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COMPARATIVE EFFICACY OF DIFFERENT POST-EMERGENCE HERBICIDES IN WHEAT (*Triticum aestivum* L.)

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A field experiment was carried out to study the efficacy of different post-emergence herbicides for controlling weeds in wheat during a Rabi season 2008-09. Experiment comprised of six treatments, i.e. weed-infested control, pyroxasulfone at 50 g a.i ha^{-1}, metribuzin at 250 g a.i ha^{-1}, isoproturon at 1080 g a.i ha^{-1}, clodinafop propargyl at 240 g a.i ha^{-1} and bromoxynil+MCPA at 247+247 g a.i ha^{-1} as post-emergence herbicides. Results revealed that Post-emergence application of isoproturon (1080 g a.i ha^{-1}) proved to be best for obtaining maximum grain plus straw yield up to the level of weed-free control. Bromoxynil+MCPA (247+247 g a.i ha^{-1}) and clodinafop propargyl (240 g a.i ha^{-1}) also gave maximum spike bearing tillers, number of grains spike^{-1} and 1000-grain weight. Isoproturon (1080 g a.i ha^{-1}) strictly reduced the weeds population as well as biomass as compared to weed-infested control. Poor weed control was achieved by using pyroxasulfone and metribuzin treatments. Hence, post-emergence Isoproturon (1080 g a.i ha^{-1}) followed by bromoxynil + MCPA (247+247 g a.i ha^{-1}) was provide to be the most effective herbicide against weeds and resulted in maximum wheat yield.
Keywords: Post-emergence herbicides, isoproturon, herbicides efficacy, weed density, *Triticum aestivum* L.

INTRODUCTION

Wheat (*Triticum aestivum* L.), the main food crop of Pakistan, is grown on an area of 9.06 million hectares with total production of 23.42 million tons and an average yield of 2585 kg ha^{-1} (Govt. of Pakistan, 2009). About one third of population based on wheat crop for protein and caloric requirements. Wheat grain yield in Pakistan is scarce due to many reasons, but one of them, very serious and less attended is weed infestation (Montazeri *et al*., 2005). Weeds compete with crop plants for natural resources, i.e. light, nutrients, space, and water etc., which consequently reduces the wheat yield (Olesen *et al*., 2004; Soufizadeh and Zand, 2004; Grichar, 2006). Zand *et al*. (2007) illustrated that 30% grain yield losses are associated with weeds infestation. Weeds are most omnipresent class of pests that interfere with crop plants through competition and allelopathy, resulting in direct loss to quantity and quality of produce (Gupta, 2004). However, weeds are the main cause of ever-increasing trouble in wheat fields.

In Pakistan, major weeds of wheat that's causing huge economic losses are bitter dock (*Rumex dentatus* L.), swine cress (*Coronopus didymus* L.), meet species (*Emex spinosa* L.), prickly chaff flower (*Achyranthes aspara*), canary grass (*Phalaris minor* R.), wild oat (*Avena fatua* L.) yellow sweetclover (*Melilotus indica* L.), fumitory (*Fumaria indica* L.), prostrate knotweed (*Polygonum plebejum* L.) and lamb's quarters (*Chenopodium album* L.). Weeds with relatively less economic importance including wild medic (*Medicago polymorpha* L.) field bindweed (*Convolvulus arvensis* L.) and lesser *bromus* spp. (Shamsi and Ahmed, 1984; Khan and Marwat, 2006).

To minimize weeds losses, there are number of chemical and non-chemical methods of weeds control such as mechanical, cultural, biological and use of herbicides (Rehman *et al*., 2010). Hand weeding is very expensive and ineffective technique, for the reason that it is very difficult to distinguish weed plants and wheat seedlings by inexperienced labor. That's why, herbicides ever more become a key factor for weed control and improving crop yield. Currently, for controlling weeds and obtaining maximum grain yield, a lot number of post-emergence herbicides are used in wheat fields. So, there is a great need to discover latest post-emergence herbicide options because not a single one of these herbicides currently gives a satisfactory weed control. Through stimulation of protein or RNA biosynthesis, these herbicides cause a plant death (Rao, 2000). Therefore, an excellent, broad spectrum of annual, biennial, and perennial weeds control can be achieved by these herbicides (Jin *et al.*, 2011). Amongst effective post-emergence herbicides, mixture of isoproturon with tralkoxydim was not in favor of many weeds (Balyan *et al.*, 1991; Villiers and Du Tott, 1992). Excellent control can also be attained with clodinafop propargyl which is more efficient in reducing weed population (Mirkamali, 1993). Fenoxaprop-p-ethyl by yourself or mixture with clodinafop propargyl also provides an excellent weed control (Everaere and Thiebault, 1990). Metribuzin with other herbicides also gives reduction in weed density in wheat but sometimes shows phytotoxic effects (Forster *et al*., 1997; Chhokar *et al*., 2002; Ritter and Menbere, 2002). Isoproturon and some other post-emergence herbicides sprayed alone or along with surfactant significantly improve herbicides injury to weeds (Malik *et al*., 1989). A tremendous weed control and maximum grain yield in wheat fields can be achieved with Isoproturon herbicide alike weed-free control (Walia *et al*., 1990; Johri and Govindra, 1991). It has been described that Isoproturon increases the grain yield by adding protein contents to wheat crop (Gupta *et al*., 1990; Johri *et al*., 1992).

Thus, herbicides proved to be very quick and effective option for weeds control in wheat. The accessibility of various post-emergence herbicides has facilitated farmers to profitably produce high-yielding wheat varieties bred to attain best yield (Powles *et al*., 1997). The objectives of this study were to realize the response of weeds and wheat yield against various post-emergence herbicides.

MATERIALS AND METHODS

To investigate the efficacy of various post-emergence herbicides on weed growth and wheat yield, a field trial was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad during Rabi season 2008-09. Naturally occurring weed density was used during this experiment (Table 1). Based on soil physico-chemical properties as described by Homer and Pratt (1961), analysis revealed that soil was sandy clay loam with pH 7.6, 0.85% organic matter, 0.062% totals nitrogen, 13.1 ppm phosphorus and 179 ppm potassium. Moldboard plow followed by disking was being used for seedbed preparation and leveled soil by means of land leveler. A high yielding wheat cultivar sahar-2006 was used as a test crop using a seed rate 125 kg ha^{-1}. The crop was sown during 3rd week of November, 2008 by a single row hand drill in 25cm apart rows. Fertilizers were applied at 125 kg N and 100 kg P_2O_5 ha^{-1}. The crop was harvested manually at physiological maturity. This was done when the green colour from the glumes and kernels disappeared completely.

The trial was planned in Randomized Complete Block Design (RCBD) comprising four replicates. Plots consisted of 8 rows, 5m in length and 2m width. Treatments consisted of pyroxasulfone 85WG @ 50 g a.i ha^{-1}, metribuzin 70%W/W @ 250 g a.i ha^{-1}, isoproturon 50WP @ 1080 g a.i ha^{-1}, clodinafop propargyl 15WP @ 240 g a.i ha^{-1}, bromoxynil + MCPA 18.2%W/W @ 247+247 g a.i ha^{-1} as a post-emergence. A weedy check was also included. At wheat tillering stage post-emergence herbicides were applied after 1st irrigation (Zadoks *et al*., 1974) by "Knapsack" hand sprayer fixed with T-jet nozzle. Volume of spray was determined by calibration with water.

Table 1. Presence of weed species at experimental site.

Weed species	Presence
Rumex dentatus L.	+
Phalaris minor R.	+
Emex spinosa L.	+
Convolvulus arvensis L.	+
Achyranthes aspara	+
Fumaria indica L.	+
Melilotus indica L.	+
Polygonum plebejum L.	+
Chenopodium album L.	+
Coronopus didymus L.	+

+ Point out weed species present at this locality.

For each weed specie, decrease in weeds density were calculated by counting the number of weeds prior to 7 days after herbicide application (DAHA); 30 DAHA; 60 DAHA and at harvest, with a fixed 1m^2 quadrate within the herbicide treated plots. Reduction in dry weed biomass was considered by using two 0.25m^2 quadrates after oven-drying at 70°C till constant weight was achieved. Weeds were separated to different species after cutting near the ground surface. Percent decrease in weed density over control was achieved by deducting weed biomass from untreated plots, dividing the product by weed biomass from untreated plot, multiplying with 100. Data on plant height, spike bearing tillers, number of grains per spike, 1000-grain weight, straw yield and grain yield were recorded. Analysis of variance was carried out according to Fisher's analysis of variance technique (Steel *et al*., 1997) and least significance difference (LSD) test was used to compare the differences among treatments' means.

RESULTS AND DISCUSSION

Weeds density (m^{-2}):

Rumex dentatus: *R. dentatus* density was affected significantly through application of different post-emergence herbicides. Minimum *R. dentatus* density at different days after herbicide application was found by post-emergence Isoproturon (1080 g a.i ha^{-1}). At 7 days after herbicide application metribuzin (250 g a.i ha^{-1}) treated plots contained the maximum *R. dentatus* density after weed infested control. The minimum *R. dentatus* density was attained in Isoproturon (1080 g a.i ha^{-1}) sprayed plots. At 30 & 60 days after herbicide application the lowest *R. dentatus* density (13.75 plants m^{-2}) and (8.50 plants m^{-2}) was obtained respectively where Isoproturon (1080 g a.i ha^{-1}) was applied. Metribuzin (250 g a.i ha^{-1}); clodinafop propargyl (240 g a.i ha^{-1}) and bromoxynil + MCPA (247+247 g a.i ha^{-1}) gave statistically similar *R. dentatus* density. At harvest, Isoproturon (1080 g a.i ha^{-1}) resulted in significant reduction in *R. dentatus* density (6.50 plants m^{-2}) (Table 2). It is

Table 2. Effect of different herbicide treatments on weed density of *Rumex dentatus*

Treatments	Dose (g a.i ha^{-1})	Days after herbicide application (DAHA)			
		7 DAHA	30 DAHA	60 DAHA	At Harvest
Weed-infested control	---	94.75 a	94.25 a	102.75 a	121.25 a
Pyroxasulfone	50	25.50 c	19.25 c	17.50 bc	15.50 bc
Metribuzin	250	29.50 b	23.50 b	18.75 b	17.50 b
Isoproturon	1080	11.25 e	13.75 e	8.50 e	6.50 e
Clodinafop propargyl	240	23.50 cd	17.50 cd	15.50 cd	13.25 cd
Bromoxynil + MCPA	247+247	21.50 d	15.75 de	13.25 d	11.50 d
LSD (P = 0.05)	---	3.22	3.09	2.26	2.77

Any two means sharing same letters did not differ significantly at 5% level of probability according to LSD test.

Table 3. Effect of different herbicide treatments on weed density of *Coronopus didymus*

Treatments	Dose (g a.i ha^{-1})	Days after herbicide application (DAHA)			
		7 DAHA	30 DAHA	60 DAHA	At Harvest
Weed-infested control	---	96.50 a	98.00 a	124.00 a	223.50 a
Pyroxasulfone	50	24.50 bc	19.75 c	54.50 c	23.75 c
Metribuzin	250	28.25 b	23.50 b	84.25 b	82.50 b
Isoproturon	1080	10.00 e	8.75 e	8.25 e	7.25 e
Clodinafop propargyl	240	21.25 cd	16.50 d	13.75 d	15.25 d
Bromoxynil + MCPA	247+247	19.25 d	15.50 d	13.25 d	13.25 d
LSD (*P* = 0.05)	---	4.50	2.90	3.13	2.58

Any two means sharing same letters did not differ significantly at 5% level of probability according to LSD test.

obvious that the reduction in *R. dentatus* density was attributed to the reason that herbicides actually target the different sites of plants. These target sites have different enzymes which were inhibited by the application of Isoproturon (1080 g a.i ha^{-1}). These results are in line with Bharat and kachroo (2007) who revealed that Isoproturon significantly reduced the *R. dentatus* density.

***Coronopus didymus*:** The lowest *C. didymus* density at different days after herbicide application (10 plants m^{-2}); (8.75 plants m^{-2}); (8.25 plants m^{-2}) and (7.25 plants m^{-2}) were obtained where Isoproturon (1080 g a.i ha^{-1}) was applied. Statistically data showed that clodinafop propargyl (240 g a.i ha^{-1}) and bromoxynil+MCPA (247+247 g a.i ha^{-1}) could not recover the *C. didymus* control efficacy (Table 3). The minimum density of *C. didymus* could be attributed to more mortality due to the blocking of the electron transport system resulting in destruction of the PS-II reaction centre. Analogous results of weed control were strongly supported by Grishin *et al*. (2001) and Khan *et al*. (2003).

***Emex spinosa*:** *E. spinosa* density was significantly affected by Isoproturon (1080 g a.i ha^{-1}). The plots which are treated with Isoproturon (1080 g a.i ha^{-1}) giving the lowest *E. spinosa* density compared to control at different days after herbicide application. Bromoxynil + MCPA (247+247 g a.i ha^{-1}) also gave a better *E. spinosa* control. New herbicide pyroxasulfone did not perform efficiently as compared to other post-emergence herbicides. Isoproturon (1080 g a.i ha^{-1}) was the most excellent option for controlling *E. spinosa* density (Table 4). Inhibition of carotenoid synthesis, chlorosis and destruction of PS-II reaction center resulted from the Post application of Isoproturon (1080 g a.i ha^{-1}). These results are in accordance with (El-Metwally *et al*., 2010).

***Weeds dry weight (m^{-2})*:** Weeds biomass (m^{-2}) was severely affected by post-emergence herbicides. Significant biomass reduction of *R. dentatus* (94.64%); *C. didymus* (93.17%) and *E. spinosa* (88.78%) over control, was achieved by means of Isoproturon (1080 g a.i ha^{-1}). Maximum weeds biomass was attained by weed-infested control followed by metribuzin (250 g a.i ha^{-1}). Bromoxynil + MCPA (247+247 g a.i ha^{-1}); clodinafop propargyl (240 g a.i ha^{-1}) statistically gave a similar *R. dentatus*; *C. didymus* and *E. spinosa* biomass. Isoproturon (1080 g a.i ha^{-1}) was proved to be most effective in reducing *R. dentatus*; *C. didymus* and *E. spinosa* biomass compared to other weed control treatments (Table 5). Maximum reduction in weeds biomass may be caused by high weed kill efficiency of post-emergence Isoproturon (1080 g a.i ha^{-1}). These results are in conformity with the work reported by EL-Metwally and Soudy (2009), Cheema and Akhtar (2005), Marwat *et al*. (2008) and Tanveer *et al*. (2003) who reported that Isoproturon (1080 g a.i ha^{-1}) significantly suppressed the weeds biomass.

Wheat yield:

***Plant height (cm)*:** Herbicides exhibited the non-significant effect on plant height. Highest plant height (98.30cm) was acquired from unweeded check while the minimum plant

Table 4. Effect of different herbicide treatments on weed density of *Emex spinosa*

Treatments	Dose (g a.i ha^{-1})	Days after herbicide application (DAHA)			
		7 DAHA	30 DAHA	60 DAHA	At Harvest
Weed-infested control	---	106.50 a	105.75 a	120.75 a	94.75 a
Pyroxasulfone	50	18.50 c	12.25 c	13.50 bc	13.00 b
Metribuzin	250	53.50 b	58.75 b	15.25 b	13.25 b
Isoproturon	1080	7.50 e	7.50 d	7.50 d	6.25 d
Clodinafop propargyl	240	15.00 d	10.75 c	11.50 bcd	11.50 bc
Bromoxynil + MCPA	247+247	13.50 d	9.75 cd	10.25 cd	10.25 c
LSD (P = 0.05)	---	3.12	2.81	4.28	2.43

Any two means sharing same letters did not differ significantly at 5% level of probability according to LSD test.

Table 5. Effect of different herbicide treatments on weed biomass reductions

Treatments	Dose (g a.i ha^{-1})	Weed species			
		Rumex dentatus L. (g m^{-2})	*Coronopus didymus* L. (g m^{-2})	*Emex spinosa* L. (g m^{-2})	Total weed biomass reduction (g m^{-2})
Weed-infested control	---	159.00 a	122.42 a	260.00 a	356.38 a
Pyroxasulfone	50	76.33 c	52.52 c	46.65 c	217.40 bc
Metribuzin	250	93.17 b	84.43 b	95.50 b	227.20 b
Isoproturon	1080	18.02 e	6.00 e	29.17 d	40.95 d
Clodinafop propargyl	240	47.20 d	50.58 c	45.92 c	193.88 c
Bromoxynil + MCPA	247+247	45.45 d	20.93 d	44.80 c	189.88 c
LSD (P = 0.05)	---	3.01	2.68	2.18	30.83

Any two means sharing same letters did not differ significantly at 5% level of probability according to LSD test.

Table 6. Effect of different herbicide treatments on wheat yield

Treatments	Dose (g a.i ha^{-1})	Parameters					
		Plant height (cm)	spike bearing tillers	number of grains $spike^{-1}$	1000-grain weight (g)	Straw yield (t ha^{-1})	Grain yield (t ha^{-1})
Weed-infested control	---	98.30 a	218.25 e	45.50 e	47.57 e	4.55 d	2.33 d
Pyroxasulfone	50	94.40 ab	267.25 c	54.25 d	55.75 cd	5.27 c	3.10 c
Metribuzin	250	92.90 bc	250.50 d	51.50 d	52.60 d	5.40 bc	3.05 c
Isoproturon	1080	88.60 c	291.00 a	68.00 a	65.30 a	6.12 a	4.84 a
Clodinafop propargyl	240	96.60 ab	272.25 c	58.50 c	57.27 bc	5.65 b	3.71 b
Bromoxynil + MCPA	247+247	93.25 bc	282.25 b	62.25 b	60.50 b	5.72 b	3.77 b
LSD (P = 0.05)	---	4.84	5.07	3.56	3.28	0.33	0.10

height (88.60cm) was attained with Isoproturon (1080 g a.i ha^{-1}) (Table 6). Actually the competition among weeds and wheat plants enforced to grow up the plant height higher than the actual height. These results are in alignment with the previous findings of Marwat *et al*. (2005) who reported that there was non-significant increase in the plant height with the application of post-emergence herbicides.

***Spike bearing tillers (m^{-2})*:** Analysis of the data revealed that different post-emergence herbicides had significant effect on spike bearing tillers (Table 6). The maximum spike bearing tillers (291) were recorded in Isoproturon (1080 g a.i ha^{-1}) treated plots while lowest spike bearing tillers (218.25) were counted in weed-infested control. Effective weed control is the main reason for increasing spike bearing tillers with the application of post-emergence Isoproturon (1080 g a.i ha^{-1}) which increased nutrients availability to the crop. Khan (2003) who investigated that herbicides application significantly influenced the number of spike bearing tillers.

***Number of grains per spike*:** Number of grains per spike was also significantly affected by various post-emergence herbicides. However, highest number of grains per spike (68.0) was obtained with Isoproturon (1080 g a.i ha^{-1}) while the lowest number of grains per spike (45.50) was found in control followed by metribuzin (250 g a.i ha^{-1}) (Table 6). Least number of grains per spike acquired in weed-infested control was possibly due to weed crop competition, which might have prominently reduced the flow of nutrients towards the grains. These results are in conformity with Shafi *et al*. (2004) who stated that number of grains per spike can be increased with post-emergence Isoproturon (1080 g a.i ha^{-1}) treatment.

1000-grain weight (g)**:** Maximum thousand grain weight (65.30g) was with Isoproturon (1080 g a.i ha^{-1}) treatments which were followed by bromoxynil + MCPA (247 + 247 g a.i ha^{-1}) (Table 6). Ahmad *et al*. (1991) reported that increment in thousand grain weight was due to more utilization of resources and good crop stand in the absence of weeds. However, results showed that satisfactory weed control is possible by using isoproturon (1080 g a.i ha^{-1}) that exceeds wheat grain yield up to 51.85%.

Straw yield (t ha^{-1})**:** Results indicated that highest straw yield (6.12 t ha^{-1}) was obtained with Isoproturon (1080 g a.i ha^{-1}) followed by bromoxynil + MCPA (247 + 247 g a.i ha^{-1}) over unweeded check. Of all herbicides evaluated, pyroxasulfone (50 g a.i ha^{-1}) gave the lowest straw yield (5.27 t ha^{-1}) but not extensively unlike the metribuzin (250 g a.i ha^{-1}) (Table 6). Similar findings were also reported by Tiwari *et al*. (2005) and Dixit and Singh (2008).

Grain yield (t ha^{-1})**:** Analysis of the data revealed that weeds competition is the main cause in declining the wheat grain yield. Most of the weeds that emerged with crop plants have similar characteristics like that of wheat crop and has a great demand for light, space and moisture etc. (Gonzalez-Ponce and Santin, 2001; Khalil *et al*., 2008).

Weeds competition with crop plants for the whole growing period decreases the grain yield. Amongst all herbicidal treatments, the lesser grain yield was seen in metribuzin (250 g a.i ha^{-1}) treated plots. Bromoxynil+MCPA (247+247 g a.i ha^{-1}) improved grain yield against weedy check, but not considerably dissimilar as of the clodinafop propargyl (240 g a.i ha^{-1}). However, Isoproturon (1080 g a.i ha^{-1}) gave maximum grain yield (4.84 t ha^{-1}) which showed that excellent control can be achieved with this herbicide (Table 6). Due to lessening the competition between the weeds and crop plants results in increased flow of nutrients towards the grains which ultimately boost up the wheat grain yield (Naik *et al*., 1997; Sharma *et al*., 2002; Singh *et al*., 2006). The control of weeds with Isoproturon (1080 g a.i ha^{-1}) at the entire stages of herbicide application resulted in excellent increase in crop yield. Application of Isoproturon (1080 g a.i ha^{-1}) resulted in 66.3 % increment in grain yield than unweeded check (El-Metwally *et al*., 2010).

Economic and marginal analysis**:** The effectiveness of any production system is ultimately evaluated on the basis of its economics. Economic analysis is the basic consideration in determining that which treatment gives the highest return while marginal analysis indicates the relative contribution of additional expenditure. All weed control treatments gave higher net benefit over unweeded check. Economic analysis (Table 7) revealed that maximum net benefits of Rs. 121057 ha^{-1} was obtained from Isoproturon (1080 g a.i ha^{-1}) at its label dose which was followed by bromoxynil + MCPA (247+247 g a.i ha^{-1}) providing a net benefit of Rs. 96742 ha^{-1}. Marginal and dominance analysis (Table 8) showed that Isoproturon (1080 g a.i ha^{-1}) treatment producing maximum marginal rate of return (MRR) which was 9393.49% and was followed by MRR of 7700%. These results are supported by the findings of Marwat *et al*. (2003) who stated that Rs. 32076 ha^{-1} net benefit and 4296% marginal rate of return was attained by the application of Isoproturon @ 1080 g a.i ha^{-1}.

CONCLUSIONS

From the experiment it is concluded that Isoproturon (1080 g a.i ha^{-1}) is the best option to attain acceptable weeds control and getting maximum grain yield. As observed, application of the new herbicide pyroxasulfone (50 g a.i ha^{-1}) did not give satisfactory control against weeds and could not prove best to gain acceptable wheat grain yield.

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Table 7. Economic analysis of different weed control treatments

Treatments	Grain yield (t ha^{-1})	Adjusted yield (t ha^{-1})	Grain yield value (Rs.)	Straw yield (t ha^{-1})	Straw yield value (Rs.)	Gross income (Rs.)	Variable weed control cost				Total cost that varied (a+b+c+d)	Net benefit (Rs. ha^{-1})
							a. Labour charges for 2 hand weeding	b. Cost of herbicides	c. Sprayer rent	d. Labour charges for herbicides application		
T_1	2.33	2.09	49637	4.55	13650	63287	---	---	---	---	---	63287
T_2	3.10	2.79	66262	5.27	15810	82072	---	490	90	150	730	81342
T_3	3.05	2.74	65075	5.40	16200	81275	---	760	90	150	1000	80275
T_4	4.84	4.35	103312	6.12	18360	121672	---	375	90	150	615	121057
T_5	3.71	3.34	79301	5.65	16950	96251	---	450	90	150	690	95561
T_6	3.77	3.39	80512	5.72	17160	97672	---	690	90	150	930	96742

Any two means sharing same letters did not differ significantly at 5% level of probability; T_1= Weedy Check; T_2= Pyroxasulfone @ 50g a.i. ha^{-1}; T_3= Metribuzin @ 250g a.i. ha^{-1}; T_4= Isoproturon @ 1080g a.i. ha^{-1}; T_5= Clodinafop propargyl @ 240g a.i. ha^{-1}; T_6= Bromoxynil + MCPA @ 247+247g a.i. ha^{-1} as post-emergence spray; Price of wheat grain @ Rs. 950/ 40 kg; Price of wheat straw @ Rs. 120/ 40 kg

Prevailing market prices of herbicides:

Pyroxasulfone @ Rs. 490; Metribuzin @ Rs. 760; Isoproturon @Rs. 375; Clodinafop propargyl @ Rs. 450; Bromoxynil + MCPA @ Rs. 690

Table 8. Marginal analysis of different weed control treatments

Treatments	Cost that varied (Rs. ha^{-1})	Net benefit (Rs. ha^{-1})	*MRR (%)
$T_{1=}$ Weedy Check	---	63287	9393.49
$T_{4=}$ Isoproturon @ 1080 g a.i ha^{-1}	615	121057	D**
$T_{5=}$ Clodinafop propargyl @ 240 g a.i ha^{-1}	690	95561	D
$T_{2=}$ Pyroxasulfone @ 50 g a.i. ha^{-1}	730	81342	7700
$T_{6=}$ Bromoxynil + MCPA @ 247+247 g a.i. ha^{-1}	930	96742	D
$T_{3=}$ Metribuzin @ 250 g a.i. ha^{-1}	1000	80275	

Cost that vary is the cost that is incurred on variable inputs in the production of a particular commodity; *Marginal rate of return (MRR%)= change in net benefit/ change in variable cost × 100; **D= dominated, any treatment that had net benefits that were less than or equal to those of a treatment with lower variable cost was taken to be dominated.

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