Indian Journal of Agronomy **54**(4): 433–437 (December 2009)

Pinoxaden: an alternate herbicide against littleseed canary grass (*Phalaris minor*) in wheat (*Triticum aestivum*)

DHARAM BIR YADAV[1], S.S. PUNIA* , ASHOK YADAV*, SAMUNDER SINGH* AND ROSHAN LAL

CCS Haryana Agricultural University Regional Research Station, Karnal, Haryana 132 001

Received: July 2009

ABSTRACT

Two field experiments were conducted at Karnal, Haryana during *rabi* 2005-06 and 2006-07 to evaluate the efficacy of pinoxaden against *Phalaris minor* in wheat. Pinoxaden 10 EC 40 g/ha + adjuvant 2,000 ml/ha and pinoxaden 5 EC (with built-in adjuvant) 50 g/ha reduced the dry weight of *Phalaris minor* to the extent of 92-99 and 89-98%, respectively, and were at par with weed free checks during both the years. Consequently, Pinoxaden 5 EC 50 g/ha and Pinoxaden 10 EC 40 g/ha + adjuvant 2,000 ml/ha being at par with weed free checks produced grain yield of wheat to the tunne of 6.1-6.2 and 5.7-6.1 t/ha. Efficacy of pinoxaden 10 EC against *P. minor* increased by about 70% with addition of adjuvant indicating that adjuvant is must with this formulation. Pinoxaden 5 EC 50 g/ha was superior to lower doses, fenoxaprop and sulfosulfuron, however, it was at par with clodinafop during both the years. Both formulations of pinoxaden were ineffective against broad-leaved weeds. Maximum net returns (Rs 14,400-19,500/ha) and benefit: cost ratio (0.74-0.91) was obtained under pinoxaden 5 EC 50 g/ha. There was no phytotoxicity on wheat and no residual toxicity on the succeeding rice crop.

Key words: Adjuvants, Economics, Formulations, Herbicides, *Oryza sativa, Phalaris minor, Wheat*

Weeds cause substantial loss in the grain yield of wheat in the rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L. emend. Fiori. & Paol.) cropping system. Litteleseed canary grass (*Phalaris minor* Retz.) is the dominant grassy weed in wheat under rice-wheat cropping system of north-western India. Evolution of resistance in *P. minor* against isoproturon (Malik and Singh, 1993, 1995; Walia *et al.*, 1997) made the situation more complex. Judicious use of alternate herbicides as a component of integrated weed management could be viable option to combat resistant *P. minor* (Yadav and Malik, 2005). Clodinafop, sulfosulfuron and fenoxaprop were recommended as alternate herbicides against isoproturon resistant *P. minor* in 1998-99. But resistance against these herbicides has also been reported over the years (Mahajan and Brar, 2001; Yadav *et al.*, 2002; Dhawan *et al.*, 2009). Under such situations, there is a need for new herbicide molecules. Pinoxaden (2,2-dimethyl-propionic acid 8-(2,6-diethyl-4-methyl-phenyl)-9-oxo-1,2,4,5-tetrahydro-9H-pyrazolo[1,2-d][1,4,5] oxadiazepin-7-yl ester) is a new herbicide belonging to phenylpyrazolin group with acetyl-CoA-carboxylase (ACCase) inhibiting action (Hofer *et al.*, 2006) is one such one. It is a selective grass killer with foliar action and has no residual herbicidal activity in soil. Hence, the present study was conducted to evaluate the efficacy of pinoxaden against *P. minor* in wheat.

[1]**Corresponding author:** (Email: dbyadav@gmail.com)

***Present address:** Department of Agronomy, CCS HAU, Hisar 125 004

MATERIALS AND METHODS

Field experiments were conducted at Karnal (76°58' E longitude, 29°43' N latitude at 243 m above mean sea level) during *rabi* 2005-06 and 2006-07. The soil of experimental field was clay loam in texture, low in available nitrogen (109 kg/ha) medium in available (13 kg/ha) and high in (304 kg/ha) with slightly alkaline in reaction (pH 8.1). Two experiments (Experiments 1 and 2) involving two different formulation of pinoxaden , viz. 5 EC formulation with built-in adjuvant and 10 EC formulation without built-in adjuvant, along with various doses of pinoxaden and adjuvant (A) were compared with already recommended herbicides (clodinafop, fenoxaprop and sulfosulfuron). Sowing of wheat (cultivar 'PBW 343' in 2005-06 and 'PBW 502' in 2006-07) was done in the second fortnight of November in rows at 20 cm apart.

Efficacy of pinoxaden 10 EC formulation and adjuvant

Experiment 1. Pinoxaden 10 EC at two doses (35 and

40 g/ha) with varying doses of adjuvant R12717 (0.5, 1.0 and 2.0 l/ha) was compared with fenoxaprop 100 g/ha, clodinafop 60 g/ha, sulfosulfuron 25 g/ha along with weed free and weedy checks. The experiment was laid out in a randomized block design with 3 replications. Density and dry weight of weeds were recorded at 90 days after sowing, and yield and yield attributes at harvest.

Efficacy of pinoxaden 5 EC formulation

Experiment 2. Pinoxaden 5 EC was evaluated during *rabi* 2005-06 and 2006-07. The treatments included different doses of pinoxaden 5 EC (35, 40, 45, 50, 100 and 200 g/ha), 2 doses of pinoxaden 10 EC (35 and 40 g/ha with 2.0 l adjuvant/ha) along with fenoxaprop 120 g/ha, clodinafop 60 g/ha, sulfosulfuron 25 g/ha, weed free and weedy checks. The experiment was laid out in a randomized block design with 3 replications. Density and dry weight of weeds were recorded at 90 DAS in first year and 75 DAS during second year. Wheat grain yield and yield attributes were recorded at maturity.

In both the experiments, herbicides were sprayed by knapsack sprayer fitted with flat-fan nozzle using 500 litres/ha of water. Crop was raised as per the recommended package of practices including 6 irrigations at critical stages (22, 45, 65, 85,105,120 DAS). Crop phytotoxicity was recorded at 15 and 30 days after spray using 0-100 scale (where 0, no mortality and 100, complete mortality). Weed control efficiency (WCE) was calculated as per cent reduction in total weed dry weight under different treatments as compared to weedy check plots. For economic evaluation, total variable cost, net returns (gross returns – total cost) and benefit: cost (B: C) ratio (net returns/total variable cost) were computed. The crop was harvested in the second fortnight of April. Data on residual toxicity of pinoxaden was also recorded on succeeding crop of rice. As there was no crop phytotoxicity on wheat and also no residual toxicity on succeeding crop of rice, the data on these aspects have not been included herein.

RESULTS AND DISCUSSION

The experimental field was infested with grassy and broad-leaved weeds to the tune of 83-90 and 10-17%, respectively. Among different weeds, infestation of littleseed canary grass (*Phalaris minor* Retz.), swine-cress (*Coronopus didymus* L.), scarlet pimpernel (*Anagallis arvensis* L.), yellow sweet clover (*Melilotus indica* All. Fl. Ped.), bur clover (*Medicago denticulata* L.), golden dock (*Rumex dentatus* L.), common vetch (*Vicia sativa* L.) and wild pea (*Lathyrus aphaca* L.) was to the extent of 86, 7, 2.5, 1.5, 1, 1, 0.5 and 0.5%, respectively.

Experiment 1

Effect on weeds

Density and dry weight of *P. minor* was reduced with the increase in the dose of pinoxaden 10 EC from 35 to 40 g/ha when compared with weedy check (Table 1). There was very significant effect of the adjuvant in enhancing the efficacy of this herbicide. Significantly lower density and dry weight of *P. minor* along with the higher yield and yield attributes were obtained under both the doses of pinoxaden with adjuvant when compared with its respective doses without adjuvant. The efficacy of the herbicide against *P. minor* also increased with increase in dose of the adjuvant. The dry weight of *P. minor* was 12.3 g/m^2 as compared to 96.4 g/m^2 when pinoxaden at 40 g/ha was applied with adjuvant 1.0 l/ha and without adjuvant, respectively. Pinoxaden 10 EC 35 g/ha + A 1-2 l and pinoxaden 40 g/ha + A 0.5-1.0 l/ha resulted in density and dry weight of *P. minor* similar to weed free check. Performance of fenoxaprop was quite low. Pinoxaden was not effective against broad-leaved weeds. Sulfosulfuron besides being quite effective against *P. minor* also reduced the dry weight of broad leaved weeds (BLW) to the extent of 64%. Maximum WCE (81%) was obtained under pinoxaden 10 EC 35 g + A 2 l/ha followed by pinoxaden 10 EC 40 g + A 1 l/ha (77%) and clodinafop (77%). The WCE was reduced drastically when adjuvant was not added to it (19%). Chhokar *et al.* (2008) also reported that pinoxaden 10 EC with adjuvant provides effective control of isoproturon resistant *P. minor* in wheat.

Effect on crop

The effective tillers in plots treated with pinoxaden 10 EC 35 g/ha without adjuvant were at par with that of weedy check (Table 1). Wheat grain yields under pinoxaden 10 EC 35 g/ha + A 1-2 l/ha and pinoxaden 40 g/ha + A 0.5-1.0 l/ha were at par with clodinafop, sulfosulfuron and weed free check. Pinoxaden 10 EC 40 g/ha + A 0.5-1.0 l/ha produced significantly higher grain yield than fenoxaprop. Pinoxaden 35 g/ha + A 2 l/ha and pinoxaden 40 g/ha + A 0.5-1 l/ha resulted in significantly higher yields than pinoxaden 35-40 g/ha without adjuvant. Highest grain yield was obtained with pinoxaden 40 g/ha + A 1 l/ha, which being at par with other treatments of pinoxaden was significantly higher than pinoxaden 35 g/ha + A 0.5 l/ha. Biological yield also showed the similar trend.

Experiment 2

Effect on weeds

Density of *P. minor* decreased with corresponding increase in the dose of pinoxaden 5 EC (Table 2). Pinoxaden 5 EC between 50-200 g/ha in 2005-06 and 45-200 g/ha in

Table 1. Effect of pinoxaden 10 EC and adjuvant on of weeds and effective tillers and grain yield of wheat (*rabi*, 2005-06)

Treatments	Dose (g/ha)	Weed density (No./m²)* *P. minor*	Weed density (No./m²)* BLW**	Weed dry weight (g/m²) *P. minor*	Weed dry weight (g/m²) BLW	WCE*** (%)	Effective tillers/ mrl#	Grain yield (t/ha)	Biological yield (t/ha)
Pinoxaden +A†	35 + 0.5 l	4.1 (16.0)	6.9 (50.0)	40.4	19.4	57.7	101.7	4.91	9.91
Pinoxaden +A	35 + 1 l	1.8 (2.7)	7.1 (52.7)	23.1	20.5	69.2	103.7	5.13	10.33
Pinoxaden +A	35 + 2 l	1.5 (2.0)	7.9 (64.0)	6.1	20.8	81.0	116.3	5.43	10.76
Pinoxaden +A	40 + 0.5 l	2.0 (3.3)	7.4 (54.7)	26.3	21.0	66.6	106.3	5.70	11.08
Pinoxaden +A	40 + 1 l	1.7 (2.7)	6.9 (46.7)	12.3	20.1	77.1	112.7	5.65	11.07
Pinoxaden (without A)	35	8.1 (66.0)	7.8 (60.7)	92.0	22.1	19.3	88.3	4.50	9.15
Pinoxaden (without A)	40	8.1 (65.3)	6.4 (40.0)	96.4	18.8	18.6	99.0	4.58	9.30
Clodinafop	60	1.4 (1.3)	8.1 (65.3)	10.8	22.4	77.1	107.3	5.60	10.93
Sulfosulfuron +S‡	25 + 0.5%	4.9 (23.3)	4.3 (17.3)	38.4	7.3	67.7	103.3	5.22	10.36
Fenoxaprop +S	100 + 0.2%	10.6(112.7)	6.4 (40.0)	73.6	18.0	35.3	99.7	4.71	9.49
Weed free		1.0 (0.0)	1.0 (0.0)	0.0	0.0	100.0	107.0	5.90	11.43
Weedy check		11.2(126.7)	4.8 (26.0)	121.3	20.2	0.0	79.7	3.54	7.39
SEm±		0.6	0.8 9.9	1.5		5.7	0.27	0.47	
CD (P=0.05)		1.7	2.4 28.9	4.5		16.6	0.79	1.38	

*Original figures in parenthesis were subjected to square root transformation (vX+1) before statistical analysis; **BLW, Broad-leaved weeds, ***WCE, Weed control efficiency, #mrl, meter row length †A, adjuvant; ‡S, surfactant

Table 2. Effect of pinoxaden 5 EC and pinoxaden 10 EC on density, dry weight and per cent control of weeds in wheat

Treatment	Dose (g/ha)	Weed density* (No./m²) *P. minor* 05-06	*P. minor* 06-07	Broad-leaved weeds 05-06	Broad-leaved weeds 06-07	Weed dry weight (g/m²) *P. minor* 05-06	*P. minor* 06-07	Broad-leaved weeds 05-06	Broad-leaved weeds 06-07	WCE (%) 05-06	WCE (%) 06-07
Pinoxaden 5EC	35	5.0 (24.0)	4.9 (23.3)	6.1 (36.7)	3.7 (12.7)	45.9	14.2	9.1	3.6	54.9	84.9
Pinoxaden 5EC	40	2.2 (4.7)	3.1 (8.7)	6.1 (36.7)	4.1 (16.7)	25.4	6.1	10.2	3.6	70.8	91.8
Pinoxaden 5EC	45	2.1 (4.0)	2.0 (3.3)	7.2 (50.7)	3.8 (14.0)	15.4	4.2	9.2	3.5	79.8	93.5
Pinoxaden 5EC	50	2.0 (3.3)	1.7 (2.0)	6.9 (48.0)	3.6 (13.3)	9.1	0.3	9.8	3.4	84.5	96.9
Pinoxaden 5EC	100	1.5 (2.0)	1.2 (0.7)	6.5 (42.7)	4.2 (16.7)	3.9	0.3	9.4	4.0	89.1	96.4
Pinoxaden 5EC	200	1.0 (0.0)	1.0 (0.0)	6.4 (40.7)	3.7 (12.7)	0.0	0.0	9.7	3.8	92.0	96.8
Pinoxaden 10EC+A†	35 + 2 l	2.0 (4.0)	1.8 (3.3)	6.2 (38.0)	4.4 (19.3)	18.7	3.3	9.5	3.2	76.9	94.5
Pinoxaden 10EC+A	40 + 2 l	1.8 (2.7)	1.5 (2.0)	6.4 (40.7)	4.3 (18.0)	12.5	1.8	10.4	3.3	81.2	95.7
Clodinafop	60	2.7 (6.7)	2.0 (4.0)	6.4 (41.3)	4.1 (16.0)	14.7	4.0	12.8	3.3	77.4	93.8
Sulfosulfuron +S‡	25 + 0.5%	4.8 (22.7)	4.7 (21.3)	2.1 (4.0)	1.5 (2.0)	36.5	20.0	2.9	0.1	67.7	83.0
Fenoxaprop	120	4.5 (19.3)	5.5 (29.3)	6.1 (36.7)	4.2 (16.7)	43.9	24.0	9.3	3.3	56.3	76.9
Weed free		1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	0.0	0.0	0.0	0.0	100.0	100.0
Weedy check		13.0(168.7)	10.4(107.3)	5.5 (29.3)	3.6 (12.0)	113.4	113.9	8.5	4.1	0.0	0.0
SEm±		0.4	0.4	0.6	0.4	5.3	3.4	1.0	0.4		
CD (P=0.05)		1.1	1.2	1.6	1.1	15.4	9.8	3.0	1.2		

*Original figures in parenthesis were subjected to square root transformation ($\sqrt{X+1}$) before statistical analysis; †A, adjuvant; ‡S, surfactant

2006-07 were at par with weed free check in respect of density of *P. minor*; whereas pinoxaden 10 EC formulation at 35-40 g/ha was at par with weed free check during both the years. All treatments of pinoxaden 5 EC and 10 EC except pinoxaden 5 EC 35 g/ha resulted in density of *P. minor* at par with clodinafop but lower than fenoxaprop and sulfosulfuron during both the years. Fenoxaprop was poor among all the herbicidal treatments in respect of reducing *P. minor* density. Pinoxaden 10 EC 35 g/ha was better than its 5 EC counterpart in this respect. Whereas, pinoxaden 10 EC 40 g/ha was at par with pinoxaden 5 EC 40 g/ha during 2005-06 and better during 2006-07. Pinoxaden 10 EC 35-40 g/ha was at par with pinoxaden 5 EC 40 g/ha during 2005-06 and 45 g/ha during 2006-07.

Dry weight of *P. minor* also decreased with corresponding increase in dose of pinoxaden 5 EC (Table 2). Pinoxaden 5 EC 50 g/ha and above during 2005-06 and 40 g/ha and above during 2006-07 were at par with weed free check, whereas, pinoxaden 10 EC 40 g/ha during 2005-06 and 35 g/ha during 2006-07 were at par. Pinoxaden 5 EC 40 g /ha and above and pinoxaden 10 EC 35-40 g/ha were at par with clodinafop but better than fenoxaprop in reducing the dry weight of *P. minor* during both the years. Pinoxaden 10 EC 35 g/ha was better than its 5 EC counterpart whereas, at 40 g/ha, both the formulations were at par with each other in respect of dry weight of *P. minor*. WCE increased with increase in dose of pinoxaden 5 EC. Pinoxaden 5 EC 50 g/ha provided 85-97% WCE which was superior to clodinafop (77-94%), sulfosulfuron (68-83%) and fenoxaprop (56-77%). Pinoxaden has already been reported very effective against isoproturon-resistant *P. minor* in wheat and barley (Porter *et al.*, 2005 and Chhokar *et al.*, 2008).

Pinoxaden 5 EC 40-200 g/ha in 2005-06 and 45-200 g/ha in 2006-07 provided >95% control of *P. minor* (data not given). Clodinafop also provided excellent control of *P. minor* (96-99%) during both the years whereas, fenoxaprop provided lowest control of *P. minor* (65-70%) followed by sulphosulfuron (78-80%).

Pinoxaden did not provide any control of the broad-leaved weeds (BLW) in respect of density and dry weight (Table 2). Among all herbicidal treatments, only sulfosulfuron 25 g/ha provided satisfactory control (70-83%) of BLW and was better than other herbicidal treatments and at par with weed free check.

Effect on crop

There was no significant effect of any of the treatments on the plant height and earhead length of wheat during both the years (Table 3). Pinoxaden 5 EC 50 g/ha and pinoxaden 10 EC 40 g/ha + A 2 l/ha produced effective tillers similar to clodinafop 60 g/ha and weed free check but more than fenoxaprop 120 g/ha and sulfosulfuron 25 g/ha.

Pinoxaden 5 EC 50 g/ha or above and pinoxaden 10 EC 40 g/ha produced grain yield of wheat at par with weed free check during both the years (Table 3). Grain yield under pinoxaden 5 EC at 45 g/ha and pinoxaden 10 EC 35 g/ha or above was at par with clodinafop during 2005-06, whereas all the pinoxaden treatments were at par with clodinafop during 2006-07. Pinoxaden 5 EC 50 g/ha and above were superior and other pinoxaden treatments were at par with sulfosulfuron during both years. Clodinafop was better than fenoxaprop between 2005-06 and 2006-07 and also superior to sulfosulfuron during 2005-06. Grain yield under pinoxaden 10 EC 40 g/ha was more than its 5 EC counterpart during 2005-06 but at par during 2006-07. Among herbicidal treatments, the maximum grain yield was obtained at pinoxaden 5 EC 50 g/ha which was better than the pinoxaden 35-40 g/ha, fenoxaprop and sulfosulfuron, and at par with clodinafop and weed free check during both the years. Similar trend was observed for the biological yield.

There was no phytotoxicity of pinoxaden on wheat and also no residual toxicity on the succeeding crop of rice (data not given).

Table 3. Effect of pinoxaden 5 EC and pinoxaden 10 EC on yield and yield attributes of wheat

Treatment	Dose (g/ha)	Plant height (cm)		Effective tillers /mrl*		Earhead length (cm)		Grain yield (t/ha)		Biological yield (t/ha)	
		05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
Pinoxaden 5EC	35	84.1	86.3	80.0	77.5	9.47	9.53	5.21	5.37	10.51	10.62
Pinoxaden 5EC	40	84.1	86.7	83.3	80.5	9.53	9.40	5.51	5.45	10.93	10.75
Pinoxaden 5EC	45	83.7	86.3	88.3	83.7	9.47	9.53	5.74	5.62	11.29	11.11
Pinoxaden 5EC	50	84.0	87.4	92.7	88.2	9.73	9.87	6.17	6.08	12.00	11.81
Pinoxaden 5EC	100	85.2	86.8	90.3	85.5	9.60	9.67	6.03	5.71	11.78	11.16
Pinoxaden 5EC	200	84.5	86.3	89.0	86.0	9.47	9.60	6.06	5.78	11.87	11.18
Pinoxaden 10EC +A†	35 + 2 l	84.3	86.4	85.7	81.7	9.27	9.47	5.61	5.51	11.01	10.83
Pinoxaden 10EC+A	40 + 2 l	84.1	86.5	89.0	85.3	9.60	9.60	6.09	5.71	11.79	11.21
Clodinafop	60	84.8	86.4	91.3	86.8	9.73	9.73	6.14	5.85	11.87	11.30
Sulfosulfuron +S‡	25 + 0.5%	84.5	85.9	82.7	82.5	9.53	9.67	5.54	5.42	10.89	10.69
Fenoxaprop	120	83.2	86.0	80.3	75.8	9.47	9.73	5.18	5.07	10.23	10.17
Weed free		85.5	87.9	93.3	88.0	9.73	9.73	6.36	6.21	12.26	12.06
Weedy check		82.5	83.0	62.3	54.5	9.13	9.20	4.16	3.96	8.56	8.28
SEm±		0.6	0.8	2.1	2.4	0.13	0.18	0.20	0.19	0.35	0.32
CD (P=0.05)		NS	NS	6.1	6.9	NS	NS	0.57	0.54	1.02	0.92

*mrl, meter row length; †A, adjuvant; ‡S, surfactant

Table 4. Economic evaluation of pinoxaden and other weed control treatments in wheat

Treatments	Dose (g/ha)	Total variable cost (x 10^3 Rs/ha)		Net returns (x 10^3 Rs/ha)		Benefit: Cost ratio	
		05-06	06-07	05-06	06-07	05-06	06-07
Pinoxaden 5EC	35	18.9	21.1	7.2	13.0	0.38	0.62
Pinoxaden 5EC	40	19.0	21.2	9.4	13.6	0.49	0.64
Pinoxaden 5EC	45	19.2	21.4	11.0	15.2	0.57	0.71
Pinoxaden 5EC	50	19.4	21.5	14.4	19.5	0.74	0.91
Pinoxaden 5EC	100	21.0	22.8	11.4	14.4	0.54	0.63
Pinoxaden 5EC	200	24.3	25.6	8.1	11.8	0.33	0.46
Pinoxaden 10EC +A†	35 + 2 l	19.1	21.3	9.9	14.0	0.52	0.66
Pinoxaden 10EC+A	40 + 2 l	19.4	21.5	13.6	15.9	0.70	0.74
Clodinafop	60	19.2	21.4	14.1	17.1	0.73	0.80
Sulfosulfuron +S‡	25 + 0.5%	19.2	21.4	9.3	13.1	0.48	0.61
Fenoxaprop	120	19.2	21.4	6.2	9.7	0.32	0.45
Weed free		23.8	26.1	11.0	15.8	0.46	0.60
Weedy check		17.5	19.9	-0.2	0.5	-0.01	0.02

†A, adjuvant; ‡S, surfactant

Economics

Maximum net returns were obtained under pinoxaden 5 EC 50 g/ha (Rs 14,400-19,500/ha) followed by clodinafop 60 g/ha (Rs 14,100-17,100/ha) and pinoxaden 10 EC 40 g + 2 l A/ha (Rs 13,600-15,900/ha), which were even higher than weed free plots (Rs 11,000-15,800/ ha). Among all the treatments, maximum B: C ratio (0.74-0.91) was obtained under pinoxaden 5 EC 50 g/ha during both the years (Table 4).

Based on two years studies, it might be concluded that pinoxaden 5 EC (with built-in adjuvant) 50 g/ha and pinoxaden 10 EC 40 g/ha + adjuvant 2 l/ha were best treatments against *Phalaris minor* in wheat. To achieve satisfactory control of *P. minor*, use of adjuvant with pinoxaden 10 EC was realized mandatory.

REFERENCES

Chhokar, R.S., Sharma, R.K. and Verma, R.P.S. 2008. Pinoxaden for controlling grass weeds in wheat and barley. *Indian Journal of Weed Science* **40**(1 and 2): 41–46.

Dhawan, R.S., Punia, S.S., Singh, S., Yadav, D. and Malik, R.K. 2009. Productivity of wheat (*Triticum aestivum*) as affected by continuous use of new low dose herbicides for management of littleseed canarygrass (*Phalaris minor*). *Indian Journal of Agronomy* **54**(1): 58–62.

Hofer, U., Muehlebach, M., Hole, S. and Zoschke, A. 2006. Pinoxaden – for broad spectrum grass weed management in cereal crops. *Journal of Plant Disease and Protection* **20**: 989–995.

Mahajan, G. and Brar, L.S. 2001. Studies on herbicide resistance in *Phalaris minor* under Punjab conditions. *Indian Journal of Weed Science* **33**(1 and 2): 1–4.

Malik, R.K. and Singh, S. 1993. Evolving strategies for herbicide use in wheat: resistance and integrated weed management. In: *Proceedings of International Symposium on Integrated Weed Management for Sustainable Agriculture,* Volume I. Indian Society of Weed Science, CCS Haryana Agricultural University, Hisar. pp. 225–238.

Malik, R.K. and Singh, S. 1995. Littleseed canary grass (*Phalaris minor*) resistance to isoproturon in India. *Weed Technology* **9**: 419–425.

Porter, D., Kopec, M. and Hofer, U. 2005. Pinoxaden – a new solution post-emergence graminicide for wheat and barley. *Weed Science Society of America Abstracts* **95**.

Walia, U.S., Brar, L.S. and Dhaliwal, B.K. 1997. Resistance to isoproturon in *Phalaris minor* Retz. in Punjab. *Plant Protection Quarterly* **12**: 138–140 .

Yadav, A. and Malik, R.K. 2005. *Herbicide Resistant Phalaris minor in Wheat : A Sustainability Issue. Resource Book.* 152 pp. Department of Agronomy and Directorate of Extension Education, CCS Haryana Agricultural University, Hisar.

Yadav, A., Malik, R.K., Chauhan, B.S. and Gill, G. 2002. Present status of herbicide resistance in Haryana. In: *Proceedings of International Workshop on Herbicide Resistance Management and Zero-tillage in Rice-Wheat Cropping System.* (Malik, R.K., Balyan, R.S., Yadav, A. and Pahwa, S.K. Eds.). CCS Haryana Agricultural University, Hisar. pp. 15–22.