Indian Journal of Weed Science **52**(2): 190–193, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Management of herbicide resistant *Phalaris minor* through sequential application of pre- and post-emergence herbicides in wheat

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Article information

DOI: 10.5958/0974-8164.2020.00035.0

Type of article: Research note

Received : 13 December 2019
Revised : 28 March 2020
Accepted : 30 March 2020

Key words

Herbicide resistance

Phalaris minor

Yield

Wheat

ABSTRACT

A field study was conducted during winter season of 2017-18 at Department of Agronomy, CCS Haryana Agricultural University, Hisar under irrigated conditions to evaluate the management of *P. minor* through sequential application of pre-emergence (PE) and post-emergence (PoE) herbicide in wheat crop and their phytotoxic effect on the succeeding crop. Total fifteen treatments consisting of pre-emergence (PE) use of pendimethalin 1500 g/ha, clodinafop 60 and 120 g/ha (35 DAS), sulfosulfuron 25 g/ha (35 DAS), sulfosulfuron + metsulfuron 32 g/ha (35 DAS), pinoxaden 50 g/ha (35 DAS), mesosulfuron + iodosulfuron (RM) 14.4 g/ha (35 DAS), PE of pendimethalin + metribuzin (RM) 2000 g/ha, PE pendimethalin + metribuzin (RM) *fb* clodinafop 60 g/ha (35 DAS), PE pendimethalin + metribuzin (RM) *fb* sulfosulfuron 25 g/ha (35 DAS), PE pendimethalin + metribuzin (RM) *fb* sulfosulfuron + metsulfuron 32 g/ha(35 DAS), PE pendimethalin + metribuzin (RM) *fb* pinoxaden 50 g/ha (35 DAS), PE pendimethalin + metribuzin (RM) *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha (35 DAS), weedy check and weed free were take. The results of present study revealed that PE followed by PoE herbicides are effective for the control of resistant *P. minor* population. The sequential application of PE pendimethalin + metribuzin (RM) 2000 g/ha *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha followed by PE pendimethalin + metribuzin (RM) 2000 g/ha *fb* sulfosulfuron + metsulfuron (RM) 32 g/ha and pinoxaden 50 g/ha were the most effective for control of resistant *P. minor* compared to alone PE or PoE herbicide. Grain yield and economics were also higher with these treatments.

As the harbinger of green revolution, wheat has played a key role in achieving self-reliance in the food production by the country. *Phalaris minor* Retz. (little seed canary grass) is a common weed of wheat in the rice-wheat cropping system in North-Western Indo-Gangetic Plains of India (Singh *et al*. 1995b, Franke *et al*. 2003, Punia *et al*. 2017). Haryana is the major wheat growing state in India with an area of 2.5 million ha (8% area of the national wheat area), 11.8 million tonnes of production (12.3% production share), and productivity of 4.72 t/ha (Anonymous 2015). Haryana still has the potential to increase the productivity of wheat with improved agronomic practices, including weed management. Although *P. minor* infests several winter season crops but morphological similarities, prolific seed production, un-synchronous and early maturity and continuous shattering of seeds before harvesting of the crop have ensured heavy prevalence of this weed in rice-wheat system.

Herbicides were largely accepted by the farmers to control this notorious weed. However, evolution of resistance against isoproturon, the most commonly used herbicide to contol *P. minor* in wheat during early 1990s was considered as one of the most serious cases of herbicide resistance in the world, resulted in total failure of crop under heavy infestation in Punjab and Haryana (Malik and Singh 1993, 1995, Walia *et al*. 1997). Therefore, new herbicides (clodinafop, sulfosulfuron, fenoxaprop and tralkoxydim) were recommended in resistance affected areas of rice- wheat cropping systems. The efficacy of these herbicides against *P. minor* was however reduced with development of multiple resistances in 2006. Excellent control of resistant *P. minor* and good grain yield were recorded in wheat fields with sequential use of pendimethalin and post-emergence herbicides clodinafop/pinoxaden and sulfosulfuron (Yadav *et al*. 2016, Kaur *et al*. 2016). Looking into the present scenario, it seems that in near future, the problem of the herbicide resistance in this weed may again pose a serious threat to the sustainability of wheat. Keeping this in view, the present study was conducted for management of herbicide resistance in *P. minor* using of pre- and post-emergence herbicides in wheat under field conditions.

The study was conducted during winter season of 2017-18 at CCS Haryana Agricultural University, Hisar under irrigated conditions. The soil of the experimental field was sandy loam in texture, having pH 8.0, low in organic carbon (0.40%) and available nitrogen (167 kg/ha), medium in available phosphorus (19 kg/ha) and high in available potassium (295 kg/ha) status. Fifteen treatments were tried in a randomized block design replicated thrice in a plot size of 7 x 7 m^2. Wheat (cultivar '*HD 2967*') was seeded on 23rd November, 2017 using a seed rate of 100 kg/ha, in 20 cm spaced rows. The wheat seed was treated with Dursban (chlorpyriphos 20 EC) 4 ml/kg seed and Vitavax (carboxin) 2 g/kg seed, before sowing. Treatments included pendimethalin 1500 g/ha (pre-emergence), clodinafop 60 and 120 g/ha (35 DAS), sulfosulfuron 25 g/ha (35 DAS), sulfosulfuron + metsulfuron 32 g/ha (35 DAS), pinoxaden 50 g/ha (35 DAS), mesosulfuron + iodosulfuron (RM) 14.4 g/ha (35 DAS), PE of pendimethalin + metribuzin (RM) 2000 g/ha, pendimethalin + metribuzin (RM) *fb* clodinafop 60 g/ha (35 DAS), pendimethalin + metribuzin (RM) *fb* sulfosulfuron 25 g/ha (35 DAS), pendimethalin + metribuzin (RM) *fb* sulfosulfuron + metsulfuron 32 g/ha (35 DAS), pendimethalin + metribuzin (RM) *fb* pinoxaden 50 g/ha (35 DAS), pre-emergence application of pendimethalin + metribuzin (RM) *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha (35 DAS), weedy check and weed free. All PE herbicides were sprayed using 500 litres of water/ha and post-emergence herbicides were sprayed with the help of knap-sack sprayer fitted with flat-fan nozzles using 375 litres of water/ha. Total rainfall received during the cropping period was 29.9 mm.

The density of *P. minor* was determined by quadrate method (Misra and Puri 1954). The quadrate (0.25 m^2) was thrown randomly at four places in each plot at 30, 60, 90 DAS and harvest. The weeds inside the quadrate were counted and the average of four quadrates was taken. The actual values were subjected to square root transformation ($\sqrt{x+1}$) for analysis as suggested by Bartlett (1947) and Blackman and Roberts (1950). The weeds present within the quadrate from two places selected at random from each plot were taken for dry matter accumulation 30, 60, 90 DAS and at harvest. These samples were first dried under the sun and then kept in oven at 65±5^{0}C until a constant weight was achieved. The dried samples were weighed and the final dry weight of *P. minor* was expressed as g/m^2.

Visual phyto-toxicity on crop was recorded on 10 and 20 days after herbicide spray using 0-100 scale (where 0 = no mortality and 100 = complete mortality). Effective tillers were counted before harvest from one meter length of crop row at three places per plot, which were already marked for all replications. All other yield attributing characters, *viz.* number of grains/spike, test weight, grain yield and biological yield were recorded at harvest. To judge significant differences between means of two treatments, the critical difference (C.D.) was worked out by analysis of variance technique given by Fisher (1958).

Effect on weeds

All the weed control treatments significantly reduced density and dry weight of weeds as compared to untreated check at 90 DAS. The impact of various herbicide treatments on *P. minor* was taken through their impact on visual control, weed control efficiency, dry weight and weed density per square meter. It was visually observed that the sequential herbicide treatments had significant advantage over alone pre- or post-emergence herbicide treatments in controlling *P. minor*. The highest visual weed control (83%) at 90 DAS was observed with pendimethalin + metribuzin (RM) *fb* mesosulfuron + iodosulfuron (RM) at 2000 g/ha and 14.4 g/ha, respectively (**Table 1**). All the herbicide treatments significantly decreased the weed density and dry weight of *P. minor* than the weedy plots. The density of *P. minor* was significantly decreased with the successive use of pendimethalin + metribuzin (RM) 2000 g/ha *fb* PoE sulfosulfuron + metsulfuron (RM) 32 g/ha or sulfosulfuron 25 g/ha or pinoxaden 50 g/ha. Although, the lowest weed density and dry-matter was recorded with the use of pendimethalin + metribuzin (RM) *fb* mesosulfuron + iodosulfuron (RM) at 2000 g/ha and 14.4 g/ha and proved better among different treatments (**Table 1**). The post-emergence application of clodinafop 60 and 120 g/ha remained less effective than pre-emergence application of pendimethalin 1.5 kg/ha alone and pendimethalin + metribuzin (RM) 2000 g/ha, alone and had higher values for density and dry weight of weeds certainly due to occurrence of resistance problem. This is in conformity with the results of Punia *et al.* (2017) which reported that pre-emergence application of pendimethalin or pendimethalin + metribuzin (RM) although provided acceptable control of *P. minor,* however not adequate to control second flush of weeds after first irrigation.

Weed control efficiency (WCE) and weed index (WI) are vital parameters to assess the execution of various weed control treatments. At 90 DAS, highest weed control efficiency (87-94%) was obtained in treatments receiving sequential application of PE pendimethalin + metribuzin (RM) 2000 g/ha *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha sulfosulfuron + metsulfuron 32 g/ha /sulfosulfuron 25 g/ha and pinoxaden 50 g/ha (**Table 1**). Among herbicides, the lowest weed control efficiency was recorded in plots treated with clodinafop at 60 and 120 g/ha. The sequential application of pendimethalin + metribuzin (RM) 2000 g/ha *fb* mesosulfuron + iodosulfuron 14.4 g/ha or sulfosulfuron or alone mesosulfuron + iodosulfuron had lower weed index values while weedy treatment followed by different dose of clodinafop 60, 120 g/ha had maximum values of weed index due to low yield obtained on account of poor control of *P. minor* (**Table 1**).

Effect on crop

Visual phyto-toxicity recorded at 10 and 20 days after spraying of herbicides indicated that there were phytotoxic symptoms of few post-emergence herbicide treatments on wheat crop (0-100 scale). Among the herbicides treatment, mesosulfuron + iodosulfuron (RM) 14.4 g/ha caused to 5 and 3.43% phyto-toxicity at 10 and 20 DAS. The sequential application of pendimethalin + metribuzin (RM) 2.0 kg/ha *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha also showed phytotoxicity of 5.0 and 2.0 per cent at 10 and 20 DAS, respectively on wheat and the phytotoxic symptoms in both the treatments disappeared with time and there was no phytotoxic symptoms on crop at 40 DAS. The data presented in **Table 2** revealed that weed control treatments significantly affected the effective tillers in wheat. Weed free treatment resulted in the highest number of effective tillers (456/m^2) whereas weedy check resulted in significantly the lowest number of effective tillers (408/m^2). Pre-emergence application of pendimethalin + metribuzin (RM) 2000 g/ha *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha (452/m^2) followed by post-emergence mesosulfuron + iodosulfuron (RM) alone 14.4 g/ha (439/m^2), pendimethalin + metribuzin (RM) 2000 g/ha *fb* pinoxaden 50 g/ha (436/m^2) produced higher number of effective tillers over other herbicide treatments and remained at par with weed free check. Post-emergence application of clodinafop 60 g/ha (409/m^2) and 120 g/ha (417/m^2) being at par with sulfosulfuron 25 g/ha (426/m^2) produced significantly the lowest number of effective tillers. This might be credited to viable weed control prompting less management challenge from weeds. Consequently, the wheat plants could completely use the accessible assets of space, sunlight based radiation, soil dampness and supplements bringing about improved photosynthesis and increasingly dry weight aggregation (Kaur *et al.* 2015).

Table 1. Effect of different treatments on visual control, density, dry matter of *P. minor*, WCE at 90 DAS and weed index

Treatment	Visual control of *P. minor* (%) 90 DAS	*P. minor* density (no./ m^2) 90 DAS	Dry matter (g/m^2) 90 DAS	Weed control efficiency (%) 90 DAS	Weed index (%)
Pendimethalin (1500 g/ha) PE	40	2.20(3.83)	66.64	51	12.31
Clodinafop (60 g/ha) at 35 DAS	24	2.33(4.43)	72.08	47	28.14
Clodinafop (120 g/ha)at 35 DAS	35	2.30(4.28)	62.56	54	25.01
Sulfosulfuron (25 g/ha) at 35 DAS	40	2.11(3.46)	46.24	66	9.41
Sulfosulfuron + metsulfuron (RM) (32 g/ha) at 35 DAS	48	2.16(3.66)	40.80	70	7.88
Pinoxaden (50 g/ha) at 35 DAS	52	2.22(3.93)	29.92	78	11.76
Mesosulfuron + iodosulfuron (RM)(14.4 g/ha) at 35 DAS	62	2.07(3.29)	16.32	88	2.30
Pendimethalin + metribuzin (2000 g/ha) PE	57	2.33(4.43)	38.08	72	6.89
Pendimethalin + metribuzin *fb* clodinafop (2000 *fb* 60 g/ha) PE at 35 DAS	53	2.10(3.43)	55.68	60	13.80
Pendimethalin + metribuzin *fb* sulfosulfuron (2000 *fb* 25 g/ha) PE at 35 DAS	61	2.17(3.72)	17.18	87	1.89
Pendimethalin + metribuzin *fb* sulfosulfuron + metsulfuron (2000 *fb* 32 g/ha) PE at 35 DAS	78	2.03(3.12)	13.96	89	3.07
Pendimethalin + metribuzin *fb* pinoxaden (2000 *fb* 50 g/ha) PE at 35 DAS	77	2.11(3.46)	13.6	90	4.34
Pendimethalin + metribuzin *fb* mesosulfuron + iodosulfuron (2000 *fb* 14.4 g/ha) PE at 35 DAS	83	2.02(3.10)	8.16	94	1.21
Weedy check	0	3.21(9.30)	136	0	39.72
Weed free	100	1.0(0)	0	100	0
LSD (p=0.05)		0.10	5.58		

Table 2. Effect of different treatments on crop phyto toxicity, yield attributes, grain yield and B: C ratio

Treatment	Phytotoxicity (%) on crop			No. of effective tillers/m^2	No. of grains/spike	Grain yield (t/ha)	B:C ratio
	10 DAS	20 DAS	40 DAS				
Pendimethalin (1500 g/ha) PE	0	0	0	429	47.95	4.77	2.06
Clodinafop (60 g/ha) at 35 DAS	0	0	0	409	46.55	3.91	1.61
Clodinafop (120 g/ha)at 35 DAS	0	0	0	417	46.91	4.08	1.65
Sulfosulfuron (25 g/ha) at 35 DAS	0	0	0	426	48.85	4.93	2.17
Sulfosulfuron + metsulfuron (RM) (32 g/ha) at 35 DAS	0	0	0	435	48.88	5.01	2.17
Pinoxaden (50 g/ha) at 35 DAS	0	0	0	433	49.57	4.90	2.09
Mesosulfuron + iodosulfuron (RM)(14.4 g/ha) at 35 DAS	5	3.43	0	435	49.78	5.22	2.31
Pendimethalin + metribuzin (2000 g/ha) PE	0	0	0	432	49.56	5.07	2.02
Pendimethalin + metribuzin *fb* clodinafop (2000 *fb* 60 g/ha) PE at 35 DAS	0	0	0	424	48.05	4.69	1.67
Pendimethalin + metribuzin *fb* sulfosulfuron (2000 *fb* 25 g/ha) PE at 35 DAS	0	0	0	439	49.80	5.27	2.06
Pendimethalin + metribuzin *fb* sulfosulfuron + metsulfuron (2000 *fb* 32 g/ha) PE at 35 DAS	0	0	0	432	48.61	5.35	2.11
Pendimethalin + metribuzin *fb* pinoxaden (2000 *fb* 50 g/ha) PE at 35 DAS	0	0	0	436	49.36	5.20	1.97
Pendimethalin + metribuzin *fb* mesosulfuron + iodosulfuron (2000 *fb* 14.4 g/ha) PE at 35 DAS	5	2	0	452	50.33	5.41	2.13
Weedy check	0	0	0	408	45.73	3.28	1.14
Weed free	0	0	0	456	50.49	5.44	1.19
LSD (p=0.05)				43.50	4.92	0.48	

Weeds growing throughout the crop-growing season significantly reduced the grain yield of wheat to the extent of 43-45%. All the herbicide treatments gave significantly higher grain yield as compared to weedy check. The sequential application of pendimethalin + metribuzin (RM) 2000 g/ha *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha recorded significant increase in grain yield (38-39%) over weedy check, and produced higher grain yield (5.41 t/ha) comparable to weed free (5.44 t/ha). Pre-emergence application of pendimethalin + metribuzin (RM) 2000 g/ha *fb* sulfosulfuron 25 g/ha (5.34 t/ha) being at par with PoE mesosulfuron + iodosulfuron 14.4 g/ha (5.22 t/ha) and produced higher grain yield than weedy check. Higher grain yield was attributed to the higher yield attributing characters in the weed free and herbicide treated plots. Application of pendimethalin + metribuzin 2000 g/ha (PE) *fb* mesosulfuron + iodosulfuron 14.4 g/ha (PoE) recorded the highest benefit: cost ratio (2.13).

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