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Bio-efficacy and selectivity of sulfosulfuron and metribuzin before and after irrigation in wheat (*Triticum aestivum*) under zero-tillage system*

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Wheat (*Triticum aestivum* L. emend. Fiori & Poal.) is an important cereal crop of northern state of India grown by various tillage practices. The intensive tillage operations after the harvest of transplanted rice not only require a huge amount of energy and time but also delay the sowing of wheat and ultimately increase the cost of production, resulting reduction in the net income. Under such situation, zero tillage technology could be a viable option of timely sowing and reduce cost of crop establishment. Weeds, like *Phalaris minor* Retz. and *Avena ludoviciana* mimics wheat plant in morphology and growth behavior, and hence it is very difficult to control manually.Amongst various methods of weed control, herbicide use assumes a significant role in the reduction of weeds under zero tilled condition (Yaduraju and Mishra 2002). Effective control of weed is important not only to check the yield losses due to weeds but also to reduce the nutrient losses. Jain *et al*. (2007) found that N,P and K uptake by the crop was 67.07, 65.97 and 64.97% respectively less when the weed are allow to grow throughout the growing season compared with the treated plots. Recently, evolution of resistance in *P. minor* against popularly used herbicide, ie isoproturon declined the productivity of wheat and emphasized the need to evaluate new low dose herbicides for weed control in wheat. Hence, there is an urgent need to identify an alternative herbicide that could control it as well as other predominant weeds. Therefore, in this study, an attempt was made to find out the efficacy of herbicides on weed dynamics in wheat under zero tillage system.

A field experiment was conducted during winter (*rabi*) season 2003–04 and 2004–05 at the agronomy research farm of Institute of Agricultural Sciences, BHU, Varanasi, which is geographically situated at 23.2° N latitude, 83.03°E longitude and at an altitude of 113 msl in the north-eastern Gangetic Plains. This location has a typical sub-tropical climate characterized by hot, dry summer and cool winter. The soil was sandy clay loam in texture with slightly saline in reaction (*p*H–7.4). It was low in organic C (0.32%) and available N (174 kg/ha), medium in available P (26.7 kg/ha) and K (201 kg/ha) in soil surface. The total rainfall received during 2004 and 2005 was 68.89 and 151.20 mm, respectively, of which 24.45 and 52.6, 18.4 and 70.4, 26.44 and 28.20 mm, respectively was received during December, January and February. The field was kept under rice *(Oryza sativa* L.*)*–wheat rotation for the last many years. The treatments consist of metribuzin 0.21 kg/ha before first irrigation, metribuzin 0.21 kg/ha after first irrigation (AFI), sulfosulfuron 0.025 kg/ha before first irrigation (BFI) sulfosulfuron 0.025 g/ha after AFI, isoproturon + 2, 4-D 0.75 + 0.5 kg/ha after first irrigation, 1 hand weeding at 30 days after sowing, 2 hand weedings at 30 and 45 days after sowing and weedy check were tested in randomized block design with 3 replications. The 'HUW 234' wheat was sown with the help of zero-till ferti-seed drill at 22 cm row spacing using 125 kg seed/ha on 25 December 2003 and 15 December 2004 in 5m × 3.5 m gross plot size. All the herbicides were applied with the help of flat fan nozzle sprayer using volume of spray 500 litres/ha, at 20 days after sowing as BFI and 35 days after sowing as first irrigation. Urea, diammonium phosphate and murate of potash were used as sources of nitrogen, phosphorus and potassium respectively. An uniform dose of 40 kg N + 60 kg P + 40 kg K/ha was applied uniformly at sowing and remaining 80 kg N was top-dressed in two equal splits, each at after first irrigation and flowering time. Three irrigations were given to critical growth stages of crop and 6 cm water were applied per irrigation. Density, dry weight and weed control efficiency of weeds were observed at 80 days after sowing of crop. Data on weed density was recorded from an area enclosed in the quadrate of 0.5 m^2

*Short note

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randomly selected at 3 places in each plot. Weed data subjected to square root transformation ("x + 0.5) before statistical analysis. Data on growth at 80 days after sowing and yield-contributing characters, grain and straw yield at harvest were studied for both the years. The soil and harvest produce in each year were evaluated for nutrients as per the standard procedures. Nutrient uptake by weed, grain and straw of crop were calculated by determining nutrient concentration in relation to dry matter production. The economics was calculated on the basis of cost of production, which includes common cost of cultivation Rs 13 690, cost of herbicide (metribuzin Rs 437, sulfosulfuron Rs 1 975, isoproturon + 2, 4-D Rs 277/ha) and gross returns including sale prices of wheat grain Rs 6.50 and straw Rs 0.5/kg in 2004 and grain Rs 7.0 and straw Rs 0.5/kg in 2005. The crop was harvested on15 April 2004 and 29 March 2005.

As the variation in sowing time during course of study greatly influenced the crop growth, yield attributes, yield and nutrients uptake and results are being presented year wise. However, pooled data of weeds are presented because of similar trend was observed on the population and dry biomass of weeds during both the years of experimentation.

The relative composition of major weed flora at the experimental site comprised *P. minor* L. (25.5%), *Cynodon dactylon* L. (18.6%), *Cyperus rotundus* L. (14.41%), *A. ludoviciana* L. (7.84%), *Solanum nigrum* L. (6.86%) and *Fumeria parviflora* L. (5.88%) were major weed species which severely competed with the wheat crop (Table 1). Besides these, *Chenopodium album* L. (3.92%), *Anagallis arvensis* L. (2.83%), *Euphorbia* spp (2.2%), *Vicia sativa* L. (2.3%), *Rumex dentatus* L. (4.2%), *Convolvulus arvensis* L. (3.01%), *Polygonium plebejum* L. (0.2%), *Ageratum conyzoides* L. (0.4%) and *Spergula arvensis* L. (0.6%) were also observed, but the competition by these species was non-significant as their population was low.

The weed control treatments significantly reduced the weed population and dry biomass of weeds than weedy check (Table 1). Sulfosulfuron (0.025 kg/ha after first irrigation proved the most effective herbicide and significantly reduced density and dry weight of weeds than other herbicidal treatments and it was at par with 1 hand weeding at 30 days after sowing (Table 1). The tank mix application of isoproturon + 2, 4-D (0.75 + 0.5 kg/ha after first irrigation) also reduced density and dry weight of weeds than 1 hand weeding at 30 days after sowing, metribuzin (0.21 kg/ha before first irrigation and after first irrigation) and sulfosulfuron (0.025 kg/ha before first irrigation). Hand weeding twice at 30 and 45 days after sowing significantly reduced density and dry biomass of weeds over other weed control treatments, due to slow pace of growth of first flush of weeds, 30 days after sowing thereafter the emergence of new flushes of weeds could not attain full growth under the shade of crop plants. These results are in conformity with those of Bharat and Kachroo (2007). Higher density and dry biomass of weeds under one hand weeding plots compared

Table 1 Effect of weed control methods on relative composition of weed flora at 80 DAS (pool data of 2 years)

Treatment	Dose (kg/ha)	Time of application	*Phalaris minor*	*Avena ludoviciana*	*Cynodon dactylon*	*Cyperus rotundas*	*Chenopodium album*	*Fumeria parviflora*	*Solanum nigrum*	*Vicia sativa*	Other weed	Total weed/m^2	Weed dry weight/ m^2	WCE (%)
Metribuzin	0.21	BFI	11(3.32)	5(2.24)	11(3.32)	9 (3.1)	2 (1.41)	2 (1.41)	7 (2.66)	2 (1.41)	6 (2.26)	55(7.41)	31.2(5.6)	46.1
Metribuzin	0.21	AFI	6 (2.45)	2(1.41)	10(3.14)	8 (2.83)	2 (1.41)		3 (1.73)	1 (1)	4 (2.0)	36(6.0)	21.1(4.6)	64.7
Sulfosulfuron	0.025	BFI	8(2.84)	6(2.45)	8 (2.83)	6 (2.45)		1 (1)	6 (2.46)	2 (1.41)	4 (2.0)	40 (6.33)	27.2 (5.22)	60.8
Sulfosulfuron	0.025	AFI	2 (1.41)	1(1)	7 (2.67)	5 (2.24)		1 (1)			3 (1.72)	20 (4.46)	14.1(3.75)	79.4
Isoproturon + 2,4-D	0.75 + 0.5	AFI	5(2.24)	5(2.23)	16 (4.1)	1 (1)					3 (1.73)	31(5.57)	20.6(4.54)	69.6
One HW		30 DAS	6(2.45)	6(2.44)	6 (2.45)	9 (3.0)	2 (1.42)	2 (1.41)	3 (1.74)	1 (1)	5 (2.24)	35(5.93)	14.4(3.76)	65.7
Two HW		30 and 45 DAS			3 (1.73)	2 (1.41)					2 (1.41)	7(2.67)	5.4 (2.32)	93.1
Weedy			26(5.1)	8(2.82)	19 (4.37)	15 (3.86)	4 (2.0)	6 (2.45)	7 (2.66)	2 (1.42)	15(3.88)	102(10.11)	86.7(9.32)	
SEm±												1.50	1.83	
CD (P=0.05)												3.23	3.92	

HW, Hand weeding; DAS, days after sowing; BFI, before first irrigation; AFI, after first irrigation

Table 2 Effect of weed control treatments on growth and yield attributes of wheat under zero-tillage system

Treatment	Dose (kg/ha)	Time of application	Plant height (cm) at 80 DAS		No of leaf/ running meter at 80 DAS		Crop dry weight/ running meter at 80 DAS		No. of effective tillers/running meter		Panicle lenght (cm)		Grains// panicle		Test weight (g)	
			Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
Metribuzin	0.21	BFI	78.2	85.3	203	221	151	165	78	85	6.9	7.5	37.1	40.4	31.8	34.7
Metribuzin	0.21	AFI	81.1	88.4	214	233	163	178	88	96	7.2	7.8	42.0	45.8	36.0	39.2
Sulfosulfuron	0.025	BFI	80.0	87.2	205	223	157	171	82	89	7.0	7.6	40.0	43.6	34.2	37.3
Sulfosulfuron	0.025	AFI	87.3	95.2	226	246	173	189	101	110	7.6	8.3	47.8	52.1	42.3	46.1
Isoproturon + 2,4-D	0.75 + 0.5	AFI	83.4	90.9	218	237	168	183	97	106	7.3	7.9	45.7	49.8	38.5	41.9
One HW		30 DAS	88.0	95.9	223	243	172	187	100	109	7.5	8.2	46.6	50.8	41.0	44.9
Two HW		30 and 45 DAS	92.3	100.6	239	260	179	195	108	118	8.0	8.7	50.8	55.4	46.2	50.4
Weedy			73.0	79.6	153	166	116	126	70	76	6.3	6.9	32.6	35.5	29.3	31.9
SEm±			0.91	0.96	1.9	2.1	0.58	0.63	0.53	0.58	0.08	0.09	0.32	0.39	0.24	0.26
CD (P=0.05)			1.95	2.13	4.1	4.45	1.25	1.36	1.12	1.22	0.17	0.19	0.68	0.74	0.51	0.56

Y_1, 2003–04; Y_2, 2004–05; HW, Hand weeding; DAS, days after sowing; BFI, before first irrigation; AFI, after first irrigation

Table 3 Effect of weed control treatments on protein, yield and economics of wheat

Treatment	Dose (kg/ha)	Time of application	Protein (%)		Protein yield (kg/ha)		Grain yield (tonnes/ha)		Straw yield (tonnes/ha)		Harvest Index (%)		Cost of cultivation (Rs/ha)		Net returns (Rs/ha)		B:C ratio	
			Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
Metribuzin	0.21	BFI	11.3	12.3	280	305.2	2.49	2.71	4.39	4.79	36.2	39.5	14 327	14 827	3 801	5 402	1.30	1.36
Metribuzin	0.21	AFI	11.9	13.0	341	371.7	2.87	3.13	4.63	5.05	38.3	41.7	14 327	14 827	6 367	7 968	1.44	1.54
Sulfosulfuron	0.025	BFI	11.7	12.8	313	341.2	2.68	2.92	4.40	4.80	37.8	41.2	15 865	16 365	3 486	5 087	1.22	1.31
Sulfosulfuron	0.025	AFI	12.5	13.6	405	441.5	3.24	3.53	4.74	5.17	40.1	43.7	15 865	16 365	7 239	8 835	1.46	1.54
Isoproturon + 2,4-D	0.75 + 0.5	AFI	12.3	13.4	365	397.9	3.00	3.27	4.66	5.08	39.1	42.6	13 967	14 467	7 564	9 165	1.54	1.63
One HW		30 DAS	12.2	13.3	383	417.5	3.10	3.38	4.71	5.13	39.9	43.5	15 690	16 190	6 504	8 105	1.41	1.50
Two HW		30 and 45 DAS	12.6	13.7	462	503.6	3.66	3.99	5.46	5.95	40.6	44.3	17 690	18 190	8 465	10 066	1.48	1.55
Weedy			10.9	11.9	227	247.4	2.08	2.27	3.97	4.33	34.4	37.5	13 690	14 190	1 606	3 207	1.12	1.23
SEm±			0.30	0.32	6.40	6.90	0.11	0.12	0.26	0.29	0.16	0.18						
CD (P=0.05)			0.66	0.70	15.1	16.5	0.23	0.25	0.56	0.61	0.36	0.40						

Y_1, 2003–04; Y_2, 2004–05; HW, Hand weeding; DAS, days after sowing; BFI, before first irrigation; AFI, after first irrigation

to sulfosulfuron (0.025 kg/ha after first irrigation) and isoproturon + 2, 4-D (0.75 + 0.5 kg/ha after first irrigation) might be due to re-growth and resurgence of weed in new flushes after its removal at 30 days after sowing. The maximum density and dry biomass of weeds were recorded with the application of metribuzin (before first irrigation) and sulfosulfuron (before first irrigation), because at that time only perennial weeds were present and seasonal weeds were germinated after first irrigation which was not controlled successfully by these herbicides. Weed control efficiency varied from 46.1 to 93.1% under different weed control treatments. Among herbicidal treatments, highest weed control efficiency (79.4%) was also recorded under sulfosulfuron after first irrigation treated plots, followed by isoproturon + 2, 4-D-after first irrigation,1 hand weeding and metribuzin after first irrigation respectively (Table 1). Hand weeding twice at 30 and 45 days after sowing significantly reduced dry biomass of weed with maximum weed control efficiency (93.1%) over other weed control treatments.

Growth, yield attributes and yield were significantly affected due to different weed control treatments over the weedy check (Tables 2, 3). Among the herbicidal treatments, sulfosulfuron after first irrigation significantly increased the plant height, number of leaf/running meter and crop dry weight/running meter, effective tillers/running meter, spike length, number of grains/spike, 1 000 grain weight, grain yield, straw yield and harvest index compared with weedy check and other herbicidal treatments mainly due to its broad-spectrum control of weeds. The increase of these attributes under sulfosulfuron (0.025 kg/ha after first irrigation) by 16.4, 32.3, 32.9, 30.4, 16.6, 31.8, 30.7, 35.8, 16.3 and 14.3% in 2003–04 and 17.9, 35.2, 35.9, 33.1, 18.2, 34.7, 33.5, 35.7, 16.2 and 15.6% in 2004–05 respectively, over weedy check. Application of isoproturon + 2, 4-D-AFI and metribuzin-after first irrigation and 1 hand weeding at 30 days after sowing significantly increase the growth, yield attributes and yield of wheat compared with metribuzin before first irrigation and sulfosulfuron. Hand weeding twice at 30 and 45 days after sowing recorded maximum growth and yield attributes which resulted higher grain yield of wheat (3.66 and 3.99 tonnes/ha) and were higher by 43.2 and 47.1% over weedy check. Maximum yield attributes and yield were recorded under hand weedings during both crop seasons due to lower crop-weed competition. These facts have conformity with the findings of Pandey *et al*. (2006). Among the herbicides, maximum protein content and protein yield was obtained with the application of sulfosulfuron-AFI over other herbicidal treatments and one hand weeding. Highest protein content (12.62%) and protein yield (461 kg/ha) recorded under hand weeding twice at 30 and 45 days after sowing might be owing to better uptake and utilization of nutrients and under favourable condition plant absorbed more nitrogen to convert it into amino acids. Pandey *et al*. (2006) reported 3.18 and 3.34% increase in grain protein content in wheat under weed-control treatment over weedy check.

The maximum NPK depletion by weeds was recorded under the weedy check (Table 4). This might be due to higher production of dry biomass of weeds. Among the weed control treatments, lowest depletion of nutrients was recorded under sulfosulfuron (0.025 kg/ha) applied after first irrigation, which was significantly superior in minimizing the nutrient loss compared to herbicidal treatments and one hand weeding. The NPK depletion by weeds was lower under sulfosulfuron (0.025 kg/ha after first irrigation) by 63.3, 62.2 and 63.2% over the weedy check. Application of metribuzin (0.21 kg/ha) before first irrigation recorded the maximum and significantly higher NPK depletion by weeds which was 47.5, 51.7 and 56.6% and 37.0, 29.8 and 46.3% higher than

Table 4 Effect of weed control treatments on nutrient uptake by wheat and weeds

Treatment	Dose (kg/ha)	Time of application	Nutrient uptake by wheat (kg/ha)						Nutrient uptake by weed (kg/ha)					
			N		P		K		N		P		K	
			Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
Metribuzin	0.21	BFI	70.4	74.6	19.2	20.3	53.5	56.0	5.49	5.98	3.29	3.59	5.21	5.68
Metribuzin	0.21	AFI	82.4	87.3	23.3	24.5	59.2	61.6	5.22	5.69	3.10	3.38	4.90	5.34
Sulfosulfuron	0.025	BFI	73.6	75.6	21.1	22.3	56.7	58.5	5.25	5.72	3.13	3.41	4.89	5.33
Sulfosulfuron	0.025	AFI	95.1	100.9	28.3	30.0	67.3	69.5	2.88	3.14	1.59	1.73	2.52	2.75
Isoproturon + 2,4-D	0.75 + 0.5	AFI	87.4	92.7	26.9	27.5	62.8	64.7	3.46	3.77	2.31	2.52	3.56	3.88
One HW		30 DAS	91.4	97.1	27.0	28.6	65.7	68.0	3.2	3.49	1.87	2.04	2.80	3.05
Two HW		30 and 45 DAS	111.6	118.3	34.5	36.6	80.8	84.0	1.23	1.34	0.66	0.72	1.06	1.16
Weedy			55.7	59.0	15.1	16.0	44.6	46.1	14.97	16.32	8.19	8.93	14.14	15.41
SEm±			2.02	2.30	0.36	0.37	1.26	1.29	0.12	0.18	0.19	0.23	0.58	0.62
CD (*P*=0.05)			4.46	4.79	0.78	0.79	2.69	2.74	0.26	0.40	0.43	0.53	1.23	1.34

Y_1, 2003–04; Y_2, 2004–05; HW, Hand weeding; DAS, days after sowing; BFI, before first irrigation; AFI, after first irrigation

sulfosulfuron after first irrigation (0.025 kg/ha) and isoproturon + 2, 4-D (0.75 + 0.5 kg/ha after first irrigation). Hand weeding twice at 30 and 45 days after sowing significantly reduced the NPK depletion by weeds over all the weed control treatments. Reduction in dry biomass of weeds might be the reason for lower nutrient depletion under these treatments. Results have conformity with the findings of Mishra (2006).

Among the weed control methods, hand weeding twice at 30 and 45 DAS recorded the maximum and significantly higher NPK uptake than herbicidal treatments (Table 4). The increase in the N, P and K uptake under hand weeding twice at 30 and 45 days after sowing was by 50.5, 56.8 and 52.2% in 2003–04 and 55.0, 61.9 and 56.9% in 2004–05 over weedy check. Among the herbicidal treatments, maximum NPK uptake by crop was recorded under sulfosulfuron after first irrigation which was 9.7,4.8 and 8.7% in 2003–04 and 10.6, 5.2 and 9.5% in 2004–05 higher than isoproturon + 2, 4-D-AFI and 15.8, 20.3 and 13.8% in 2003–04 and 17.2, 22.1 and 15.0% in 2004–05 higher than the metribuzin after first irrigation. Increase the nutrient uptake by crop under sulfosulfuron-AFI was due to effective control of weeds resulted higher biomass production and hence, higher uptake in grain and straw (Pandey *et al*. 2007).

All the weed control treatments recorded higher net returns and benefit : cost ratio than weedy check (Table 3). Maximum net returns (Rs 8 465 and 10 066) observed under hand weeding twice at 30 and 45 days after sowing, which was due to higher grain yield than herbicidal treatments. Among the herbicidal treatments, isoproturon + 2, 4-D-AFI recorded the maximum net returns (Rs 7 564 and 9 165) and benefit : cost ratio (1.54 and 1.63), followed by sulfosulfuron-AFI and one hand weeding. The higher net returns and benefit : cost ratio under isoproturon + 2, 4-D was due to lower cost of herbicides. The lower benefit : cost ratio under 2 hand weedings and sulfosulfuron-treated plots due to higher cost investment.

SUMMARY

A field experiment was conducted during winter (*rabi*) season of 2003–04 and 2004–05 at agronomy research farm, BHU, Varanasi, to study the bio-efficacy and selectivity of sulfosulfuron and metribuzin before and after irrigation in wheat (*Triticum aestivum* L. emend. Fiori & Paol.) under zero-tillage system. Eight weed control treatments, viz metribuzin 0.21 kg/ha before first irrigation (BFI), metribuzin 0.21 kg/ha after first irrigation (AFI), sulfosulfuron 0.025 kg/ha BFI, sulfosulfuron 0.025 kg/ha AFI, isoproturon + 2, 4-D 0.75 + 0.5 kg/ha AFI, 1 hand weeding at 30 days after sowing (DAS), 2 hand weedings at 30 and 45 days after sowing and weedy check were tested in randomized block design with 3 replications. Sulfosulfuron (AFI) significantly reduced weed density, dry weight and NPK depletion by weeds with maximum weed control efficiency (79.4%) and improve the NPK uptake by crop which cause significant impact on crop growth and yield attributes which resulted higher grain yield (3.24 and 3.53 tonnes/ha), being at par with that of one hand weeding at 30 days after sowing. Isoproturon + 2, 4-D (AFI) significantly reduced density and dry weight of weeds over metribuzin (BFI) and sulfosulfuron (BFI) and it was at par with metribuzin (AFI) and 1 hand weeding. Among the herbicidal treatments, maximum net returns (Rs 7 564 and 9 165/ha) and benefit : cost ratio (1.54 and 1.63) were recorded under isoproturon + 2, 4-D (AFI). Hand weeding twice at 30 and 45 DAS recorded significantly higher yield attributes, grain yield, nutrients uptake with maximum weed control efficiency, net returns and benefits : cost ratio over all other weed control treatments.

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