g ha^{-1}, T_3=Siniron 10WP at 187 g ha^{-1}, T_4=Herbikill 10 WP at 150 g ha^{-1}, T_5=Res Q 25 EC at 1.2 L ha^{-1}, T_6=Remover 10 WP at 187 g ha^{-1}, T_7=Safety 10 WP at 200g ha^{-1}, T_8=Laser 10 WP at125 g ha^{-1}, T_9=Three hand weeding at 15, 30 and 45 DAT (days after transplanting) and T_{10}=Weedy check. The common name of Res Q 25 EC is Oxadiazon and rests of them are Pyrazosulfuron-ethyl. All the tested commercial herbicides were postemergence and applied at 2-3-leaf stage of weeds. Seeds of *Boro* rice cv. BRRI dhan29 were sown in seed bed on December 20, 2008 and transplanted in the main field on January 28, 2009. The planting distance was at 20 cm (row-row) × 20 cm (hill-hill). The field was fertilized with urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate at 220, 100, 60, 60 and 10 kg ha^{-1}, respectively. Except urea, the whole amounts of fertilizers were added during land preparation. Urea was top dressed in three installments at 15, 30 and 45 DAT. Intercultural operations such as gap filling, irrigation and plant protection were carried out as required. Data regarding weeds were recorded at 50 DAT. Weed dry weights were taken by drying them in electric oven at 60°C for 72 hours. Relative weed density (RWD), Importance value of weed (IVW), Weed control efficiency (WCE), Weed Index (WI) and Marginal Rate of Return (MRR) was calculates as follows:

$$RWD = \frac{\text{Density of individual weed species in the community}}{\text{Total density of all weed species in the community}} \times 100$$

$$IVW = \frac{\text{Dry weight of a given oven dried weed species}}{\text{Dry weight of all oven dried weed species}} \times 100$$

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

$$WI = \frac{\text{Grain yield in weed free plot- Grain yield in treated plot}}{\text{Grain yield in treated plot}} \times 100$$

$$MRR = \frac{\text{Marginal gross margin of X}}{\text{Marginal variable cost of X}} \times 100$$

At harvest, plant characters and yield data were recorded. The data were analyzed following Analysis of Variance (ANOVA) technique and mean separations were adjusted by the Multiple Comparison test [7] using the statistical computer program MSTAT-C v.1.2 [8].

RESULTS AND DISCUSSION

Weed Infestation: The conditions, which are favorable for dry season rice cultivation, are also favorable for the exuberant growth of numerous weed species that compete with crop plants. Different species of weeds belong to various families infested the experimental plots. The weeds that grown in in the experimental field were grasses, broadleaves and sedges including Poaceae, Cyperaceae, Pontederiaceae and Oxalidaceae families (Table 1). The relative density and importance value of these weed species were also different. It might be seen that the most important weeds in the experimental site was *Scirpus maritimsu* followed by *Echinochloa crusgalli* and the lowest one *Leptochloa chnensis*. Among the weed species maximum relative weed density was observed for *Scirpus maritimsu* where minimum relative weed density was observed in case of *Leptochloa chnensis*. In this study it was also observed that broadleaves were less dominating weed species.

Weed Control: Weed density was significantly affected by different weeding treatments (Fig. 1). Weed density was highest in unweeded control plots (T_{10}). Weeding treatments significantly reduced weed population. Among the treatments T_8 exhibited the highest reduction (93.6%) of weed population per square meter. It was observed that T_5 and T_9 showed identical result. Again, T_6 and T_9 gave identical result also in relation to weed density. Al-Kothayri and Hasan [9] reported that all herbicidal treatments reduced weed population significantly compared with weedy check.

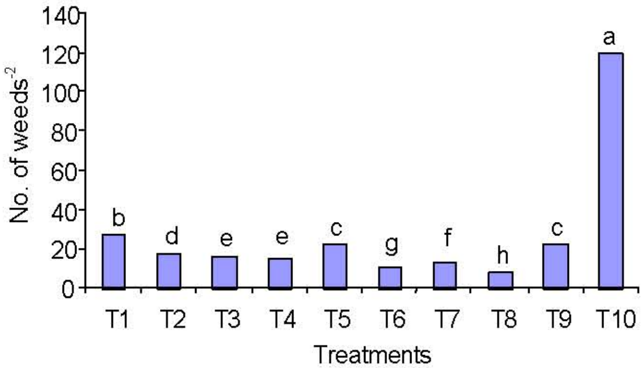

Fig. 1: Weed density in rice field as affected by weed control options

Table 1: Importance value and relative density of weed vegetation growing in the dry season rice cultivation

Name of Weeds	Family	Types of weeds	Importance value (%)	Relative density (%)
Scirpus maritimus	Cyperaceae	Sedge	24.70	25.21
Echinochloa crusgalli	Poaceae	Grass	17.60	21.14
Monochoria vaginalis	Pontederiaceae	Broadleaf	16.31	13.65
Oxalis europea	Oxalidaceae	Broadleaf	14.55	10.24
Cynodon dactylon	Poaceae	Grass	10.43	9.58
Cyperus difformis	Cyperaceae	Sedge	9.86	14.09
Leersia hexandra	Poaceae	Grass	5.25	3.96
Leptochloa chinensis	Poaceae	Grass	1.30	2.13

[T_1=Zealus 10 WP at 125 g ha^{-1}, T_2=Amaraj 10 WP at 150 g ha^{-1}, T_3=Siniron 10WP at 187 g ha^{-1}, T_4=Herbikill 10 WP at 150 g ha^{-1}, T_5=Res Q 25 EC at 1.2 L ha^{-1}, T_6=Remover 10 WP at 187 g ha^{-1}, T_7=Safety 10 WP at 200g ha^{-1}, T_8=Laser 10 WP at125 g ha^{-1}, T_9=Three hand weeding at 15, 30 and 45 DAT and T_{10}=Weedy check]

Table 2: Weed dry matter, weed control efficiency and weed index as affected by different weed control options

Treatments	Total weed biomass (gm^{-2})	Weed control efficiency (%)	Weed index (%)
T_1	9.7 b	88.0 e	31.0 b
T_2	10.6 b	87.0 f	20.2 b
T_3	8.6 b	89.0 d	27.2 b
T_4	8.3 b	90.0 cd	27.1 b
T_5	15.3 b	81.0 h	11.6 b
T_6	6.6 b	92.0 a	14.3 b
T_7	11.2 b	86.0 g	23.6 b
T_8	7.5 b	90.6 b	23.5 b
T_9	8.3 b	89.8 c	-
T_{10}	79.6 a	-	88.9 a
$LSD_{0.05}$	12.9	0.54	20.7

In a column the values having common letter(s) do not differ significantly

[T_1=Zealus 10 WP at 125 g ha^{-1}, T_2=Amaraj 10 WP at 150 g ha^{-1}, T_3=Siniron 10WP at 187 g ha^{-1}, T_4=Herbikill 10 WP at 150 g ha^{-1}, T_5=Res Q 25 EC at 1.2 L ha^{-1}, T_6=Remover 10 WP at 187 g ha^{-1}, T_7=Safety 10 WP at 200g ha^{-1}, T_8=Laser 10 WP at125 g ha^{-1}, T_9=Three hand weeding at 15, 30 and 45 DAT and T_{10}=Weedy check]

Table 3: Plant characters and yield components of transplanted rice as affected by weed control methods

Treatments	Plant height (cm)	No. of panicles m^{-2}	Panicle length (cm)	No. of grains panicle^{-1}	1000-grain weight (g)	Sterility (%)
T_1	96.2	165.7 bc	23.9	99.3 abc	23.8	12.7
T_2	96.3	201.7 ab	23.7	100.3 abc	23.1	14.5
T_3	93.1	178.7 b	23.7	91.0 bc	24.1	13.8
T_4	93.3	197.3 ab	23.3	83.3 c	24.2	14.5
T_5	95.9	233.7 a	24.0	103.7 ab	23.8	13.1
T_6	95.3	197.3 ab	23.3	103.7 ab	23.6	14.5
T_7	96.5	207.3 ab	23.9	99.7 ab	23.6	14.1
T_8	95.8	174.7 bc	23.1	108.7 ab	23.3	14.3
T_9	96.0	192.3 ab	24.3	111.3 a	24.1	13.9
T_{10}	91.8	129.7 c	23.1	66.3 d	23.06	17.40
$LSD_{0.05}$		44.94		16.10		

In a column the values having common letter(s) do not differ significantly

[T_1=Zealus 10 WP at 125 g ha^{-1}, T_2=Amaraj 10 WP at 150 g ha^{-1}, T_3=Siniron 10WP at 187 g ha^{-1}, T_4=Herbikill 10 WP at 150 g ha^{-1}, T_5=Res Q 25 EC at 1.2 L ha^{-1}, T_6=Remover 10 WP at 187 g ha^{-1}, T_7=Safety 10 WP at 200g ha^{-1}, T_8=Laser 10 WP at125 g ha^{-1}, T_9=Three hand weeding at 15, 30 and 45 DAT and T_{10}=Weedy check]

Table 4: Yield and harvest index of dry season rice as affected by different weed control options

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
T_1	4.27 b	5.66 c	43.0
T_2	4.64 b	6.54 abc	41.44
T_3	4.37 b	6.05 bc	42.1
T_4	4.37 b	6.30 bc	41.0
T_5	4.95 ab	6.77 ab	42.2
T_6	4.84 ab	6.75 ab	41.8
T_7	4.53 b	6.60 abc	40.6
T_8	4.50 b	6.57 abc	40.6
T_9	5.52 a	7.39 a	42.9
T_{10}	2.94 c	4.40 d	40.0
$LSD_{0.05}$	0.72	0.96	

In a column the values having common letter(s) do not differ significantly

[T_1=Zealus 10 WP at 125 g ha^{-1}, T_2=Amaraj 10 WP at 150 g ha^{-1}, T_3=Siniron 10WP at 187 g ha^{-1}, T_4=Herbikill 10 WP at 150 g ha^{-1}, T_5=Res Q 25 EC at 1.2 L ha^{-1}, T_6=Remover 10 WP at 187 g ha^{-1}, T_7=Safety 10 WP at 200g ha^{-1}, T_8=Laser 10 WP at125 g ha^{-1}, T_9=Three hand weeding at 15, 30 and 45 DAT and T_{10}=Weedy check]

Table 5: Treatment wise variable cost (Herbicide & labour), gross return and gross margin of dry season rice cultivation

Treatments	Variable cost (US $ ha^{-1})	Gross return (US $ ha^{-1})	Gross margin (US $ ha^{-1})
T_1	16.27	833.4	817.2
T_2	29.63	908.4	878.8
T_3	35.15	854.8	819.6
T_4	19.45	856.6	837.1
T_5	49.36	967.6	918.3
T_6	26.75	947.1	920.3
T_7	37.64	888.4	850.8
T_8	24.39	882.6	858.3
T_9	158.36	1077.9	919.6
T_{10}	0.00	577.4	577.4

[T_1=Zealus 10 WP at 125 g ha^{-1}, T_2=Amaraj 10 WP at 150 g ha^{-1}, T_3=Siniron 10WP at 187 g ha^{-1}, T_4=Herbikill 10 WP at 150 g ha^{-1}, T_5=Res Q 25 EC at 1.2 L ha^{-1}, T_6=Remover 10 WP at 187 g ha^{-1}, T_7=Safety 10 WP at 200g ha^{-1}, T_8=Laser 10 WP at125 g ha^{-1}, T_9=Three hand weeding at 15, 30 and 45 DAT and T_{10}=Weedy check]

Table 6: Treatment wise cost dominant analysis

Gross margin (US $ ha^{-1})	Treatments	Variable cost (US $ ha^{-1})	Cost dominated treatments
920.32	T_6	26.75	
919.57	T_9	158.36	*
818.28	T_5	49.36	*
878.80	T_2	29.63	*
858.25	T_8	24.39	
850.79	T_7	37.64	*
837.12	T_4	19.45	
819.64	T_3	35.15	*
817.16	T_1	16.27	
577.43	T_{10}	0.00	

[T_1=Zealus 10 WP at 125 g ha^{-1}, T_2=Amaraj 10 WP at 150 g ha^{-1}, T_3=Siniron 10WP at 187 g ha^{-1}, T_4=Herbikill 10 WP at 150 g ha^{-1}, T_5=Res Q 25 EC at 1.2 L ha^{-1}, T_6=Remover 10 WP at 187 g ha^{-1}, T_7=Safety 10 WP at 200g ha^{-1}, T_8=Laser 10 WP at125 g ha^{-1}, T_9=Three hand weeding at 15, 30 and 45 DAT and T_{10}=Weedy check]

Table 7: Marginal analysis of non-dominated treatments

Gross margin (US $ ha^{-1})	Treatments	Variable cost (US $ ha^{-1})	Marginal variable cost (US $ ha^{-1})	Marginal gross margin (US $ ha^{-1})	Marginal rate of return (%)
920.32	T_6	26.75	2.36	62.07	2630.02
858.25	T_8	24.39	4.94	21.13	427.76
837.12	T_4	19.45	3.18	19.96	627.76
817.16	T_1	16.27	16.27	239.73	1473.45
577.43	T_{10}	0.00			

[T_1=Zealus 10 WP at 125 g ha^{-1}, T_4=Herbikill 10 WP at 150 g ha^{-1}, T_6=Remover 10 WP at 187 g ha^{-1}, T_8=Laser 10 WP at 125 g ha^{-1} and T_{10}=Weedy check]

Similar result was observed by Hasanuzzaman *et al.* [10]. Significant differences in weed dry weight were observed due to different weeding treatments (Table 2). Among the treatments T_6 produced the lowest weed dry matter, which is identical with other treatment effect. It reveals that use of post emergence herbicides reduce the weed biomass effectively. The second lowest weed dry matter was recorded with T_8. The highest weed dry matter (79.56 g m^{-2}) was produced by weedy check treatment (T_{10}). Above 80% weed control efficiency was found from each treatment. Among, the treatments, T_6 showed the best result (92%), which was superior than other treatments (Table 2). It might be due to emergence of minimum weed species. The treatments T_3 and T_4 produced similar results. The lowest weed control efficiency (81%) was shown in T_5. This result was partially supported by Hasanuzzaman *et al.* [10]. The significant effect on weed index (%) was found due to different herbicidal treatments (Table 2). The lowest weed index (11.6%) was found in T_5, which was identical with other herbicidal treatments. It was due to efficient control of weeds by herbicidal treatments. The highest weed index (88.9%) was found in case of weedy check treatment.

Yield Contributing Characters: Yield components such as number of panicle m^{-2} and number of grains panicle^{-1} were significantly influenced by different treatments used in this experiment (Table 3). Plant height, panicle length, sterility percent and 1000-grain weight did not differ significantly due to different weeding methods. Among weeding methods, T_7 produced the tallest plants (96.5 cm) and unweeded control plots showed the shortest one. The reduction of plant height in unweeded check might be due to the inter plant competition for longer period which inhibited the plants to become taller. Significantly highest number of panicle m^{-2} (234) was found from T_5 but it was statistically similar with T_2, T_4, T_6, T_7 and T_9. This is because proper control of weeds reduced the weed density which facilitates the crop plants to have sufficient space, light, nutrient and moisture and thus the number of panicle m^{-2} increased. The lowest number of panicle m^{-2} (129.67) was recorded from weedy check (T_{10}). The treatment T_9 produced the highest length of panicle followed by T_5 and shortest was found from weedy check T_{10}. Weeds always compete with crop for resources like light, water, nutrient etc. which are needed for plant growth to produce more grains [11]. In this study, greater weed infestation in the unweeded plots resulted in the lowest number of grain panicle^{-1}. The treatment T_9 produced the maximum number of grain panicle^{-1}, which was statistically similar with T_5, T_6, T_7 and T_8 (Table 3) mainly due to weed free conditions in these treatments. Hasanuzzaman *et al.* [10] and Ahmed *et al.* [12] found that application of any herbicides produced similar number of grains per panicle. In this study, 1000-grain weight was not significantly affected by weeding treatments. The highest grain weight was observed with T_9 followed by T_3 and the lowest with T_{10}. It was found that sterility (%) did not significantly affected by weeding treatments. However, the highest percentage of grain sterility was observed with T_{10} and the lowest with T_1.

Yield and Harvest Index: As the treatment T_9 (Three hand weeding) showed the maximum control of weed, the ultimate reflection of this treatment was appeared as the highest grain yield (5.52 t ha^{-1}) of transplanted dry season rice cultivation (Table 4). It was statistically similar to $_5$ and T_6. It might be the resultant effects of significant highest number of panicle m^{-2} and number of grains panicle^{-1} with those treatments (Table 3). T_5, T_6 and T_9 produced 40.6%, 39.3 and 46.7% higher yield than unwedded control, respectively. This result was partially supported by Hasanuzzaman *et al.* [10]. Straw yield also significantly affected by weeding treatments (Table 4). The highest straw yield was observed with T_9 which was statistically similar with T_5 and T_6. It revealed that the herbicide application has more or less similar effect to hand weeding treatments. Uncontrolling weeds resulted in the lowest straw yield. In this study different treatment effects were non-significant in terms of harvest index. However, the highest harvest index was observed from T_1 where the lowest harvest index was observed in T_{10}.

Economic Analysis of Alternative Weed Control Options in Dry Season Rice Cultivation: Different weed control treatments involved different amounts of weeding cost, which affect the cost of production in dry season rice cultivation (Table 5). The economic analysis indicated that the maximum cost of weeding was hand weeding (T_9) due to more labour requirement. This result was supported by Hasanuzzaman *et al.* [10]. The treatment T_5 recorded the second highest cost, which was almost one-third of T_9. The gross return from dry season rice cultivation was found to be the maximum with the treatment T_9 (Three hand weeding) followed by T_5 (Res Q 25 EC at 1.2 L ha^{-1}) and T_6 (Remover 10 WP at 187 g ha^{-1}). The lowest gross return was obtained from weedy check due to its lowest production of grain and straw. The highest gross margin was received from the treatment T_6 (Remover 10 WP at 187 g ha^{-1}) which was even higher than T_9 (Table 5). By cost dominant analysis it was found that five treatments T_2, T_3, T_5, T_7 and T_9 were cost dominated. In these treatments cost was more but gross margin was less than that of many other treatments (Table 6). The marginal analysis of non-dominated treatments showed that the highest marginal rate of return (2630.02 %) was found from T_6 (Table 7). This result signifies that the herbicide Remover 10 WP at 187 g ha^{-1} if applied for controlling weeds in dry season rice cultivation the highest marginal rate of return (MRR) on investment was obtained. It means that herbicidal treatment was more profitable than hand weeding. So the use of post emergence herbicides may be an alternative option in controlling weeds more easily and cheaply. From this study it may be concluded that the application of Remover 10 WP at 187 g ha^{-1} for controlling weeds in dry season rice cultivation maximized the rate of return to capital and can be used as an alternative weed control option.

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