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Control of *Phalaris minor* with sequential application of pre- and post-emergence herbicides and herbicide combinations in wheat

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ABSTRACT

The field efficacy of pre- and post-emergence herbicides and rotational use of different group of herbicides were tested against *Phalaris minor* in wheat on farmers' fields during the year 2015-16 and 2016-17. Clodinafop is being used by 64% farmers at Makowal and 44% at village Mallu Nangal from the last five years. None of the farmer was using pre-emergence herbicide. The higher herbicide dose (76% at site I and 80% at site II) coupled with hallow cone nozzle and less quantity of water (200-225 l/ha) resulted in poor control of *P.minor*. At site I, continuous use of clodinafop resulted in poor weed control efficiency (58.7%) with lower grain yield (4.46 t/ha). Sequential application of pre-emergence herbicide pendimethalin followed by post-emergence application of clodinafop provided effective control of *P.minor* (WCE 76.8%) and significantly higher yield (5.1 t/ha) over the existing farmers' practices (2 sprays of clodinafop at 45 and 65 DAS). At the second site,compared to clodinafop with pendimethalin, mesosulfuron + iodosulfuron, fenoxaprop + metribuzin or sulfosulfuron resulted into higher yield with effective weed control efficiency. Highest yield was recorded with spray of mesosulfuron + iodosulfuron (5.1 t/ha) which was statistically at par with pendimethalin (5.06 t/ha), fenoxaprop+ metribuzin (5.01 t/ha) and sulfosulfuron at 15 DAS (4.98 t/ha).

INTRODUCTION

Wheat (*Triticum* aestivum L.) is an important cereal crop in India. This crop has competition with several grassy and broad-leaf weeds during its growth period depending upon the adopted agronomic practices, soil types, underground water quality, weed control techniques and cropping system followed. *Phalaris minor* has become the most dominant weed of wheat in the rice-wheat cropping system (RWCS) in the north-western Indo-Gangetic Plains of India.

Several groups of herbicides with different mode of action have been evuauluated and recommended after evolution of resistance in *P. minor* biotypes against isoprotouron. The herbicides, *viz.* clodinafop, sulfosulfuron and fenoxaprop were recommended to control isoproturon resistant population of *P. minor* during1997-98. These herbicides provided effective control of this weed up to 2007 (Chhokar and Sharma 2008) and improved the productivity of wheat. However, due to the continuous use of these herbicides, *P. minor* also evolved resistance against them (Dhawan *et al.* 2009). Presently, its control has become even more difficult after it evolved multiple herbicide resistance to recommended herbicides: diclofop-methyl, fenoxaprop-p-ethyl, clodinafop-propargyl, pinoxaden (ACCase); sulfosulfuron and pre-mix of mesosulfuron + iodosulfuron (ALS inhibitors); mediated by enhanced metabolism and target site mutations (Dhawan *et al.* 2012). This multiple herbicide resistant populations of *P. minor* in wheat in RWCS was again threatened wheat productivity and profitability. During surveys and meeting with farmers, it was reported that the herbicide resistance in weeds evolved due to non following of herbicide rotation, wrong time and method of herbicide application. If one herbicide stops working, farmers only change the brand, not the group of the herbicides. This indicated the need for intervention of herbicides with different mode of action in the rotation or sequential application for control of complex weed flora in wheat.

Tank-mix or pre-mix use of different herbicide chemistries or sequential application of pre- and post-emergence herbicides at different times showed effective weed control (Baghestani *et al.* 2008). Hence, the present investigation was carried out to evaluate the efficacy of pre- and post-emergence herbicides and their combination against *P. minor*, and also on productivity and profitability of wheat.

MATERIALS AND METHODS

To control the *Phalaris minor* in wheat, two farmers' participatory field experiments were conducted in winter season during the year 2015-16 and 2016-17 in the villages Makowal (Site-1) and Mallu Nangal (Site-2) of Amritsar District, Punjab. Before conducting these experiments, a survey was conducted in which 50 farmers are interviewed for the different aspects of weed control in wheat. On the basis of this survey, two different scenarios were selected. In the first scenario, farmers were using wrong time of application with wrong dose of herbicide and in the second scenario, farmers were using same group of herbicide from last five years. Farmers of these blocks were selected as the mixing of herbicides and two sprays of same herbicides was very common scene. But the wrong mixing of herbicides was harming the wheat crop. So farmers were guided to choose the compatible herbicides with right dose for getting the good results. The detail of the treatments has been given below:

Site 1: Affected with clodinafop resistance in *P. minor*

Seven different treatments *i.e.* Pendimethalin pre-emergence (PE) at 0.75 kg/ha, pendimethalin PE *fb* clodinafop post-emergence (PoE) at 0.75 kg + 0.06 kg/ha, clodinafop at 30 DAS at 0.06 kg/ha, two sprays of clodinafop at 45 and 65 DAS at 0.06 + 0.06 kg/ha, clodinafop + metribuzin (PoE tank mix) 0.06 + 0.123 kg/ha, weed free and weedy check were replicated three times.

Site 2: Herbicide rotation is not followed

Eight different treatments, *viz*. pendimethalin PE 0.75 kg/ha, pendimethalin (PE) *fb* mesosulfuron + idosulfuron (PoE) 0.75kg + 0.0144 kg/ha, sulfosulfuron (PoE) at 15 DAS 0.025 kg/ha), fenoxaprop +metribuzin (PoE) 0.1 kg/ha, clodinafop applied twice at 45 and 65 DAS 0.06 + 0.06 kg/ha, clodinafop +metribuzin (PoE tank mix) 0.06 +0.123 kg/ha, weed free and weedy check were replicated thrice.

The experiments were laid out in randomized complete block design with a plot size of 20 x 8 m. Small untreated plots (5 x 5 m)were also maintained during both the years in which herbicides were not sprayed. In both the years and both sites, wheat cultivar '*HD 2967*' was sown with seed rate 100 kg/ha at 22.5 cm spacing. All the herbicides were sprayed with battery operated knapsack sprayer fitted with flat fan nozzle using spray volume of 375 l/ha at 40 psi pressure. The data on weed density were recorded by placing 1.0 x 1.0 m quadrant at two places randomly per plot at harvest and were subjected to square root transformation before statistical analysis. Weed count data were taken after herbicide spray at 65 DAS. Weed control efficiency was calculated as given below:

$$\text{Weed control efficiency (\%)} = \frac{\text{weed count in control plot-} \ \text{weed count in treatment plot}}{\text{weed count in control plot}} \times 100$$

The data were analyzed by using standard statistical procedures and comparisons were made at 5% level of significance.

RESULTS AND DISCUSSION

Survey data showed the trend of weed management practices at both experimental sites

Table 1. Survey data on herbicidal use at two locations in wheat in Amritsar district of Punjab, India

Particulars	2015-16 (% farmers)	
	Makowal	Mallu Nangal
Dose of herbicide use		
- Application at recommended dose	24	20
- Application at lower than	-	-
recommended dose	76	80
- Application at higher than		
recommended dose		
Herbicide use from last five years		
- Clodinafop	64	44
- Sulfosulfuron+ metsulfuron	10	10
- Sulfosulfuron	-	26
- Metribuzin	26	22
- Fenoxaprop	-	-
- Mesosulfuron+iodosulfuron	-	-
- Pendimethalin	-	-
Crop Rotation		
- Rice-wheat	100	100
- other	-	-
Application time		
- Application at recommended time	34	26
- Application after recommended time	66	74
Type of nozzle use		
- Flat fan	24	22
- Flood- zet	14	26
- Hollow cone	42	52
Type of spray pump		
- Power operated knap-sack spray	70	96
pump	30	4
- Manual operated spray pump		
Quantity of water used for herbicide		
spray	50	46
- 200l/ha	34	36
- 225l/ha	16	18
- 300l/ha	-	-
- 375l/ha		

(**Table 1**). Farmers used 76 to 80% higher dose of herbicide than the recommended dose, which led to development of resistance in *P. minor*. This practice was also coupled with delayed spraying time (66% at village Makowal and 74% at village Mallu Nangal) and use of hallow cone nozzle (42-52%). Less use of water for herbicide spray could also be another reason for poor control and phototoxic effect of herbicide on the crop as no farmer at both the sites used the recommended quantity of water. Continuous use of one herbicide from many years was the major reason for the resistance in *P. minor*. Clodinafop followed by the metribuzin was the favorite choice of the farmers. None of the farmer used pre-emergence herbicide (pendimethalin) and other group of herbicide like fenoxaprop, mesosulfuron + iodosulfuron. Sulfosulfuron + metsulfuron was the choice of only 10% farmers at both sites. Unrecommended herbicide metribuzin was used by 22-26% of the farmers, but it caused toxicity in the wheat crop.

At Site-1 (**Table 2**), it was found that the sequential application of pre-emergence herbicide pedimethalin at 0.75 kg/ha followed by post-emergence application of clodinafop at 0.06 kg/ha had good control on *P. minor* (77.7%) and it was at par with single spray of pre-emergence herbicide (68.3%). The sequential application of pre- and post-emergence herbicide treatment had significantly higher yield (5.33 t/ha) over the farmers' practice (two sprays of clodinafop at 45 and 60 DAS and tank mix application of clodinafop + metribuzin 4.23 and 4.8 t/ha respectively). Pre-emergence application of pendimethalin had no significant higher yield (7.1 %) over the tank mix application of unrecommended herbicides clodinafop + metribuzin though it had 70.8% weed control efficiency but the grain yield was lower due to the toxicity on the crop. The results

Table 2. Effect of different weed control treatments on weeds and grain yield of wheat (pooled data of 2015-16 and 2016-17) at site I

Treatment	Dose (kg/ha)	*P. minor* count at 65 DAS (m^2)	Dry weight of *P. minor* at harvest (g/m^2)	Weed control efficiency (%)	Grain yield (t/ha)
Pendimethalin PE	0.75	3.68(12.7)	4.46(19.0)	68.3	5.17
Pendimethalin (PE) *fb* clodinafop (PoE)	0.75+0.06	3.31(10.0)	3.78(13.3)	77.7	5.33
Clodinafop at 30 DAS	0.06	4.27(17.3)	5.05(25.0)	58.7	4.46
Two sprays of clodinafop at 45 and 65 DAS (Farmers' practice)	0.06+0.06	4.02(15.3)	5.96(35.0)	42.8	4.23
Clodinafo+metribuzin (PoE tank mix) (Farmers' practice)	0.06 +0.123	3.68(12.7)	4.31(17.7)	70.8	4.80
Weed free	-	1.0(0)	1.0(0)	100	5.46
Weedy	-	5.67(31.0)	7.83(60.7)	0	2.80
LSD (p=0.05)	-	0.55	0.82	11.9	0.38

PE: Pre-emergence, PoE: Post-emergence, *fb*: followed by; Figures in the parentheses are means of original values subjected of square root transformation $(\sqrt{x+1})$

Table 3. Effect of different weed control treatments on weeds and grain yield of wheat (pooled data of 2015-16 and 2016-17) at site II

Treatment	Dose (kg/ha)	Counts of *P. minor* at 65 DAS (m^2)	Dry weight of *P. minor* (g/m^2) at harvest	Weed control efficiency (%)	Grain yield (t/ha)
Pendimethalin PE	0.75	3.35(10.3)	4.71(21.3)	70.9	5.06
Mesosulfuron+iodosulfuron (PoE)	0.75 +0.0144	3.18(9.33)	4.20(17.0)	76.8	5.10
Sulfosulfuron (PoE) at 15 DAS	0.025	3.5(11.33)	4.61(20.3)	72.7	4.98
Fenoxaprop +metribuzin (PoE)	0.1	3.46(11.0)	4.75(21.6)	70.9	5.01
Clodinafop (PoE)	0.06	4.11(16.0)	5.90(34.0)	54.5	4.37
Clodinafop +metribuzin (PoE tank mix)	0.06 +0.123	3.49(11.33)	5.24(26.7)	64.3	4.47
Weed free	-	1.0(0)	1.00(0)	100.0	5.23
Weedy	-	5.9(34.0)	8.70(75.0)	0.00	2.83
LSD (p=0.05)	-	0.63	0.78	8.56	0.42

PE: Pre-emergence, PoE: Post-emergence, *fb*: followed by; Figures in the parentheses are means of original values subjected of square root transformation $(\sqrt{x+1})$

of Kaur *et al* (2017) also support this study. So the sequential application of pre-emergence followed by post-emergence herbicide proved effective.

Similarly at Site-2 (**Table 3**), herbicidal combination proved effective for controlling the *P. minor*. Pre-emergence application of pendimethalin, post-emergence application of mesosulfuron + iodosulfuron and fenoxaprop + metribuzin and sulfosulfuron at 15 DAS being at par with each other resulted in higher values of weed control efficiency and grain yields over the farmers' practices *i.e.* application of clodinafop or tank mix clodinafop + metribuzin. These results are in conformity with the earlier findings by Punia *et al.* (2017).

It was concluded that for the effective weed control and to manage resistance in *Phalaris minor* sequential application of pre-emergence followed by post-emergence herbicides was a good option. Similarly the herbicidal rotation of mesosulfuron + iodosulfuron and fenoxaprop + metribuzin and sulfosulfuron at 15 DAS proved good control over the *Phalaris minor.*

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