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Pinoxaden for Controlling Grass Weeds in Wheat and Barley

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ABSTRACT

Pinoxaden was evaluated for the control of grass weeds in wheat and barley. It was very effective in controlling *Phalaris minor* Retz., *Avena ludoviciana* Dur. and *Polypogon monspeliensis* (L.) Desf., but was ineffective in controlling broad-leaved weeds. The efficacy of pinoxaden without surfactant was significantly inferior to surfactant application. In various experiments, pinoxaden with surfactant improved the wheat yield >68% over control. The efficacy of pinoxaden (35 g/ha) in controlling grass weeds in wheat was similar to that of clodinafop 60 g/ha, fenoxaprop 100 g/ha and sulfosulfuron 25 g/ha. Wheat yields among these herbicides were similar, where fields were having dominance of grass weeds, but in the presence of both grassy and broad-leaved weeds, sulfosulfuron had an edge over three grass herbicides (pinoxaden, fenoxaprop and clodinafop) tested. Toxicity was not observed on any of the 18 barley genotypes screened for their sensitivity to pinoxaden (30 and 60 g/ha). Pinoxaden @ 30 g/ha effectively controlled isoproturon resistant *P. minor* in barley and provided 21.6% higher yield compared to isoproturon application.

Key words : Herbicide resistance, *Phalaris minor*, crop safety, barley sensitivity, weed control

INTRODUCTION

Weeds substantially reduce the productivity and production of wheat and barley. The reduction in productivity depends upon the type of weed flora and weed density (Balyan and Malik, 1989; Balyan *et al.*, 1991; Afentouli and Eleftherohorinos, 1996; Walia and Brar, 2001). Among weeds, grass weeds, particularly the Littleseed canary grass (*Phalaris minor* Retz.) and wild oat (*Avena ludoviciana* Dur.) are the most serious problems of wheat and barley under irrigated conditions (Balyan *et al.*, 1991; Singh *et al.*, 1995). Due to the strong competitiveness, these weeds can cause yield reduction in the range of 15 to 50% in barley (Gill and Brar, 1975; Morishta and Thill, 1988) and 15 to 100% in wheat (Balyan and Malik, 1989; Balyan *et al.*, 1991; Malik and Singh, 1995; Afentouli and Eleftherohorinos, 1996; Walia and Brar, 2001; Chhokar and Malik, 2002; Chhokar *et al.*, 2008).

Resistance has evolved in *P. minor* against isoproturon, which was the most commonly used herbicide earlier in wheat and barley (Malik and Singh, 1995; Singh *et al.*, 1999; Chhokar and Malik, 2002). It is being realised that resistance problem emerged due to sole dependence on single herbicide as the herbicides are preferred over other weed control measures in wheat. Therefore, alternative herbicides will remain the key for resistance management and their evaluation is urgently needed. Isoproturon resistant *P. minor* is also a problem in some of the barley growing areas of Punjab and Haryana. Alternative herbicide is needed for control of grassy weeds including isoproturon resistant *P. minor* in barley. Some of the wheat herbicides (sulfosulfuron and mesosulfuron) used for control of isoproturon resistant *P. minor* in wheat are not safe for barley (Shinn *et al.*, 1999; King, 2007). Therefore, the present study was conducted with the aim of identifying herbicides for the control of grass weeds including isoproturon resistant *P. minor* in wheat and barley.

MATERIALS AND METHODS

Wheat cv. PBW-343 was sown in three replications in randomized block during first fortnight of November for four consecutive years (2003-04 to 2006-07) at Resource Management Block, Directorate of Wheat Research, Karnal, Haryana, India. Three repeated experiments involving various doses of pinoxaden and surfactant alongwith two herbicide formulations (5 and 10 EC) were conducted.

Evaluation of Pinoxaden 10 EC Formulation

Pinoxaden (Axial 10 EC) was evaluated under two sets of experiments. In the first experiment, herbicides treatments comprised pinoxaden at 20 to 40 g/ha alongwith clodinafop, fenoxaprop, sulfosulfuron and weedy check (Table 1). Surfactant, A 12127 was

Table 1. Efficacy of 10 EC formulation of pinoxaden (Axial 10 EC) and other herbicides against *P. minor* and broad-leaved weeds in wheat (Pooled analysis of 2003-04 and 2004-05)

Herbicide	Dose (g/ha)	*P. minor* dry weight (g/m^2)	Broad-leaved weeds dry weight (g/m^2)	Wheat yield (q/ha)
Pinoxaden+S	20+0.5%	34.3	18.1	51.2
Pinoxaden+S	25+0.5%	23.4	19.5	52.1
Pinoxaden+S	30+0.5%	3.0	20.0	54.4
Pinoxaden+S	35+0.5%	0.3	16.7	53.8
Pinoxaden+S	40+0.5%	0.0	21.9	53.9
Clodinafop	60	1.1	24.6	54.2
Sulfosulfuron+S	25+ 1250 ml	1.5	1.5	55.7
Fenoxaprop+S	100+ 500 ml	5.1	22.0	53.5
Weedy check		213.0	5.5	30.5
LSD (P=0.05)		14.4	7.3	4.0

S–Surfactant.

used @ 0.5% spray solution with pinoxaden. In the second experiment, pinoxaden at two rates 35 and 40 g/ha was evaluated with various rates of surfactant (A 12127) alongwith recommended herbicides (Table 2). Surfactants, Leader mix 1250 ml/ha and Puma activator 500 ml/ha were used with sulfosulfuron (Leader 75 WDG) and fenoxaprop (Puma Power 10 EC), respectively. The time of herbicide application was 32-37 days after sowing (DAS). The herbicide spraying was done with knapsack sprayer having flat fan nozzle using 350 l water/ha. Crop was raised according to the package of practices of the region. Observations on weed dry weight were recorded 120 DAS.

Evaluation of Pinoxaden 5 EC Formulation

Pinoxaden (Axial 5 EC) doses ranging from 35 to 200 g/ha alongwith clodinafop, fenoxaprop, sulfosulfuron and weedy check were evaluated against grass weeds in wheat crop during two **rabi** seasons of 2005-06 and 2006-07 (Table 3). The 5 EC formulation of pinoxaden had in-built surfactant. Surfactants, Leader mix 1250 ml/ha and Puma activator 500 ml/ha were added with sulfosulfuron and fenoxaprop, respectively. The herbicides were applied at 35-37 DAS with knapsack sprayer using 350 l water/ha. The dry weight of grass (*P. minor* and *Avena ludoviciana*) and broad-leaved weeds was taken 120 DAS by placing a quadrat of 50 x 50 cm at two places in each replication.

Evaluation of Pinoxaden in Barley and its Efficacy against *A. ludoviciana* and *Polypogon monspeliensis*

Eighteen barley genotypes including released cultivars (BCU 73, DWR 28 and DWR 46 in two row growing lines and Jyoti, K 551, K 603, K 675, K 713, K 723, Lakhan, NDB 1173, RD 2503, RD 2508, RD 2624, RD 2634, RD 2035, RD 2552 and RD 2636 six row type)

Table 2. Effect of 10 EC formulation of pinoxaden (Axial 10 EC) with surfactant and other herbicides on dry weight of grass and broad-leaved weeds in wheat and wheat grain yield

Herbicide	Dose (g/ha)	Weed dry weight (g/m^2)					Wheat grain yield (q/ha)	
		2004-05	2005-06				2004-05	2005-06
		P. minor	*Avena ludoviciana*	*P. minor*	Total grasses	Broad-leaved		
Pinoxaden+S	35+0.5%	3.0	0.7	17.0	17.7	123.0	46.3	45.2
Pinoxaden+S	35+1.0%	2.3	0.0	3.0	3.0	130.3	47.0	47.4
Pinoxaden+S	35+2.0%	1.8	0.0	0.0	0.0	126.0	45.9	46.3
Pinoxaden+S	40+0.5%	1.5	0.0	3.9	3.9	138.0	46.0	48.4
Pinoxaden+S	40+1.0%	0.8	0.0	0.0	0.0	140.5	47.1	47.7
Pinoxaden without S	40	46.8	103.3	190.6	293.9	76.2	42.7	28.9
Clodinafop	60	1.6	0.0	0.0	0.0	134.0	47.1	46.3
Sulfosulfuron+S	25+1.25%	2.6	4.3	4.7	8.9	3.5	46.8	54.4
Weedy check		264.5	256.5	237.5	494.0	38.3	28.0	17.3
Weed free		0.0	0.0	0.0	0.0	0.0	48.1	55.1
LSD (P=0.05)		10.4	45.6	30.5	39.8	18.7	3.6	4.7

S–Surfactant.

Table 3. Effect of pinoxaden (Axial 5 EC) in managing *P. minor* and *Avena ludoviciana* in wheat (Two years' pooled data)

Herbicide	Dose (g/ha)	Weed dry weight (g/m²)				Wheat grain yield (q/ha)
		P. minor	*Avena ludoviciana*	Total grass weeds	Broad-leaved	
Pinoxaden (5 EC)	35	13.9	0.2	14.1	45.2	51.7
Pinoxaden (5 EC)	40	4.1	0.0	4.1	50.9	52.7
Pinoxaden (5 EC)	45	1.8	0.0	1.8	49.3	52.2
Pinoxaden (5 EC)	50	1.2	0.0	1.2	49.5	52.2
Pinoxaden (5 EC)	100	0.4	0.0	0.4	52.5	52.4
Pinoxaden (5 EC)	200	0.1	0.1	0.1	45.5	51.6
Pinoxaden (10 EC)+S (A12127)	35+2000 ml	10.5	0.0	10.5	55.0	52.6
Clodinafop	60	1.3	0.3	1.6	46.8	52.7
Sulfosulfuron+S	25+1250 ml	2.6	7.1	9.8	1.4	55.5
Fenoxaprop+S	100+500 ml	16.7	0.5	17.1	49.2	51.0
Weedy check		275.9	200.3	476.2	5.0	21.2
Weed free		0.0	0.0	0.0	0.0	55.0
LSD (P=0.05)		34.5	21.4	29.2	14.3	2.7

S–Surfactant.

alongwith two grassy weeds (*Avena ludoviciana* and *Polypogon monspeliensis*) were sown on 12 Nov. 2003. Three rows of each test species were sown at a R x R spacing of 30 cm. Pinoxaden was evaluated at 0, 30 and 60 g/ha. Herbicide treatments were kept in main block and test species in sub-plot. Pinoxaden was applied at 40 DAS with knapsack sprayer fitted with flat fan nozzles. Three replications were kept for each treatment. Eight weeks after herbicide application visual phytotoxicity was recorded.

The performance of pinoxaden was also evaluated against isoproturon resistant *P. minor* in barley for two consecutive **rabi** seasons of 2005-06 and 2006-07. Isoproturon at 1000 g/ha and pinoxaden at 30 g/ha were applied at 32-35 DAS. During both the years *P. minor* was dominant weed and the density of broad-leaved weeds was negligible. For the control of broad-leaved weeds, metsulfuron methyl 3 g a. i./ha was applied 2 to 3 days before isoproturon and pinoxaden application. The dry weight (g/m²) of *P. minor* was recorded at 100 DAS. Significance of treatment means was compared using "paired t test" (Fig. 1).

RESULTS AND DISCUSSION

Evaluation of Pinoxaden Formulation, Axial 10 EC in Wheat

Pinoxaden was evaluated at 20 to 40 g/ha in wheat having dominance of *P. minor*. The maximum *P. minor* dry weight (213.0 g/m²) was under uncontrolled check (Table 1). Significant reduction in *P. minor* dry weight was observed under various herbicides application treatments compared to weedy check. Like fenoxaprop and clodinafop, pinoxaden was also ineffective against broad-leaved weeds. These three grass herbicides had higher broad-leaved weeds dry weight than weedy check and sulfosulfuron treatments. There were some escapes at lower doses of pinoxaden i. e. 20 and 25 g/ha and at higher doses (130 g/ha) effective control was achieved. Due to reduced weed dry weight, all the herbicide treatments resulted in significantly higher wheat yield than weedy check (Table 1). The yield increase recorded with herbicide treatments was > 67.9%. Wheat yield among pinoxaden (>25 g/ha), sulfosulfuron, fenoxaprop and clodinafop was not significantly different. The effective *P. minor* control with sulfosulfuron, clodinafop and fenoxaprop has also been reported earlier (Chhokar and Malik, 2002).

Effect of Surfactant on Pinoxaden Efficacy

The surfactant effect on pinoxaden efficacy against grass weeds was studied for two consecutive years (Table 2). In this study, *P. minor* was dominant weed during first year and during second year *P. minor* and *Avena ludoviciana* were dominant weeds in

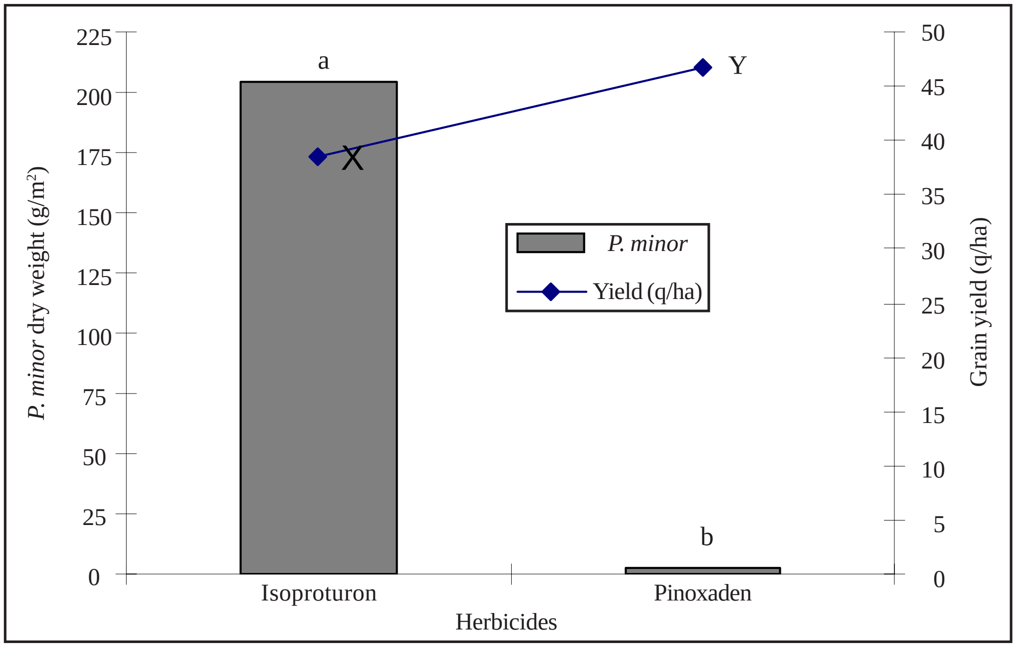

Fig. 1. Performance of pinoxaden against isoproturon resistant *P. minor* in barley. The data having different letters were significantly different at 5% level of significance using "paired t test".

experimental field. The grass weed dry weight under uncontrolled check was 264.5 and 494.0 g/m^2, respectively, during 2004-05 and 2005-06, respectively. Various herbicide application treatments significantly reduced the grass weed dry weight compared to weedy check. As a consequence of reduction in weed dry weight, various herbicide treatments yielded significantly higher than weedy check.

The application of pinoxaden with surfactant (A 12127) was significantly better than without surfactant. The mean grass weeds (*P. minor* and *Avena ludoviciana*) dry weight in pinoxaden at 40 g/ha with and without surfactant was 0 to 3.9 and 293.9 g/m^2, respectively. No significant differences were found between various rates of surfactant application. However, during second year at lower doses of pinoxaden i. e. 35 g/ha, the higher doses of surfactant (more than equal to 1.0 l/ha) were slightly better than lower dose of 0.5 l/ha. The yield levels were also statistically similar among two rates of the pinoxaden with different levels of surfactants. The grain yield with pinoxaden 40 g/ha without surfactant (28.89 q/ha) was significantly lower than its application with surfactant. Numerous studies have demonstrated the beneficial effect of surfactant in enhancing herbicide efficacy (Hart *et al.*, 1992; Malik *et al.*, 1988; Kudsk and Mathiassen, 2007; Green and Beestman, 2007). The severe competition from grass weeds resulted in the lowest grain yield (28.0 and 17.3 q/ha) under untreated control. The pinoxaden efficacy with surfactant was similar to clodinafop, sulfosulfuron and fenoxaprop for the control of grass weeds (*P. minor* and *Avena ludoviciana*). During 2nd year of study, the yield levels were significantly superior to sulfosulfuron due to control of complex weed flora. In earlier study also yield advantage was observed with sulfosulfuron over grass herbicides (fenoxaprop, clodinafop and tralkoxydim) due to additional control of broad-leaved weeds (Chhokar and Malik, 2002). The broad-leaved weeds dry weight was significantly lower (28.0 g/m^2) in weedy control compared to different graminicide treatments (76.2 to 140.5 g/m^2). This was due to strong competition offered by two grassy weeds.

Performance of 5 EC (Axial 5 EC) Formulation of Pinoxaden

In this study also, grass weeds (*P. minor* and *Avena ludoviciana*) were dominant and their dry weight under uncontrolled check was 476.2 g/m^2 (Table 3). Significant reduction in grass weed dry weight was observed in various herbicide application treatments compared to weedy check. This led to significantly more yield than weedy control. The yield reduction due to grass weeds infestation was upto 61.8%, as evident from the grain yield under untreated control.

Earlier studies have also reported *P. minor* and *A. ludoviciana* as highly competitive weeds causing significant wheat yield reduction (Balyan and Malik, 1989; Balyan *et al.*, 1991; Afentouli and Eleftherohorinos, 1996; Walia and Brar, 2001; Chhokar *et al.*, 2006). Application of pinoxaden (Axial 5 EC)≥35 g/ha controlled the *P. minor* and *Avena ludoviciana* effectively and yielded similar to fenoxaprop and clodinafop.

Only sulfosulfuron had effect on broad-leaved weeds and other tested herbicides had no effect on broad-leaved weeds as a result their dry weight was higher compared to weedy check and sulfosulfuron treatments. Due to control of complex weed flora, sulfosulfuron had an edge over other herbicides tested. The lower broad-leaved weed dry weight in weedy control was mainly due to their suppression by heavy infestation of grass weeds (*P. minor* and *A. ludoviciana*). The efficacy of pinoxaden (Axial 10 EC)+surfactant (35 g+2.0 l/ha) against grass weeds was similar to that of pinoxaden (Axial 5 EC) 35 g/ha as 5 EC formulation of pinoxaden had in-built surfactant. Pinoxaden was highly selective to wheat crop as only 3.3% visual toxicity was observed with highest rate of application (200 g/ha). The optimum pinoxaden dose was 35 g/ha.

Evaluation of Pinoxaden in Barley and its Efficacy against Wild Oat and Foxtail Grass

Eighteen barley genotypes consisting of three two-row and 15 six-row type were screened for selectivity against pinoxaden (Table 4). No visual phytotoxicity of pinoxaden was observed on any of the barley cultivars upto 2X dose (60 g/ha). Complete control of *A. ludoviciana* and *P. monspeliensis* was observed at both the doses of pinoxaden (30 and 60 g/ha). It means that it is selective in barley and can be effectively used for combating grass infestation.

Table 4. Visual phytotoxicity on barley genotypes and weed species

Test species	Visual phytotoxicity (%)		
	Control	Pinoxaden (30 g/ha)	Pinoxaden (60 g/ha)
Two-row barley genotypes (n=3)	0	0	0
Six-row barley genotypes (n=15)	0	0	0
Avena ludoviciana	0	100	100
Polypogon monspeliensis	0	100	100

In another field study, pinoxaden was examined for control of isoproturon resistant *P. minor* in barley. Application of pinoxaden @ 30 g/ha provided the effective control of isoproturon resistant *P. minor* (Fig. 1). The *P. minor* dry weight under pinoxaden and isoproturon was 2.6 and 204.3 g/m^2, respectively. The effective *P. minor* control with pinoxaden application led to significant yield improvement compared to isoproturon application. Similarly, the barley yield improvement by the effective control of grass weed (*Avena fatua*) using diclofop was also reported by Barton *et al.* (1992).

Based on this study, it can be concluded that pinoxaden 30-35 g/ha is highly effective against grass weeds (*Phalaris minor*, *Avena ludoviciana* and *Polypogon monspeliensis*). It is also effective against isoproturon resistant *Phalaris minor*. For the better efficacy of pinoxaden, addition of surfactant is a must and it can be safely used both in wheat and barley crop.

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