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# Control of mixed weed flora in wheat with sequential application of pre- and post-emergence herbicides

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## ABSTRACT

The field efficacy of pre- and post-emergence herbicides for control of mixed weed flora in wheat was evaluated in a field study conducted at Punjab Agricultural University, Ludhiana during *Rabi* seasons *of* 2014-15 and 2015-16. The season long growth of weeds reduced wheat yield upto 38.5%. Pendimethalin and metribuzin recorded 65-73 and 73-78% control of *Phalaris minor,* respectively and their tank-mix application enhanced *P. minor* control to 78-85%. Pendimethalin and metribuzin recorded 26-33 and 58-63% control of *Medicago denticulata,* respectively and their tank-mix application enhanced control to 77-92% of this weed. Pendimethalin and metribuzin provided control of *Rumex dentatus* to the extent of 98-100% and 68-92%, respectively, while provided 98-100 and 63-72%, respectively control of *C. album*. Sequential application of pendimethalin as pre-emergence followed by sulfosulfuron as post-emergence recorded the highest weed control efficiency (96%) and wheat grain yield (4.8 t/ha), and it was at par to pre-emergence pendimethalin + metribuzin, post-emergence pinoxaden + metsulfuron, mesosulfuron + iodosulfuron, sulfosulfuron + metsulfuron and two hand weeding.

**Key words**: Herbicides, Mixed weed flora, Pre-mix, Sequential application, Tank-mix, Weed control, Wheat

Wheat (*Triticum aestivum* L.) is infested with complex weed flora. The average yield losses due to weeds in wheat vary from 20 to 32% across different wheat growing regions in India (Chhokar *et al*. 2008). Herbicides are the key component of weed management program in wheat in India, particularly in North Western states. All types of weeds are not controlled by a single herbicide and the continuous use of a single herbicide results in weed shifts and evolution of herbicide resistance. The presence of mixed weed flora warrants integrated use of chemical control measures. The continuous use of isoproturon in wheat resulted in evolution of resistant in *Phalaris minor* against this herbicide (Malik and Singh 1995) and this weed now has evolved multiple resistance against fenoxaprop, clodinafop and sulfosulfuron (Chhokar and Sharma 2008, Singh *et al.* 2010) and recently to pinoxaden (Kaur *et al*. 2015). More recently, herbicide resistance has been reported in *Rumex dentatus* against metsulfuron-methyl (Chhokar *et al*. 2017) and in *Avena ludoviciana* against clodinafop (Singh 2016). 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. Metribuzin, a PS II inhibiting herbicide, as pre-emergence has been found effective against *P. minor* and other grasses and broad-leaf weeds (Malik *et al.* 2005), however, its variable effect on weed control and also on phytotoxicity in wheat under higher soil moisture or faulty application made it a limited choice herbicide among farmers. 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). Besides managing mixed weed flora, the integrated use of herbicides may help in managing herbicide resistance problems. In present study, the efficiency of combination of pre- and post-emergence herbicides used in sequence, as tank-mix or as pre-mix against weeds and growth and yield of wheat was evaluated.

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## MATERIALS AND METHODS

A field experiment was conducted at Punjab Agricultural University, Ludhiana during winter season of 2014 and 2015. The experimental site was situated in Trans-Gangetic Agro-Climatic zone, representing the Indo-Gangetic alluvial plains at 30°56' N latitude, 75°52' E longitude and at an altitude of 247 m above mean sea level. The experimental soil was loamy sand with neutral pH (7.43) and EC (0.22 dS/m) and it was low in organic carbon (0.42%) and available nitrogen (210 kg/ha) and very high in available phosphorus (77 kg/ha) and high in available potassium (352.5 kg/ha).The wheat cultivar '*HD 2967*' was sown in first week of November in 2014 and 2015. The experiment was laid out in a randomized complete block design with 4 replications. Twelve weed control treatments included were pendimethalin 0.75, 1.0 kg/ha as pre-emergence (PE), metribuzin 0.175 and 0.21 kg/ha as PE, tank-mix of pendimethalin + metribuzin 0.75 + 0.175, 1.0 + 0.175 kg/ha as PE, sulfosulfuron 0.025 kg/ha as post-emergence (PoE), clodinafop 0.06 kg/ha as PoE, sequential application of pendimethalin 0.75, 1.0 kg/ha as PE followed by (*fb*) sulfosulfuron 0.018 kg/ha as PoE, sulfosulfuron + metsulfuron 0.03+0.002 kg/ha (pre-mix) as PoE, tank-mix of pinoxaden + metsulfuron 0.06 + 0.004 kg/ha as PoE, mesosulfuron + iodosulfuron 0.012 + 0.0024 kg/ha (pre-mix) as PoE, clodinafop + metsulfuron 0.06 + 0.004 kg/ha (pre-mix) as PoE, two hand weedings at 20 and 40 days after sowing (DAS), and unweeded control. The plot size was 7.0 x 2.8 m. The pre-emergence herbicides were sprayed on the day of sowing using 500 litre water/ha and post-emergence were sprayed at 35 DAS with 375 litre water/ha, using knapsack sprayer fitted with flan-fan nozzle. The crop toxicity and visual weed control under different weed control treatments was recorded at 30 days after spray. The crop was manually harvested in third week of April. Final plant height was recorded up to base of spike from 10 randomly selected plants and average was reported. The data on yield attributes and grain yield was recorded at crop harvest. The prevailing market prices of inputs and outputs were used for calculating economic returns and benefit-cost ratio (B:C) under different weed control treatments. Weed data was squareroot transformed before statistical analysis. The data were analyzed by using standard statistical procedures and comparisons were made at 5% level of significance.

## RESULTS AND DISCUSSION

### Effect on weeds

The experimental field was infested with *Phalaris minor* (36%), *Medicago denticulata* (34%), *Rumex dentatus* (20%), *Chenopodium album* (5%) and *Coronopus didymus* (5%) in both the years of study.

As 30 DAS, pre-emergence herbicides had significant effect on density of *M. denticulata, R. dentatus* and *C. album* at 30 DAS. Pendimethalin 0.75 and 1.0 kg/ha recorded 65-73%, and metribuzin 0.175 and 0.21 kg/ha recorded 73-78% control of *P. minor* (**Figure 1**); tank-mix application of metribuzin 0.175 kg/ha with pendimethalin 0.75 and 1.0 kg/ha enhanced *P. minor* control to 78-85%. Pendimethalin alone or as tank mix with metribuzin provided 98-100% control of *R. dentatus* and *C. album*. Metribuzin alone recorded 68-92% control of *R. dentatus* and 63-72% of *C. album.* Singh *et al.* (2011) also reported that metribuzin 150 g/ha failed to control *C. album* and *R. dentatus.* Pendimethalin and metribuzin used alone recorded poor control of 26-33% and 58-63%, respectively, of *Medicago denticulata;* their tank-mix application recorded effective control to the extent of 77-92% of this weed.

At 60 DAS, pendimethalin alone 0.75 and 1.0 kg/ha resulted in 54-74% weed control efficiency (WCE) and metribuzin of 53-69%; their tank-mix application recorded higher WCE (74-82%) compared to their alone application. The post-emergence tank-mix application of pinoxaden + metsulfuron, pre-mix of sulfosulfuron + metsulfuron, mesosulfuron + odosulfuron, clodinafop + metsulfuron provided effective control (87-100%) of broad-leaf weeds and significantly reduced the weed biomass than unweeded control (**Table 1**); pinoxaden + metsulfuron recorded the significant control of *P. minor* than all other post-emergence herbicides and pendimethalin 0.75 kg/ha, metribuzin 0.175 kg/ha, clodinafop, sulfosulfuron, clodinafop + metsulfuron, sulfosulfuron + metsulfuron recorded similar density of *P. minor to* unweeded control. Tank-mix application of pendimethalin + metribuzin at 1.0+0.175 kg/ha, sequential application of pendimethalin at 0.75 and 1.0 kg/ha as PE *fb* sulfosulfuron at 0.018 kg/ha as PoE, tank-mix of pinoxaden+metsulfuron as PoE recorded >80% WCE and provided effective control of both grasses and broad-leaf weeds, and significantly reduced the weed biomass. The synergistic response for weed control was observed when herbicides were applied in mixture (Baghestani *et al.* 2008). Sequential application of pendimethalin followed by pre-mix of mesosulfuron + iodosulfuron, tank mix of pinoxaden + metsulfuron, pre-mixes of sulfosulfuron + metsulfuron and fenoxaprop + metribuzin or two applications of PoE herbicides in rotation was effective for weed control in wheat (Singh *et al.* 2011). *Medicago denticulata* was the troublesome weed in pendimethalin and metribuzin alone treated plots. Clodinafop failed to control *P. minor* as experimental field was infested with confirmed resistant biotype against clodinafop and was ineffective on broad-leaf weeds. Sulfosulfuron was also poor on *P. minor* and *R. dentatus,* but recorded effective control of *M. denticulata, C. album* and *C. didymus*. Reports of evolution of resistance in *P. minor* populations to FOPS in Pakistan (Yasin *et al.* 2011), Iran (Gherekhloo *et al.* 2011) and *Avena* *ludoviciana* to diclofop, fenoxaprop, sethoxydim, clethodim and pinoxaden herbicides in Australia (Ahmad-Hamdani *et al.* 2012) signifies that all the selective herbicides being used in wheat have a limited shelf life and their judicious use will help in effective weed control and integrated approaches of chemical rotations or sequential use or pre-mix and tank-mix may help in this regard.

## Effect on crop growth, yield and economics

All pre-emergence herbicides treatments recorded similar population of wheat plants at 30 DAS (**Figure 1**). No crop phyto-toxicity was observed during both the years. All weed control treatments resulted in more crop biomass than unweeded control except clodinafop 0.06 kg/ha. More crop biomass was due to effective weed control. All weed control treatments resulted in more number of effective tillers than unweeded control at harvest. Weed control treatments recorded significantly higher wheat grain yield and yield attributes than unweeded control. Application of pendimethalin 1.0 kg/ha or metribuzin 0.21 kg/ha or tank-mix of pendimethalin 0.75 and 1.0 kg/ha + metribuzin at 0.175 kg/ha or sequential application of pendimethalin 0.75 and1.0 kg *fb* sulfosulfuron at 0.018 kg or tank-mix of pinoxaden + metsulfuron 0.06+0.004 kg/ha or pre-mix of sulfosulfuron + metsulfuron at 0.03+0.002 kg/ha or pre-mix of mesosulfuron + iodosulfuron at 0.012 + 0.0024 kg/ha resulted in statistically similar wheat grain yield to two hand weeding. Clodinafop 60 g/ha recorded significantly higher grain yield and yield attributes than unweeded control but it was significantly low as compared to other herbicidal treatments (**Table 2**). The tank-mix of pinoxaden + metsulfuron recorded

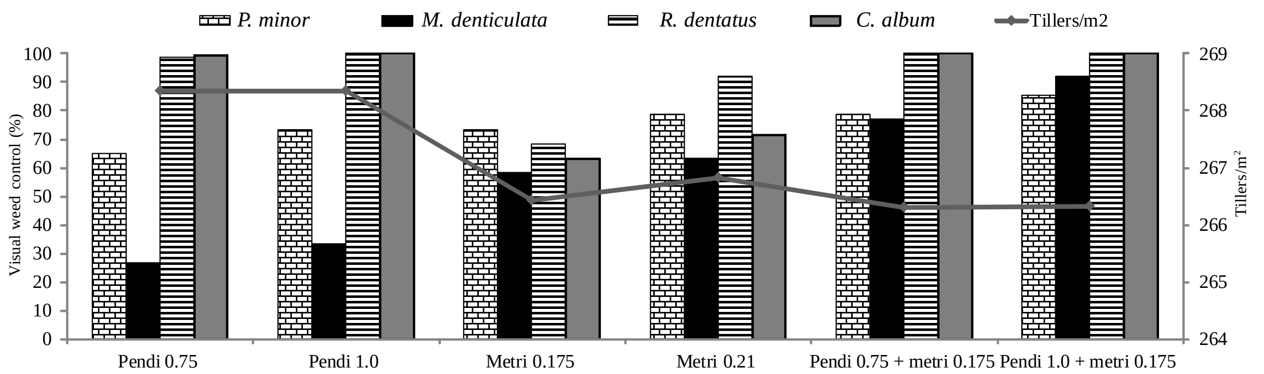


**Figure 1. Visual weed control of different weeds at 30 DAS with pre-emergence herbicides. Visual weed control was taken with respect to unweeded control**

**Table 1. Effect of different weed control treatments on weeds in wheat (pooled data of 2014-15 and 2015-16)**

| Treatment | Weed density and biomass at 60 days after sowing | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Density (no./m$^2$) | | | | | Biomass (g/m$^2$) | | WCE (%) |
| | *P. minor* | *M. denticulata* | *R. dentatus* | *C. album* | *C. didymus* | Grasses | BLW | |
| Pendimethalin (PE) 0.75 kg/ha | 4.0 (15) | 4.9 (25) | 1.3 (1) | 1.3 (1) | 1.9 (3) | 4.9 (23) | 3.0 (8) | 54.4 |
| Pendimethalin (PE) 1.0 kg/ha | 2.8 (7) | 4.8 (25) | 1.1 (0) | 1.0 (0) | 1.3 (1) | 3.6 (12) | 2.6 (6) | 73.5 |
| Sulfosulfuron (PoE) 0.025 kg/ha | 4.0 (15) | 1.0 (0) | 5.1 (25) | 1.2 (1) | 1.3 (1) | 4.3 (18) | 3.3 (10) | 58.8 |
| Metribuzin (PE) 0.175 kg/ha | 3.6 (12) | 4.6 (22) | 3.2 (10) | 1.9 (3) | 1.0 (0) | 4.6 (21) | 3.4 (11) | 52.9 |
| Metribuzin (PE) 0.21 kg/ha | 2.8 (7) | 4.1 (17) | 3.0 (9) | 1.6 (2) | 1.5 (1) | 3.7 (13) | 3.0 (8) | 69.1 |
| Clodinafop PoE 0.06 kg/ha | 4.5 (20) | 4.2 (18) | 5.3 (27) | 2.4 (5) | 3.0 (8) | 5.3 (28) | 4.2 (17) | 33.8 |
| Pendimethalinc + metribuzin (tank-mix as PE) 0.75 + 0.175 kg/ha | 3.3 (10) | 4.3 (20) | 1.3 (1) | 1.0 (0) | 1.8 (2) | 3.7 (12) | 2.6 (6) | 73.5 |
| Pendimethalin + metribuzin (tank-mix as PE) 1.0 + 0.175 kg/ha | 2.6 (6) | 4.0 (17) | 1.1 (0) | 1.0 (0) | 1.4 (1) | 3.0 (8) | 2.2 (4) | 82.4 |
| Pendimethalin (PE) *fb* sulfosulfuron (PoE) 0.75 *fb* 0.018 kg/ha | 2.5 (6) | 1.2 (1) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 2.3 (5) | 1.2 (0) | 92.6 |
| Pendimethalin (PE) *fb* sulfosulfuron (PoE) 1.0 *fb* 0.018 kg/ha | 2.1 (4) | 1.1 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.9 (3) | 1.1 (0) | 95.6 |
| Sulfosulfuron + metsulfuron (pre-mix as PoE) 0.03 + 0.002 kg/ha | 4.2 (17) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 5.3 (28) | 1.0 (0) | 58.8 |
| Pinoxaden + metsulfuron (pre-mix as PoE) 0.06 + 0.004 kg/ha | 2.7 (8) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 3.3 (13) | 1.0 (0) | 80.9 |
| Mesosulfuron + iodosulfuron (pre-mix as PoE) 0.012 + 0.0024 kg/ha | 3.6 (13) | 1.5 (2) | 1.0 (0) | 1.7 (2) | 1.0 (0) | 4.2 (18) | 1.2 (1) | 72.1 |
| Clodinafop + metsulfuron (pre-mix as PoE) 0.06 + 0.004 kg/ha | 4.5 (20) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 4.4 (19) | 1.0 (0) | 72.1 |
| 2 Hand weeding (20 and 40 DAS) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 1.0 (0) | 100.0 |
| Unweeded control | 4.3 (18) | 4.3 (18) | 5.2 (27) | 3.1 (9) | 2.7 (6) | 5.9 (34) | 5.7 (34) | - |
| LSD (p=0.05) | 0.4 | 0.3 | 0.2 | 0.3 | 0.3 | 0.6 | 0.3 | - |

PE: Pre-emergence; PoE: Post-emergence; *fb*-Followed by; Figures in parentheses are means of original values subjected to square root transformation

**Table 2. Wheat grain yield and yield attributes and economics under different weed control treatments (pooled data of 2014-15 and 2015-16)**

| Treatment | Plant height at harvest (cm) | Effective tillers (no./m$^2$) | Spike length (cm) | Grain yield (t/ha) | Biological yield (t/ha) | B:C* |
|---|---|---|---|---|---|---|
| Pendimethalin (PE) 0.75 kg/ha | 73.8 | 337 | 11.2 | 4.35 | 12.5 | 2.21 |
| Pendimethalin (PE) 1.0 kg/ha | 73.6 | 358 | 11.7 | 4.60 | 12.68 | 2.28 |
| Sulfosulfuron (PoE) 0.025 kg/ha | 87.9 | 330 | 11.5 | 4.52 | 12.42 | 2.26 |
| Metribuzin (PE) 0.175 kg/ha | 87.1 | 340 | 11.3 | 4.51 | 12.86 | 2.32 |
| Metribuzin (PE) 0.21 kg/ha | 90.0 | 345 | 11.6 | 4.61 | 12.72 | 2.34 |
| Clodinafop PoE 0.06 kg/ha | 88.8 | 297 | 11.3 | 3.45 | 11.26 | 1.74 |
| Pendimethalinc + metribuzin (tank-mix as PE) 0.75 + 0.175 kg/ha | 87.4 | 367 | 11.6 | 4.68 | 12.91 | 2.32 |
| Pendimethalin + metribuzin (tank-mix as PE) 1.0 + 0.175 kg/ha | 87.5 | 365 | 11.4 | 4.74 | 12.88 | 2.35 |
| Pendimethalin (PE) *fb* sulfosulfuron (PoE) 0.75 *fb* 0.018 kg/ha | 88.4 | 358 | 11.5 | 4.67 | 12.83 | 2.31 |
| Pendimethalin (PE) *fb* sulfosulfuron (PoE) 1.0 *fb* 0.018 kg/ha | 88.4 | 374 | 11.6 | 4.86 | 13.19 | 2.38 |
| Sulfosulfuron + metsulfuron (pre-mix as PoE) 0.03 + 0.002 kg/ha | 88.1 | 355 | 11.4 | 4.69 | 12.55 | 2.33 |
| Pinoxaden + metsulfuron (pre-mix as PoE) 0.06 + 0.004 kg/ha | 90.2 | 353 | 11.4 | 4.827 | 12.428 | 2.39 |
| Mesosulfuron + iodosulfuron (pre-mix as PoE) 0.012 + 0.0024 kg/ha | 88.6 | 352 | 11.3 | 4.724 | 12.116 | 2.33 |
| Clodinafop + metsulfuron (pre-mix as PoE) 0.06 + 0.004 kg/ha | 87.2 | 305 | 11.3 | 4.482 | 12.380 | 2.24 |
| 2 Hand weeding (20 and 40 DAS) | 90.1 | 365 | 11.2 | 4.813 | 13.538 | 1.94 |
| Unweeded control | 85.9 | 254 | 10.9 | 2.959 | 10.911 | 1.55 |
| LSD (p=0.05) | NS | 29 | NS | 0.338 | 0.831 | - |

*B:C: Benefit-cost ratio, calculated by dividing gross returns with variable cost of cultivation

the highest returns and B:C, which was comparable to tank-mix of pendimethalin 1.0 kg + metribuzin 0.175 kg/ha, pendimethalin 1.0 kg *fb* sulfosulfuron 0.018 kg/ha and metribuzin 0.21 kg/ha. Baghestani *et al*. (2008) also reported that tank-mix use of herbicides resulted in higher grain yield of wheat.

It can be concluded that pre-emergence application of tank-mix of pendimethalin 0.75 and 1.0 kg/ha plus metribuzin 0.175 kg/ha or sequential application of pendimethalin 0.75-1.0 kg as pre-emergence and sulfosulfuron 0.018 kg as post-emergence or post-emergence application of tank-mix of pinoxaden + metsulfuron 0.06+0.004 kg/ha or pre-mix of sulfosulfuron + metsulfuron 0.03 + 0.002 kg/ha or pre-mix of mesosulfuron+iodosulfuron at 0.012 + 0.0024 kg/ha could be adopted for broad-spectrum weed control in wheat.

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