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Effect of Different Herbicides Alone and in Mixture on the Control of Isoproturon-Resistant and Susceptible Populations of *Phalaris minor*

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ABSTRACT

Isoproturon at 1.0 kg, metoxuron at 1.6 kg and methabenzthiazuron 1.4 kg ha^{-1} applied at 3-leaf stage provided more than 80% control of both susceptible (S) biotypes (R1 and H2) of *P. minor;* however, these herbicides were ineffective against resistant (R) biotypes (H3, KR1 and UP1) even at higher doses. Mon-48549 at 25 and 50 g, and Foe-5043 at 300 and 600 g ha^{-1} also did not control this weed satisfactorily. Performance of diclofop and metribuzin was also erratic against R and S biotypes. Clodinafop at 60 g, fenoxaprop at 120 g, sulfosulfuron at 25 g and tralkoxydim at 350 g ha^{-1} applied at 3-leaf stage resulted in 82-95% reduction in the dry weight of R as well as S biotypes of *P. minor.* Metribuzin at 200 and 400 g ha^{-1}, and Mon-48549 at 25 and 50 g ha^{-1} caused 15 to 30% phytotoxicity to wheat. Metribuzin either alone or in mixture caused phytotoxicity to wheat crop without adding to weed control efficiency (WCE).

INTRODUCTION

Evolution of resistance in littleseed canary grass (*Phalaris minor* Retz.) against isoproturon in 1992-93 in wheat was considered as one of the most serious cases of herbicide resistance in the world resulting in total crop failure under heavy infestation (Malik and Singh, 1993, 1995). Since after reporting this problem, many biotypes of *P. minor* were subjected to resistance screening and found to require 2-11 times more dose of isoproturon compared to prestine populations to cause 50% reduction in their growth (Malik and Singh, 1995; Malik and Yadav, 1997; Yadav *et al.,* 1997). Hence, existing recommendation of isoproturon against *P. minor* was replaced in 1997 by four new herbicides (clodinafop, fenoxaprop, sulfosulfuron and tralkoxydim) in resistance-affected areas of rice-wheat cropping system. These new herbicides are comparatively 3-4 times costly than isoproturon and also future of alternate herbicides is not a sure one-way bet, and hence, continuous research efforts are required to find out other comparatively more cost effective herbicides used either alone or in mixture having different modes of action. The proper growth stage of a particular weed at the time of spray is also important in determining the effectiveness of any herbicide. Keeping these points in view, the present investigation was undertaken.

MATERIALS AND METHODS

To evaluate the bio-efficacy of different herbicides alone and in combination, and also to study the impact of stage of application of herbicides against resistant (R) and susceptible (S) populations of *Phalaris minor,* four separate field experiments were conducted during 1998-99 and 1999-2000 at Research Farm of CCS Haryana Agricultural University (CCSHAU), Hisar, India. The soil of the experimental field was sandy loam in

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Table 1. Effect of different herbicides applied at 3-leaf stage on the dry weight of R and S biotypes of *P. minor*, and phytotoxicity on wheat at 21 days after spray

Herbicide	Dose ($g\ ha^{-1}$)	Dry weight ($g\ m^{-2}$) of different biotypes of *P. minor* and WCE (%)					Toxicity (%) on wheat
		R1	H2	H3	KR1	UP1	
Isoproturon	1000	1.06 (96)	3.06 (87)	27.80 (9)	23.31 (8)	23.80 (30)	0
Isoproturon	2000	0.10 (99)	1.30 (95)	19.16 (37)	15.01 (41)	18.33 (46)	0
Clodinafop	60	1.32 (93)	2.22 (90)	3.88 (87)	2.02 (92)	4.16 (88)	0
Diclofop	880	2.66 (87)	7.35 (68)	13.33 (56)	10.67 (58)	24.25 (28)	0
Fenoxaprop	120	1.98 (90)	3.17 (86)	5.02 (84)	4.61 (82)	5.88 (83)	0
Metoxuron	1600	2.09 (89)	4.32 (81)	16.00 (47)	12.50 (50)	26.01 (23)	0
Metoxuron	3200	1.12 (94)	2.16 (91)	13.83 (55)	11.51 (54)	19.32 (43)	0
Sulfosulfuron	25	1.08 (95)	2.13 (91)	3.19 (89)	3.64 (86)	4.01 (88)	0
Sulfosulfuron	50	0.94 (95)	1.27 (95)	3.01 (90)	2.50 (90)	3.22 (90)	0
Tralkoxydim	350	2.33 (88)	3.43 (85)	3.88 (87)	4.61 (82)	4.16 (88)	0
Mon-48549	25	8.33 (58)	11.67 (49)	18.50 (40)	16.84 (33)	24.17 (29)	15
Mon-48549	50	4.67 (77)	8.83 (61)	16.00 (48)	12.66 (50)	20.02 (41)	30
Foe-5043	300	18.83 (6)	19.67 (14)	28.83 (6)	21.33 (16)	30.17 (11)	0
Foe-5043	600	10.17 (49)	11.33 (51)	20.87 (32)	15.83 (37)	26.51 (22)	0
Metribuzin	200	6.18 (69)	7.83 (66)	17.01 (45)	12.35 (51)	14.66 (57)	18
Metribuzin	400	2.00 (90)	1.31 (94)	6.32 (79)	6.00 (76)	7.32 (78)	30
Methabenzthiazuron	1400	2.50 (87)	4.60 (80)	26.83 (12)	22.16 (12)	32.67 (4)	0
Untreated	-	20.00 (0)	22.94 (0)	30.64 (0)	25.27 (0)	33.92 (0)	0
LSD (P=0.05)		2.87	3.29	2.76	2.44	3.28	-

The data on WCE (%) have been given in parentheses.

texture, low in available N (114.9 kg ha^{-1}), medium in P_2O_5 (13.6 kg ha^{-1}) and high in K_2O (512.4 kg ha^{-1}) with pH 8.0. In experiments 1 and 2, five biotypes of *P. minor* including two susceptible R1 (Rohtak, Haryana) and H2 (Research Farm, CCSHAU, Hisar), and three resistant H3 (Laloda, Fatehabad, Haryana), KR1 (Karnal, Haryana) and UP1 (Uttar Pradesh) were included alongwith wheat variety PBW 343. Whereas in experiments 3 and 4, only three resistant biotypes (H3, KR1 and UP1) of *P. minor* were included for herbicidal screening. The seeds of resistant biotypes were collected from fields in the resistance-affected rice-wheat growing areas where isoproturon was being used continuously for the last 10-15 years. The seeds of prestine population (R1) of *P. minor* were collected from fields where isoproturon had never been used, and seeds of susceptible biotype (H2) were collected from Research Farm of CCSHAU, Hisar where isoproturon was still very effective against this weed due to herbicidal use in rotation.

Four rows of each of five biotypes of *P. minor* and one variety of wheat PBW 343 in experiments 1 and 2 were sown on 15 January 1998 and 12 January 1999. Whereas three biotypes of *P. minor* in experiments 3 and 4 per plot were sown on 11 December 1998 and 10 December 1999. The seed rate of *P. minor* was used at 0.2 $g\ m^{-2}$ and in case of wheat it was used at 100 kg ha^{-1}. The furrows were kept open after sowing in order to ensure satisfactory germination. A light irrigation was also applied at 17 days after sowing alongwith urea application as per requirement of wheat. The herbicides in experiments 1 and 2 were applied at 30 days after sowing (3-leaf stage of *P. minor*) and in experiments 3 and 4 at 6-7-leaf stage with knapsack sprayer fitted with flat fan nozzles using spray volume of 500 l m ha^{-1}. All the experimental plots were kept free from other weeds to avoide their interference in the herbicidal performance. The herbicides and their doses used in experiments are given in the relevant tables. Each of the four experiments was laid out in randomized block design replicated thrice.

The data on dry weight accumulation g m^{-2} of *P. minor* were recorded at 21 days after treatment (DAT) in experiments 1 and 2, and at 30 DAT in experiments 3 and 4. The data on visual crop phytotoxicity (%) were also recorded at 21 DAT in experiments 1 and 2 using 0-100 scale (where, 0=no mortality and 100=complete mortality). The data in each experiment were subjected to pooled analysis. Based on dry matter accumulation, weed control efficiency (WCE in %) of various herbicidal treatments against different biotypes was also computed in all the four experiments.

RESULTS AND DISCUSSION

Isoproturon at 1.0 kg, metoxuron at 1.6 kg and methabenzthiazuron at 1.4 kg ha^{-1} applied at 3-leaf stage provided more than 80% control of both

Table 2. Effect of different herbicides in combination with metribuzin applied at 3-leaf stage on the dry weight of R and S biotypes of *P. minor*, and phytotoxicity on wheat at 21 days after spray

Herbicide	Dose (g ha^{-1})	Dry weight (g m^{-2}) of different biotypes of *P. minor* and WCE (%)					Toxicity (%)
		R1	H2	H3	KR1	UP1	on wheat
Isoproturon	1000	1.01 (95)	3.62 (85)	21.66 (21)	18.87 (23)	21.34 (39)	0
Isoproturon+ Metribuzin	1000+ 90	1.83 (91)	2.10 (91)	16.01 (41)	16.34 (34)	19.17 (46)	10
Isoproturon+ Metribuzin	1000+ 180	1.02 (95)	1.24 (95)	11.33 (58)	12.01 (51)	14.50 (59)	17
Isoproturon+ Metribuzin	1000+ 270	0.67 (97)	0.83 (97)	9.02 (67)	8.26 (66)	10.00 (72)	25
Clodinafop+ Metribuzin	50+ 90	1.52 (92)	2.80 (89)	4.50 (83)	5.83 (76)	6.64 (81)	10
Clodinafop+ Metribuzin	50+ 180	0.83 (96)	2.04 (92)	3.16 (88)	4.27 (83)	4.36 (88)	18
Clodinafop+ Metribuzin	50+ 270	0.67 (97)	1.06 (96)	2.07 (92)	3.04 (88)	3.83 (89)	27
Fenoxaprop+ Metribuzin	100+ 90	3.61 (81)	3.61 (85)	6.50 (76)	6.23 (75)	9.36 (73)	5
Fenoxaprop+ Metribuzin	100+ 180	3.22 (83)	3.31 (86)	4.43 (84)	5.00 (80)	7.15 (80)	9
Fenoxaprop+ Metribuzin	100+ 270	1.64 (92)	2.03 (92)	3.61 (87)	3.85 (84)	5.34 (85)	20
Diclofop+ Metribuzin	700+ 90	11.70 (40)	13.62 (45)	12.38 (55)	10.27 (58)	22.67 (36)	0
Diclofop+ Metribuzin	700+ 180	9.16 (53)	9.02 (63)	11.16 (59)	8.15 (67)	14.84 (58)	0
Diclofop+ Metribuzin	700+ 270	7.02 (64)	6.38 (74)	10.24 (63)	7.80 (68)	12.35 (65)	0
Metoxuron+ Metribuzin	1600+ 90	5.76 (70)	6.67 (73)	17.67 (35)	14.34 (42)	22.44 (36)	15
Metoxuron+ Metribuzin	1600+ 180	3.83 (80)	5.83 (76)	11.84 (57)	11.80 (52)	17.50 (50)	20
Metoxuron+ Metribuzin	1600+ 270	2.01 (90)	4.65 (81)	10.33 (62)	9.85 (60)	10.21 (71)	25
Tralkoxydim+ Metribuzin	300+ 180	7.50 (61)	9.82 (60)	9.16 (66)	6.02 (76)	25.22 (28)	0
Untreated	-	19.51 (0)	24.6 (0)	27.29 (0)	24.60 (0)	35.28 (0)	0
LSD (P=0.05)		2.64	2.87	3.73	2.62	3.51	-

The data on WCE (%) have been given in parentheses.

susceptible biotypes (R1 and H2) of *P. minor;* however, these herbicides were ineffective against resistant biotypes (H3, KR1 and UP1) even at higher doses (Table 1). Mon-48549 at 25 and 50 g, and Foe-5043 at 300 and 600 g ha^{-1} also could not control this weed satisfactorily. Mon-48549 at 25 and 50 g ha^{-1} also caused 15 to 30% phytotoxicity to wheat. Performance of diclofop at 880 g and metribuzin at 200 g ha^{-1} was also erratic against R and S biotypes. Metribuzin at 400 g ha^{-1} reduced the dry weight of various biotypes to the extent of 78-94%; however, it also caused 18 and 30 % toxicity to wheat at 200 and 400 g ha^{-1}, respectively (Table 1). Clodinafop at 60 g, fenoxaprop at 120 g, sulfosulfuron 25 g and tralkoxydim at 350 g ha^{-1} applied at 3-leaf stage resulted in 82-95% reduction in the dry weight of R as well as S biotypes of *P. minor.*

Tank mix application of metribuzin at 90, 180 and 270 g each with isoproturon at 1.0 kg, metoxuron at 1.6 kg and 20% reduced (i. e. 50 and 100 g ha^{-1}, respectively) than recommended doses of clodinafop (60 g ha^{-1}) and fenoxaprop (120 g ha^{-1}) applied at 3-leaf stage of *P. minor* could marginally increase their mortality against R and S biotypes with the corresponding increase in the dose of metribuzin (Table 2). However, it also resulted in enhanced phytotoxicity against wheat crop with the corresponding increase in the dose of metribuzin in the mixture. Combination of metribuzin at 90, 180 and 270 g with diclofop at 700 g ha^{-1} could reduce the dry weight of different biotypes only to the extent of 36-74 % (Table 2) and weed control efficiency (WCE) was either equal or even less than the alone application of diclofop at 880 g ha^{-1} (Table 1) against some biotypes. Tralkoxydim+metribuzin at 300+180 g ha^{-1} reduced the dry weight of R and S biotypes to the tune of only 28-76% (Table 2) as against 82-88% with tralkoxydim alone at 350 g ha^{-1} (Table 1). These results clearly indicate that metribuzin alone or in mixture with isoproturon, metoxuron, diclofop, clodinafop, fenoxaprop or tralkoxydim would be only a futile exercise against *P. minor* in resistance-affected areas of rice-wheat cropping system.

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