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# Management of herbicide resistant *Phalaris minor* in wheat

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**ABSTRACT**

Field experiment was conducted at CCS Haryana Agricultural University during *Rabi* 206-17 and 2017-18 to evaluate bio-efficacy of different herbicides and their combination against cross resistant *P. minor* in wheat, and to study the phytotoxic effects on the crop, if any. The treatments included application pre-emergence herbicides pendimethalin 1500 g/ha and its mixture with metribuzin 175 g/ha alone, pendimethalin + pyroxasulfone Tank mix (TM) at 1500 + 102 g/ha alone and their sequential application with post-emergence herbicides application (PoE) of mesosulfuron + iodosulfuron ready mix (RM) 14.4 g/ha and pinoxaden 60 g/ha along with weedy check treatment. The minimum density of *P. minor,* weed biomass and the highest wheat grain yield was observed with pendimethalin + pyroxasulfone TM *fb* mesosulfuron+ iodosulfuron RM (1500 + 102 *fb* 14.4 g/ha). All the herbicides significantly reduced the weed biomass as compared with the control but maximum reduction in the weed biomass was achieved with pendimethalin + pyroxasulfone TM *fb* mesosulfuron+ iodosulfuron RM. Pinoxaden at 60 g/ha did not control *Rumex dentatus* and *Chenopodium album.* Only pre-emergence application of metribuzin, pendimethalin + metribuzin (before sowing), pinoxaden + metribuzin TM caused toxicity of up to 5% at 10 days after treatment (DAT). The wheat recovered from toxicity by 20 DAT without any yield penalty. On-farm demonstrations of pyroxasulfone at 127.5 g/ha PE in Haryana revealed 88.3 % control of multiple herbicide resistant *P. minor.* Its integration with pendimethalin at 1.5 kg/ha (PE) and post-emergence herbicides at 35 DAS has improved control of *P. minor* to 92.1%.

## INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second most important food grain of India with an area of 29.6 million ha, a production of 99.8 million tones, and an average productivity of 3.37 t/ha (Anonymous 2018-19). Haryana is the major wheat growing state in India with an area, production and productivity of 2.5 million ha, 11.5 million tons, and 4.51 t/ha, respectively (Anonymous 2016-17). *Phalaris minor* Retz. (little seed canarygrass) is the dominant and troublesome grass weed of wheat in rice-wheat cropping system in the north-western Indo-Gangetic Plains of India. Evolution of resistance in *P. minor* against isoproturon in the early 1990s was considered as one of the most serious cases of herbicide resistance in the world resulting in total crop failure under heavy infestation. The $GR_{50}$ (dose of a herbicide required to cause 50% growth reduction) of isoproturon in resistant biotypes of *P. minor* from different parts of Haryana was reported to increase by 2-11 times as compared to its susceptible populations (Yadav *et al.* 1996, Malik and Yadav 1997, Chhokar and Malik 2002). Therefore, the existing recommendation of isoproturon against *P. minor* was replaced by four new herbicides (clodinafop, sulfosulfuron, fenoxaprop) in resistance affected areas. Clodinafop 60 g/ha, fenoxaprop 120 g/ha, sulfosulfuron 25 g/ha applied at three leaf stage reduced the dry weight of resistant and susceptible biotypes by 82-95% (Yadav *et al.* 2004, Yadav and Malik 2005). Complaints of poor efficacy of these alternate herbicides started appearing at farmers' fields after their continuous use. Even the repeated application of these herbicides or their application at higher doses failed to provide satisfactory control of resistant population of *P. minor*.

Pyroxasulfone is a new pre-emergence herbicide that provides effective control of *P. minor* including populations with evolved resistance to multiple herbicide modes of action (Busi *et al.* 2012). Pyroxasulfone inhibits multiple steps in the elongation of very-long-chain fatty acids (VLCFA) in susceptible seedlings, with excellent selectivity in several crops such as wheat, maize and soybean (Tanetani *et al.* 2009) The present study was conducted with the objectives of evaluating the efficacy of different herbicide mixtures and their sequential application for control of resistant *P. minor* in wheat and to study the phytotoxic effects on the crop, if any.

## MATERIALS AND METHODS

A field experiment was conducted during *Rabi* 2016-17 and 2017-18 at CCS HAU Hisar which is isituated at a iheight of iabout 215.2 m above mean sea level with latitude iof 29º10' in the North and longitude of 75º46' in ithe East iin ithe subtropical zone. The soil of the experimental field was sandy loam in texture, low in available N, medium in P and high in K with slightly alkaline in reaction (pH 8.2). The treatments included pre-emergence (PE) application of pendimethalin 1500 g/ha and mixture with metribuzin 175 g/ha alone, pendimethalin + pyroxasulfone (TM) at 1500 + 102 g/ha alone and their sequential post-emergence herbicides application (PoE) of mesosulfuron + iodosulfuron (RM) 14.4 g/ha and pinoxaden 60 g/ha. Herbicides were applied using 375 L/ha through knapsack sprayer fitted with flat-fan nozzle. The experiment was laid out in a randomized block design. Wheat cultivar '*HD 2967*' was sown on November 12th and November 19th, during 2016 and 2017, respectively at a row spacing of 20 cm using seed rate of 100 kg/ha. The weed density ($m^2$) was recorded at 30 and 60 days after treatment (DAT) during both the years. From each plot, one square meter area was selected at random for recording number of tillers, weed density and grain yield. Phyto-toxicity in terms of chlorosis, stunting, leaf burning and epinasty was recorded at 10 and 20 DAT. Data collected was analyzed statistically using analysis of variance and least significantly difference (LSD) at 5% probability level to compare treatment means.

The efficacy of pyroxasulfone 127.5 g/ha was assessed at farmers' fields too. Seven demonstrations were organized in rice-wheat growing areas of state, and it was compared with pre-emergence application of pendimethalin 1.5 kg/ha and recommended post-emergence herbicides during *Rabi* 2017-18.

## RESULTS AND DISCUSSION

The major species identified in the experimental field were *Phalaris minor, Rumex dentatus* and *Chenopodium album* during both the years.

The weed density was significantly affected by different pre- and post-emergence herbicides. The minimum *P. minor* density (**Table 1**), weed biomass and higher weed control efficiency (**Table 2**) at 30 DAT and 60 DAT was recorded during both the years with pendimethalin + pyroxasulfone (TM) *fb* mesosulfuron + iodosulfuron (RM) (1500+102 *fb* 14.4 g/ha).

**Table 1. Effect of different treatments on weeds density (no./m²) in wheat (2016-17 and 2017-18)**

| Treatment | *P. minor* | | | | *Rumex dentatus* | | | | *Chenopodium album* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | | 2017 | | 2016 | | 2017 | | 2016 | | 2017 | |
| | 30 DAT | 60 DAT | 30 DAT | 60 DAT | 30 DAT | 60 DAT | 30 DAT | 60 DAT | 30 DAT | 60 DAT | 30 DAT | 60 DAT |
| Pendimethalin (1500 g/ha) PE | 5.9 (33.4) | 9.5 (90.0) | 5.6 (31.3) | 9.4 (86.7) | 1.0 (0) | 1 (0) | 1.4 (1.0) | 1.0 (0) | 1.8 (2.4) | 1.3 (0.7) | 1.6 (2.0) | 1.2 (0.6) |
| Metribuzin (210 g/ha) PE | 5.6 (30.2) | 9.5 (88.4) | 5.4 (28.7) | 9.3 (86.0) | 1.2 (0.4) | 1.1 (0.3) | 1.1 (0.3) | 1.0 (0) | 1.7 (1.8) | 1.3 (0.7) | 1.6 (2.0) | 1.2 (0.6) |
| Pendimethalin + metribuzin (1500+175 g/ha) PE | 4.2 (16.3) | 9.1 (81.4) | 4.2 (17.0) | 8.6 (78.7) | 1.4 (1.0) | 1.0 (0) | 1.0 (0) | 1.1 (0.3) | 1.0 (0) | 1 (0) | 1.0 (0) | 1.0 (0) |
| Pendimethalin + metribuzin *fb* pinoxaden (1000 + 175 *fb* 60 g/ha) PE *fb* PoE | 4.6 (20.4) | 8.4 (70.2) | 4.4 (19.3) | 8.3 (68.7) | 1.0 (0) | 1.1 (0.3) | 1.0 (0) | 1.0 (0) | 1.5 (1.4) | 1.0 (0) | 1.5 (1.3) | 1.0 (0) |
| Pendimethalin + metribuzin *fb* mesosulfuron + iodosulfuron (1000 + 175 *fb* 14.4 g/ha) PE *fb* PoE | 4.2 (16.4) | 7.8 (59.6) | 4.0 (15.3) | 7.5 (57.3) | 1.1 (0.3) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.4 (1.0) | 1.0 (0) | 1.0 (0) | 1.0 (0) |
| Pendimethalin + pyroxasulfone (1500+102 g/ha) PE | 3.1 (8.4) | 5.2 (25.8) | 2.6 (7.3) | 5.1 (26.7) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.1 (0.3) | 1.1 (0.4) | 1.1 (0.3) | 1.1 (0.3) |
| Pendimethalin + pyroxasulfone *fb* pinoxaden (1500+102 *fb* 60 g/ha) PE *fb* PoE | 2.6 (5.6) | 4.8 (22.2) | 2.2 (4.3) | 4.5 (20.0) | 1.1 (0.3) | 1.1 (0.3) | 1.0 (0) | 1.0 (0) | 1.4 (1.0) | 1.0 (0) | 1.3 (1.0) | 1.0 (0) |
| Pendimethalin + pyroxasulfone *fb* mesosulfuron+ iodosulfuron (1500+102 *fb* 14.4 g/ha) PE *fb* PoE | 2.3 (4.4) | 4.7 (21.7) | 2.2 (4.3) | 4.6 (20.0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.2 (0.4) | 1.0 (0.2) | 1.1 (0.3) | 1.0 (0) |
| Pendimethalin + metribuzin *fb* pinoxaden (1500+175 *fb* 60 g/ha) before sowing *fb* PoE | 5.2 (26.4) | 8.3 (67.8) | 5.0 (24.3) | 7.3 (66.7) | 1.1 (0.3) | 1.1 (0.3) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) |
| Sulfosulfuron *fb* pinoxaden (25 *fb* 60 g/ha) BI *fb* PoE | 5.5 (29.9) | 11.3 (121.7) | 5.4 (28.7) | 10.9 (118.7) | 1.9 (2.7) | 1.7 (1.7) | 1.9 (3.0) | 1.0 (0) | 1.4 (1.0) | 1.0 (0) | 1.5 (1.3) | 1.0 (0) |
| Pinoxaden (60 g/ha) PoE | 4.8 (22.3) | 11.4 (128.4) | 4.5 (21.0) | 11.2 (126.7) | 2.7 (6.4) | 1.9 (2.7) | 2.4 (5.0) | 1.5 (1.3) | 2.9 (7.3) | 1.5 (1.4) | 2.9 (8.3) | 1.7 (2.0) |
| Pinoxaden + metribuzin (50+120 g/ha) PoE | 4.4 (18.4) | 9.4 (88.2) | 4.5 (19.7) | 9.3 (86.6) | 1.1 (0.3) | 1.2 (0.4) | 1.1 (0.3) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) |
| Pinoxaden + metribuzin (50+150 g/ha) PoE | 3.9 (14.3) | 8.5 (71.6) | 3.9 (15.7) | 8.5 (72.0) | 1.2 (1.4) | 1.6 (1.7) | 1.1 (0.3) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) |
| Mesosulfuron + iodosulfuron (14.4 g/ha) PoE | 4.6 (20.6) | 9.1 (80.2) | 4.6 (22.3) | 9.1 (82.6) | 1.1 (0.3) | 1.0 (0) | 1.1 (0.3) | 1.1 (0.3) | 1.1 (0.3) | 1.1 (0.3) | 1.0 (0) | 1.0 (0) |
| Weedy check | 6.5 (41.4) | 12.4 (154.4) | 6.2 (38.3) | 12.5 (157.3) | 2.8 (7.2) | 1.2 (0.5) | 2.4 (6.0) | 1.1 (0.3) | 3.1 (8.4) | 1.6 (2.5) | 3.5 (12) | 1.4 (1.3) |
| Weed free | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) |
| LSD (p=0.05) | 1.5 | 2.7 | 1.8 | 3.1 | 0.7 | 0.2 | 0.7 | 0.2 | 0.72 | 0.4 | 0.7 | 0.4 |

Pre-emergence application of pendimethalin + pyroxasulfone (RM) at 1500 + 102 g/ha either alone or followed by sequential use of pinoxaden 60 g/ha , meso + iodosulfuron (RM) 14.4 g/ha at 35 DAS caused significant reduction in density *P. minor* and provided 83-93% control of *P. minor* as reported earlier (Punia *et al.* 2018)

Above treatment also showed significant result for the control of broad leaf weed such as *Rumex dentatus* and *Chenopodium album*. *Rumex dentatus* was fully controlled with the application of this treatment. These results were in conformity with Singh *et al.* (2011) who reported that tank mix application of metsulfuron + carfentrazone provided 92% control over broad-leaf weeds. Pinoxaden at 60 g/ha did not provide any control of *R. dentatus* and *C. album* and this was in line with the finding of Singh *et al.* (2011). There was significant increase in number of tillers/ $m^2$ and wheat grain yield with pendimethalin + pyroxasulfone (TM) *fb* mesosulfuron +

**Table 2. Effect of different treatments on weed biomass and weed control efficiency in wheat (2016-17 and 2017-18)**

| Treatment | Weed biomass (g/m$^2$) | | | | Weed control efficiency (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2016 | | 2017 | | 2016 | | 2017 | |
| | 30 DAT | 60 DAT | 30 DAT | 60 DAT | 30 DAT | 60 DAT | 30 DAT | 60 DAT |
| Pendimethalin (1500 g/ha) PE | 4.3(17.4) | 20.2(410.4) | 4.12 (16.1) | 19.4 (401.6) | 49.7 | 47.69 | 56.3 | 49.6 |
| Metribuzin (210 g/ha) PE | 4.3(18.2) | 20.6(424.1) | 4.64 (20.6) | 20.36(418.7) | 47.3 | 45.9 | 43.9 | 47.4 |
| Pendimethalin + metribuzin (1500+175 g/ha) PE | 4.4(18.4) | 19.0(360.2) | 3.94(14.8) | 19.2(372.9) | 46.9 | 54.0 | 59.7 | 53.2 |
| Pendimethalin + metribuzin *fb* pinoxaden (1000 + 175 *fb* 60 g/ha) PE *fb* PoE | 4.2(16.6) | 18.4(340.7) | 3.64(12.2) | 18.1(328.7) | 51.9 | 56.5 | 66.7 | 52.4 |
| Pendimethalin + metribuzin *fb* mesosulfuron + iodosulfuron (1000 + 175 *fb* 14.4 g/ha) PE *fb* PoE | 3.2(9.6) | 16.15(260.1) | 3.37(10.4) | 15.8(257.0) | 72.3 | 66.8 | 71.7 | 67.4 |
| Pendimethalin + pyroxasulfone (1500+102 g/ha) PE | 2.7(6.4) | 10.06(100.2) | 2.48(5.9) | 9.9 (98.8) | 81.5 | 87.2 | 83.8 | 87.6 |
| Pendimethalin + pyroxasulfone *fb* pinoxaden (1500+102 *fb* 60 g/ha) PE *fb* PoE | 2.5(5.4) | 9.8(96.3) | 2.35(4.5) | 9.5 (89.6) | 84.4 | 87.7 | 87.5 | 88.7 |
| Pendimethalin + pyroxasulfone *fb* mesosulfuron+ iodosulfuron (1500+102 *fb* 14.4 g/ha) PE *fb* PoE | 2.2(3.8) | 9.9(97.3) | 1.70 (2.3) | 9.5 (94.6) | 89.0 | 87.5 | 93.5 | 88.1 |
| Pendimethalin + metribuzin *fb* pinoxaden (1500+175 *fb* 60 g/ha) before sowing *fb* PoE | 4.4(18.6) | 21.9(481.1) | 4.25(17.1) | 21.8(476.8) | 46.3 | 38.6 | 53.5 | 40.1 |
| Sulfosulfuron *fb* pinoxaden (25 *fb* 60 g/ha) BI *fb* PoE | 4.4(18.6) | 22.2(493.4) | 4.34(17.9) | 22.3(498.2) | 46.2 | 37.0 | 51.3 | 28.6 |
| Pinoxaden (60 g/ha) PoE | 4.1(16.8) | 19.7(390.1) | 3.89(14.2) | 19.6(383.8) | 53.5 | 50.2 | 61.3 | 51.7 |
| Pinoxaden + metribuzin (50+120 g/ha) PoE | 3.7(13.3) | 18.7(352.1) | 3.63(12.2) | 18.5(349.2) | 61.5 | 55.0 | 66.7 | 56.2 |
| Pinoxaden + metribuzin (50+150 g/ha) PoE | 3.5(11.6) | 18.2(331.1) | 3.37(10.4) | 17.9(329.1) | 66.5 | 57.7 | 71.7 | 58.7 |
| Mesosulfuron + iodosulfuron (14.4 g/ha) PoE | 3.8(13.5) | 19.7(390.2) | 3.91(14.3) | 19.6(384.5) | 61.0 | 50.2 | 61.0 | 51.7 |
| Weedy check | 6.0(34.6) | 28.0(784.2) | 6.10(36.7) | 28.2(797.1) | 0 | 0 | 0 | 0 |
| Weed free | 1.0(0) | 1.0(0) | 1.0(0) | 1(0) | 100 | 100 | 100 | 100 |
| LSD (p=0.05) | | | 1.1 | 5.5 | | | | |

**Table 3. Effect of different treatments on crop phytotoxicity, no. of tillers and grain yield of wheat (2016-17 and 2017-18)**

| Treatment | Crop phytotoxicity (%) | | | | No. of tillers/ m$^2$ | | Grain yield (t/ha) | |
|---|---|---|---|---|---|---|---|---|
| | 2016 | | 2017 | | 2016 | 2017 | | |
| | 10 DAT | 20 DAT | 10 DAT | 20 DAT | Harvest | | 2016 | 2017 |
| Pendimethalin (1500 g/ha) PE | 0 | 0 | 0 | 0 | 390 | 396 | 5.56 | 4.86 |
| Metribuzin (210 g/ha) PE | 5 | 0 | 0 | 0 | 398 | 396 | 4.63 | 4.80 |
| Pendimethalin + metribuzin (1500+175 g/ha) PE | 0 | 0 | 0 | 0 | 410 | 404 | 5.51 | 5.06 |
| Pendimethalin + metribuzin *fb* pinoxaden (1000 + 175 *fb* 60 g/ha) PE *fb* PoE | 0 | 0 | 0 | 0 | 404 | 407 | 6.08 | 5.10 |
| Pendimethalin + metribuzin *fb* mesosulfuron + iodosulfuron (1000 + 175 *fb* 14.4 g/ha) PE *fb* PoE | 0 | 0 | 0 | 0 | 402 | 410 | 6.16 | 5.41 |
| Pendimethalin + pyroxasulfone (1500+102 g/ha) PE | 0 | 0 | 0 | 0 | 436 | 438 | 5.09 | 5.80 |
| Pendimethalin + pyroxasulfone *fb* pinoxaden (1500+102 *fb* 60 g/ha) PE *fb* PoE | 0 | 0 | 0 | 0 | 438 | 439 | 6.16 | 5.80 |
| Pendimethalin + pyroxasulfone *fb* mesosulfuron+ iodosulfuron (1500+102 *fb* 14.4 g/ha) PE *fb* PoE | 0 | 0 | 0 | 0 | 439 | 441 | 6.28 | 5.82 |
| Pendimethalin + metribuzin *fb* pinoxaden (1500+175 *fb* 60 g/ha) before sowing *fb* PoE | 5 | 5 | 5 | 5 | 371 | 386 | 5.99 | 4.42 |
| Sulfosulfuron *fb* pinoxaden (25 *fb* 60 g/ha) BI *fb* PoE | 0 | 0 | 0 | 0 | 388 | 399 | 6.11 | 5.00 |
| Pinoxaden (60 g/ha) PoE | 0 | 0 | 0 | 0 | 382 | 396 | 5.11 | 4.80 |
| Pinoxaden + metribuzin (50+120 g/ha) PoE | 5 | 0 | 5 | 0 | 390 | 400 | 5.02 | 5.00 |
| Pinoxaden + metribuzin (50+150 g/ha) PoE | 5 | 0 | 5 | 0 | 404 | 401 | 5.23 | 5.05 |
| Mesosulfuron + iodosulfuron (14.4 g/ha) PoE | 0 | 0 | 0 | 0 | 400 | 401 | 5.90 | 4.92 |
| Weedy check | 0 | 0 | 0 | 0 | 376 | 370 | 4.17 | 3.64 |
| Weed free | 0 | 0 | 0 | 0 | 442 | 435 | 6.17 | 5.80 |
| LSD (p=0.05) | | | | | 27.9 | 28.1 | 0.14 | 0.13 |

**Table 4. Efficacy of pyroxasulfone alone and in combination with other herbicides in wheat (2017-18)**

| Name and address of farmer | $T_1$ | $T_2$ | *P. minor* control (%) | | | Grain yield (t/ha) | | | $T_9$ | $T_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ | | |
| Sudan Nain V. Kalwan Teh. Narwana (Jind) | 90 | 90 | 90 | 70 | 60 | 5.40 | 5.45 | 5.40 | 5.10 | 5.00 |
| Balraj s/o Hawa Singh, V. Kalwan Teh. Narwana (Jind) | 85 | 90 | 90 | 60 | 55 | 5.28 | 5.30 | 5.34 | 5.10 | 4.90 |
| Amarjeet Gill, V. Samain, Teh. Tohana (Fatehbad) | 88 | 90 | 95 | 85 | 80 | 5.40 | 5.45 | 5.45 | 5.28 | 5.20 |
| Satpal Singh, V. Samain. Teh. Tohana (Fatehbad) | 90 | 95 | 95 | 75 | 75 | 5.46 | 5.50 | 5.50 | 5.20 | 5.25 |
| Kala s/o Balraj Nain V. Kalwan Teh. Narwana (Jind) | 85 | 90 | 90 | 65 | 60 | 5.58 | 5.50 | 5.60 | 5.22 | 5.18 |
| Chanda Ram, V. Danoura (Ambala) | 95 | 100 | 100 | 90 | 80 | 4.80 | 4.86 | 4.86 | 4.80 | 4.80 |
| Prem Gujjar, V. Kheri Raiwali (Kaithal) | 85 | 88 | 85 | 75 | 65 | 5.60 | 5.60 | 5.58 | 5.10 | 5.08 |
| Mean | 88 | 92 | 92 | 74 | 68 | 5.36 | 5.38 | 5.39 | 5.11 | 5.06 |

$T_1$- Pendimethalin + pyroxasulfone (1000 + 127.5 g/ha (PE); $T_2$- Pendimethalin + pyroxasulfone (1000 + 255 g/ha (PE) *fb* PoE herbicide; $T_3$- Pendimethalin + pyroxasulfone (1000 + 127.5 g/ha (PE *fb* PoE herbicide; $T_4$- Pendimethalin + metribuzin 1.5 kg/ha (PE) *fb* PoE herbicide; $T_5$- Pendimethalin 1500 g/ha *fb* PoE herbicide; $T_6$- Pendimethalin + pyroxasulfone (1000 + 127.5 g/ha (PE); $T_7$- Pendimethalin + pyroxasulfone (1000 + 255 g/ha (PE) *fb* PoE herbicide; $T_8$- Pendimethalin + pyroxasulfone (1000 + 127.5 g/ha (PE *fb* PoE herbicide; $T_9$- Pendimethalin + metribuzin 1.5 kg/ha (PE) *fb* PoE herbicide; $T_{10}$- Pendimethalin 1500 g/ha *fb* PoE herbicide

iodosulfuron (RM) (**Table 3**). The probable reason for the higher grain yield under this treatment may be due to lowest weed density resulting in no crop- weed competition and higher number of tillers. The other reason may be the lack of phytotoxicity to wheat with these herbicides. These findings were in concurrence with those of Malik *et al.* (1998) who reported that wheat grain yield enhances with the use of herbicides due to increase in weed control efficiency and number of tillers and thus grain weight.

## On-farm evaluation of pyroxasulfone in wheat

The use of pre-emergence application of pyroxasulfone at 127.5 g/ha was demonstrated at 7 sites in rice–wheat growing areas of Haryana. It provided 88.3% control of multiple herbicide resistant *P. minor* whereas integration of this herbicide with pendimethalin at 1.5 kg/ha (PE) and post-mergence herbicides at 35 DAS improved control of *P. minor* to 92.1% with grain yield of 5.39 t/ha which was 6.54% higher than earlier recommended herbicide pendimethalin at 1.5 kg/ha (**Table 4**).

It may be concluded that pre-emergence of application of pyroxasulfone at 127.5 g/ha followed by post-emergence application of meso + iodosulfuron at 14.4 g/ha at 35 DAS provides effective control of multiple herbicides resistant *P. minor*, without any toxicity to wheat crop.

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