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Efficacy of herbicides applied alone and in tank mixture with isoproturon against wild oat (*Avena ludoviciana*) and broad-leaf weeds in wheat (*Triticum aestivum*)

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ABSTRACT

An investigation was conducted during winter seasons of 1996–97 and 1997–98 at Gurdaspur, Punjab, on fields heavily infested with broad-leaf of weeds. An application of metribuzin (0.175 kg/ha) or pendimethalin (0.7 kg/ha) alone or tank mixture of isoproturon + metribuzin (0.75 + 0.131 kg/ha), isoproturon + atrazine (0.75 + 0.094 kg/ha) or isoproturon + 2, 4-D (0.94 + 0.5 kg/ha) provided effective control of broad-leaf weeds in wheat (*Triticum aestivum* L. emend. Fiori & Paol.) Application of 2, 4-D or diclofopmethyl/tralkoxydim alone was not effective against broad-leaf weeds, especially *Medicago denticulata* Willd., *Lathyrus aphaca* L. and *Vicia sativa* L. However, diclofopmethyl or tralkoxydim alone in tank mixture with isoproturon effectively controlled wild oat. Isoproturon + atrazine and isoproturon + 2, 4-D recorded the lowest dry matter of weeds in the first and second year respectively. The maximum weed density and dry matter of weeds were recorded in weedy check. Application of metribuzin (0.175 kg/ha) resulted in the maximum grain yield which was at par with tank mix application of isoproturon + metribuzin, isoproturon + atrazine, isoproturon + 2,4-D, isoproturon and pendimethalin, whereas weedy check resulted in the minimum grain yield. The maximum net returns were obtained with metribuzin (0.175 kg/ha) application, followed by isoproturon + metribuzin. However, maximum benefit : cost ratio was registered with atrazine applied @ 0.094 kg/ha. Diclofopmethyl resulted in the lowest net returns and benefit : cost ratio.

Key words : Chemical weed control, Broad-leaf weeds, Wild oat, Wheat

In areas where varied weed situations exist and no single herbicide is effective in giving desirable control, using herbicide mixture can prove to be a boon. Isoproturon can be tank mixed with number of herbicides and thus provides an opportunity to control broad spectrum of weeds. With these objectives, the present investigation was conducted to study the relative efficacy of different herbicides applied alone and

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their tank mixture with isoproturon against weeds and to work out the economics of application of such herbicides.

MATERIALS AND METHODS

The field investigation was conducted during winter seasons of 1996–97 and 1997–98, at Regional Research Station, Punjab Agricultural University, Gurdaspur. The soil of the experimental field was loamy sand in texture, neutral in reaction (pH, 7.1) and tested low in organic carbon (0.39%), medium in available phosphorus (18.0 kg/ha) and low in available potassium (100 kg/ha). Fourteen treatments replicated thrice were laid out in randomized block design. Details of treatments are given in Table 1. During the first year, diclofop-methyl (0.875 kg/ha) was used and during the second year, it was replaced with tralkoxydim (0.35 kg/ha). Application of herbicides was made with knapsack sprayer fitted with flat-fan nozzle using 500 litres/ha water.

Wheat variety 'PBW 343' was sown on 19 November in both years using recommended seed rate (100 kg/ha) and doses of NPK (125 kg N, 62.5 kg P_2O_5 and 30 kg P_2O_5/ha). Half dose of N and full of P and K were drilled at sowing, while the remaining N was applied after the first irrigation. All other recommended agronomic practices were followed. Three irrigations were applied in each year and well-distributed rainfall of 368 and 546 mm was received during crop-growth period during 1996–97 and 1997–98 respectively. Gross and net plot size was 6.0 m × 1.61 m and 5.0 m × 1.15 m respectively.

Number of wild oat *(Avena ludoviciana)* and broad-leaf weeds (species-wise) were counted separately from 0.5 m × 0.5 m quadrate 60 days after sowing and at harvest. Similarly, final weeds dry matter (of both grassy and broad-leaf weeds) was recorded at harvest using the quadrate of same size. Data of number of weeds were subjected to square-root transformation before statistical analysis. The crop was harvested in the first week of May in both years.

RESULTS AND DISCUSSION

Weed flora

The experimental field was heavily infested with natural population of broad-leaf weeds. The dominant weeds were *Anagallis arvensis* L. (68.9%), *Lepidium sativum* L. (11.4%), *Medicago denticulata* Willd. (11,4%), *Vicia sativa* L. (3.0%) and *Lathyrus aphaca* (2.5%). Among grassy weeds, *Avena ludoviciana* Dur. (3.1%) was present.

Weed density

Different herbicides applied alone (except 2, 4-D and diclofopmethyl or tralkoxydim) or in tank mixture with isoproturon significantly controlled the broad-leaf weeds as compared weedy check throughout growth period in both the years (Table 1). Higher dose of metribuzin (0.175 kg/ha) in 1996–97 recorded the lowest population of broad-leaf weeds which was significantly superior to diclofopmethyl, 2, 4-D, isoproturon + diclofop-methyl (0.75 + 0.875 kg/ha) and weedy check at 60 days and also isoproturon (0.94 kg/ha), atrazine (0.125 kg/ha) and isoproturon + atrazine at harvest. However

Table 1. Effect of herbicides on population of weeds (number/m²) infesting wheat at different growth stages

Herbicides	Dose (kg/ha)	Broad-leaf weeds						Wild oat					
		60 DAS			At harvest			60 DAS			At harvest		
		1996–97	1997–98	Mean	1996–97	1997–98	Mean	1996–97	1997–98	Mean	1996–97	1997–98	Mean
Isoproturon	0.940	2.34 (3.0)	5.40 (29.3)	3.87 (17.6)	2.27 (5.3)	3.07 (10.7)	2.67 (8.0)	1.14 (0.3)	1.14 (0.3)	1.14 (0.3)	1.83 (2.7)	1.52 (1.3)	1.67 (2.0)
Metoxuron	1.500	2.05 (5.0)	5.32 (28.7)	3.69 (16.9)	2.06 (4.3)	4.54 (20.7)	3.30 (12.5)	1.52 (1.3)	2.10 (3.7)	1.81 (2.5)	1.38 (1.0)	1.80 (2.3)	1.59 (1.7)
Pendimethalin	0.750	2.29 (5.3)	3.44 (12.0)	2.86 (8.70)	1.88 (4.0)	3.16 (10.0)	2.52 (7.0)	1.49 (1.3)	1.93 (3.0)	1.70 (2.2)	1.90 (3.0)	1.66 (2.0)	1.77 (2.5)
2, 4-D	0.500	8.04 (65.7)	8.49 (73.7)	8.26 (69.7)	4.24 (18.7)	4.26 (19.0)	4.25 (19.4)	1.49 (1.3)	2.46 (5.3)	1.97 (3.3)	2.69 (6.3)	1.61 (1.61)	2.15 (2.15)
Metribuzin	0.131	1.47 (2.3)	3.46 (14.0)	2.47 (8.2)	1.88 (3.7)	2.79 (8.70)	2.34 (6.2)	1.14 (0.3)	1.27 (0.7)	1.20 (0.5)	2.47 (5.3)	1.49 (103)	1.97 (3.3)
Metribuzin	0.175	1.33 (2.0)	3.00 (9.0)	2.00 (5.5)	1.27 (1.7)	2.64 (7.0)	1.95 (4.4)	1.00 (0.0)	1.93 (3.0)	1.46 (1.5)	2.54 (6.7)	1.52 (1.3)	2.03 (4.0)
Atrazine	0.094	2.51 (6.7)	6.58 (4.3)	4.55 (25.0)	2.09 (5.0)	5.19 (27.0)	3.64 (16.0)	1.14 (0.3)	2.52 (5.7)	1.83 (3.0)	2.38 (5.7)	1.73 (2.0)	2.05 (3.8)
Atrazine	0.125	2.92 (8.7)	9.13 (84.7)	6.03 (46.7)	2.92 (8.70)	5.00 (28.3)	4.08 (17.5)	1.75 (1.71)	2.37 (4.7)	2.06 (3.2)	2.51 (5.3)	1.69 (2.0)	2.00 (3.7)

Table 1. Continued

Herbicides	Dose (kg/ha)	Broad-leaf weeds						Wild oat					
		60 DAS			At harvest			60 DAS			At harvest		
		1996–97	1997–98	Mean	1996–97	1997–98	Mean	1996–97	1997–98	Mean	1996–97	1997–98	Mean
Diclofopmethyl	0.875	8.64	12.6	10.6	5.99	5.70	5.85	1.00	1.73	1.36	1.00	1.52	1.25
		(75.0)	(161.3)	(18.2)	(36.7)	(33.0)	(34.9)	(0.0)	(2.3)	(1.2)	(0.0)	(1.3)	(0.7)
Isoproturon + metribuzin	0.750 0.131	1.87	1.75	1.81	1.33	1.55	1.44	1.27	1.0	1.13	2.58	1.27	1.93
		(5.0)	(3.3)	(4.1)	(2.0)	(3.0)	(2.50)	(0.7)	(0.0)	(0.3)	(5.7)	(0.7)	(3.2)
Isoproturon + atrazine	0.750 0.094	2.32	1.66	1.99	2.80	2.23	2.51	1.52	1.14	1.32	2.37	1.27	1.82
		(6.3)	(3.0)	(4.7)	(8.0)	(6.30)	(7.1)	(1.3)	(0.3)	(0.8)	(5.7)	(0.7)	(3.2)
Isoproturon + dislofopmethyl	0.750 10.875	5.21	7.54	6.37	3.79	3.58	3.69	1.00	1.47	1.23	1.00	1.52	1.25
		(31.7)	(59.7)	(45.7)	(15.3)	(13.7)	(14.5)	(0.0)	(1.3)	(0.7)	(0.0)	(1.3)	(0.7)
Isoproturon + 2, 4-D	0.940 0.500	1.69	3.97	2.83	2.19	1.73	1.95	1.00	1.69	1.34	1.48	1.38	1.43
		(94.7)	(151.0)	(122.8)	(30.0)	(32.9)	(32.9)	(2.3)	(8.7)	(5.5)	(1.7)	(1.0)	(1.3)
Weedy check		9.55	12.3	10.9	5.45	5.94	5.69	1.61	3.10	2.36	3.31	1.49	2.40
		(94.7)	(151.0)	(122.8)	(30.0)	(32.9)	(32.9)	(2.3)	(8.7)	(2.36)	(11.7)	(1.3)	(6.5)
CD (P = 0.05)		1.83	1.68	1.28	0.94	1.17	0.79	NS	0.76	NS	1.11	NS	NS

Values in parentheses are the original ones
DAS, Days after sowing

in 1997–98, tank mixture of lower doses of isoproturon + metribuzin (0.75 + 0.131 kg/ha) and isoproturon + atrazine (0.75 + 0.125 kg/ha) recorded significantly lower population of broad-leaf weeds than weedy check, application of tralkoxydim or diclofopmethyl, 2, 4-D, isoproturon, metoxuron, metribuzin (0.131 kg/ha) and atrazine (0.094 and 0.125 kg/ha) at 60 days, whereas at harvest, tank mixture of isoproturon + metribuzin gave significantly lower population of broad-leaf weeds than other treatments except metribuzin (0.175 kg/ha), isoproturon + 2,4-D (0.94 + 0.50 kg/ha) and isoproturon + atrazine (0.75 + 0.094 kg/ha). The maximum weed density during both years was recorded under weedy check. Population of broad-leaf weeds in weedy check and with application of diclofopmethyl was virtually the same. From the mean data of 2 years, it can be inferred that tank mixture of isoproturon + metribuzin (0.75 + 0.131 kg/ha) controlled the broad-leaf weeds at 60 days to the maximum extent and this treatment was at par with tank mixture of isoproturon + atrazine (0.75 + 0.125 kg/ha), isoproturon + 2,4-D (0.94 + 0.5 kg/ha), pendimethalin (0.75 kg/ha) and metribuzin (0.131 or 0.175 kg/ha) but significantly better than rest of the treatments. Better control of broad-leaf weeds with isoproturon, 2, 4-D and tank mixture of isoproturon + 2,4-D was reported Balyan and Malik (1988), Singh and Malik (1994) and Dixit and Bhan (1997). However, at harvest, only metribuzin (0.175 kg/ha) and isoproturon + 2,4-D could give control of broad-leaf weeds (mean of 2 years) similar to that of isoproturon + metribuzin (0.75 + 0.131 kg/ha).

Different herbicides except 2, 4-D or diclofopmethyl applied alone or isoproturon + diclofopmethyl or tralkoxydim (0.75 + 0.875/0.35 kg/ha) effectively controlled *Anagallis arvensis* over weedy check. Likewise, except 2,4-D, pendimethalin, atrazine (0.125 kg/ha) and diclofopmethyl, all other herbicides effectively controlled *Medicago denticulata.* Similarly, *Lepidium sativum* was effectively controlled by different herbicides except atrazine and diclofopmethyl. Application of 2, 4-D and diclofopmethyl provided the least effective control of *Vicia sativa.* Singh *et al.* (1993) reported effective control of different broad-leaf weeds with isoproturon, 2, 4-D atrazine, metribuzin and pendimethalin. Control of *Anagallis arvensis* and *Melilotus indica* with metribuzin has also been reported in pea + Indian mustard intercropping system (Tewari *et al.*, 1997)

Post-emergence application of diclofopmethyl or tralkoxidim, isoproturon and tank mixture of isoproturon + diclofopmethyl or tralkoxydim effectively controlled *Avena* sp. However, pendimethalin, 2,4-D isoproturon + metribuzin and isoproturon + atrazine were not effective against *Avena* population. Gill and Mehra (1981) and Gill and Walia (1988) reported similar control of *Avena* sp. with diclofopmethyl and tralkoxydim. Similarly, control of *Avena* sp. in wheat with isoproturon was reported by Balyan *et al.* (1993)

The maximum dry weight of weed was recorded in case of weedy check in both years (Table 2). The mean dry matter of weeds in weedy check was similar to that obtained with application of diclofopmethyl

Table 2. Effect of herbicides on final dry matter of weeds, yield attributes, grain and straw yields of wheat

Herbicides	Dose (kg/ha)	Weeds dry matter (q/ha)			Spikes/running (m)			1,000-grain weight (g)			Grain yield (q/ha)			Straw yield (q/ha)		
		1996–97	1997–98	Mean	1996–97	1997–98	Mean	1996–97	1997–98	Mean	1996–97	1997–98	Mean	1996–97	1997–98	Mean
Isoproturon	0.940	3.33	3.73	3.53	42.4	40.4	41.4	39.8	45.5	42.6	34.8	33.6	34.2	57.4	62.0	59.7
Metoxuron	1.500	4.53	8.47	6.50	42.3	33.7	38.0	41.0	42.1	41.5	32.6	26.4	29.5	54.3	49.0	51.7
Pendimethalin	0.75	4.60	5.73	5.16	44.0	34.3	39.2	41.7	44.1	42.9	35.5	31.6	33.6	60.2	58.3	59.2
2, 4-D	0.50	6.13	10.53	8.33	42.6	34.1	38.3	40.3	45.9	43.1	29.7	21.7	25.7	57.9	40.3	49.1
Metribuzin	0.131	3.33	6.47	4.90	42.1	41.1	41.6	42.6	42.8	42.7	33.1	34.2	33.6	56.2	58.0	57.1
Metribuzin	0.175	4.67	3.00	3.84	43.5	37.3	40.4	40.2	47.0	43.6	35.8	36.5	36.2	56.4	60.9	58.7
Atrazine	0.094	3.53	8.13	5.83	42.6	32.3	37.5	39.2	44.5	41.9	34.5	25.5	30.0	55.9	48.7	52.3
Atrazine	0.125	7.13	5.60	6.36	40.1	32.5	36.3	39.7	43.8	41.8	30.1	24.1	27.1	54.5	46.7	50.6
Diclofopmethyl	0.875	14.26	11.87	13.07	43.7	30.0	36.8	39.9	39.1	39.5	25.1	19.9	22.5	50.9	38.8	44.9
Isoproturon + metribuzin	0.750 0.131	4.87	1.67	3.27	45.9	38.6	42.3	40.4	42.1	41.3	36.7	34.5	35.5	64.8	60.3	62.6
Isoproturon + atrazine	0.750 0.094	4.07	1.00	2.54	40.3	40.0	40.1	41.5	45.4	43.4	34.5	36.0	35.2	58.8	60.9	59.8
Isoproturon + diclofopmethyl	0.750 0.875	7.93	4.13	6.03	40.0	36.8	38.4	42.6	46.0	44.3	34.1	30.4	32.3	55.8	55.4	55.6
Isoproturon + 2, 4-D	0.940 0.500	3.87	1.33	2.60	44.6	49.0	46.8	40.5	40.5	40.5	31.0	33.3	32.2	50.8	55.4	55.6
Weedy check		11.40	15.87	13.65	36.8	27.4	32.1	39.1	44.1	41.6	26.6	18.0	22.3	49.8	36.5	43.2
CD (P = 0.05)		4.69	4.57	3.15	NS	6.2	5.0	NS	2.6	2.2	6.2	4.3	4.2	NS	9.7	8.1

applied alone but was significantly higher than rest of the treatments. All the herbicides recorded significantly lower dry weight of weeds than weedy check in both years except atrazine (0.125 kg/ha) and isoproturon + diclofopmethyl (0.75 + 0.875 kg/ha) in 1996–97. Likewise, all the herbicides were more effective in reducing weeds dry weight than diclofopmethyl in both the years except metoxuron and 2, 4-D applied alone in 1997–98. The mean dry weight of weeds was the lowest in isoproturon + atrazine, closely followed by isoproturn + 2, 4-D.

Effect of crop

The maximum number of spikes/m in 1997–98 and in pooled data were recorded with isoproturon + 2,4-D, whereas weedy check registered the minimum number of spikes/m. Grain yield with application of isoproturon + metribuzin (0.75 + 0.131 kg/ha) in 1996–97 and with metribuzin alone (0.175 kg/ha) in 1997–98 and in the pooled data was the maximum, while the lowest grain yield was obtained from diclofopmethyl in 1996–97 and from weedy check in 1997–98. Consequently, in the pooled data, weedy check registered the lowest grain yield. Better control of broad-leaf weeds obtained with the application of metribuzin alone or through tank mixture of isoproturon with metribuzin or 2, 4-D or atrazine resulted in higher grain yield of wheat. Sharma *et al.* (1987), Malik *et al.* (1989) and Dixit and Bhan (1997) reported similar results. Since diclofopmethyl or tralkoxydim was not effective against broad-leaf weeds and provided effective control of only *Avena* sp. (Gill and Walia, 1988; Malik *et al.*, 1989; Katyal *et al.*, 1997), grain yield with diclofopmethyl or tralkoxydim alone was not better than weedy check in both the years.

The pooled mean data (Table 2) indicated that the maximum grain yield was obtained with metribuzin (0.175 kg/ha), being at par with tank mix application of isoproturon with other herbicides, isoproturon (0.94 kg/ha), pendimethalin (0.75 kg/ha) and metribuzin (0.131 kg/ha). Similarly, the maximum straw yield in 1997–98 and in the mean data was obtained with application of isoproturon and isoproturon + metribuzin, respectively, whereas weedy check registered the lowest straw yield, which was closely followed by diclofopmethyl .

Although isoproturon + metribuzin (0.75 + 0.131 kg/ha) gave the maximum total income, followed by metribuzin (0.175 kg/ha) application alone, reverse trend was observed for net returns. While weedy check recorded the minimum gross income, the lowest mean net income was obtained with application of diclofopmethyl or tralkoxydim thus incurring a net loss of Rs 1,207/ha or Re 0.8/rupee invested compared with weedy check. Except diclofopmethyl or tralkoxydim, herbicide application was quite remunerative as is evident from benefit : cost ratio (Table 3). All the herbicides except isoproturon + diclofopmethyl and pendimethalin, gave benefit : cost ratio of more than 10. Although net returns were higher with metribuzin applied alone or in combination with isoproturon, the maximum benefit : cost ratio was obtained with atrazine applied alone at 0.094 kg/ha (85.3), followed by its application at 0.125 kg/ha (43.5). This was

Table 3. Economics and benefit : cost ratio of different herbicides applied to wheat (mean data of 2 years)

Herbicides	Dose (kg/ha)	Cost of herbicide	Total income (Rs/ha)	Net income (Rs/ha)	Benefit : cost ratio
Isoproturon	0.940	362.5	21,469	21,106	18.9
Metoxuron	1.500	375.0	18,390	18,015	10.0
Pendimethalin	0.75	1,000.0	21,059	20,059	5.8
2, 4-D	0.50	118.7	16,400	16,280	17.0
Metribuzin	0.131	350.6	20,982	20,631	18.2
Metribuzin	0.175	468.7	22,227	21,757	16.0
Atrazine	0.094	50.4	18,607	18,557	85.3
Atrazine	0.125	67.0	17,242	17,175	43.5
Diclofopmethyl	0.875	1,500.0	14,551	13,051	-0.8
Isoproturon + metribuzin	0.750 0.131	640.6	22,349	21,708	11.6
Isoproturon + atrazine	0.750 0.094	340.4	21,993	21,652	21.7
Isoproturon + diclofopmethyl	0.750 10.875	1790.0	20,092	18,302	2.2
Isoproturon + 2, 4-D	0.940 0.500	481.7	19,848	19,366	10.6
Weedy check			1,4258	14,258	

due to very low cost of atrazine (Rs 268/kg). The profit margin benefit : cost drastically decreased in spite of higher net return in case of metribuzin because of its high cost (Rs 1,875/kg). Diclofopmethyl incurred loss due to ineffective control of broad-leaf weeds by it and its cost (Rs 480/kg).

Thus broad-leaf weeds in wheat can be effectively controlled with the application of metribuzin, isoproturon, pendimethalin or tank mixture of isoproturon with different herbicides. Diclofopmethyl and tralkoxydim provide effective control of *Avena* sp. infesting wheat crop.

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