Management of Herbicide resistant *Phalaris minor*: A Review

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**ABSTRACT**

Littleseed canarygrass (*Phalaris minor* Retz), an annual species of the family Poaceae, is a major weed problem in many wheat-producing countries. The excessive dependence on herbicides for its control led to the evolution of multiple herbicides resistance and yield losses. The first case of resistant *P. minor* in India was to the Photosystem-II inhibitor isoproturon in the early 1990’s. *P. minor* has been found resistant to Acetolactate Synthase (ALS) inhibitors, Acetyl-CoA Carboxylase (ACCase) inhibitors, Photosystem II inhibitors. It is highly competitive and in severe cases can cause complete crop failure, forcing farmers to harvest their crop as fodder or ploughing the standing crop along with weeds. For management of these multiple herbicide resistant *P. minor*, pyroxasulfone, pendimethalin, flumioxazin, trifluralin and flufenacet can be used as alternative herbicides. Moreover, in-depth biological and ecological studies on *P. minor* should be carried out for devising integrated weed management strategies. The long-term strategies of efficient weed management and sustainability of wheat production should include the use of alternative herbicides, herbicide mixture, crop rotation along with other non-chemical methods like manual removal of weeds, mulching, Summer ploughing etc providing the competitive advantages to the wheat crop over *P. minor*, at the same time increasing the profitability of the farmer by controlling the weed effectively and reducing the selection pressure on the weeds which will inturn reduce the resistance development in weeds.

**Key words:** Multiple herbicide resistance, Integrated weed management, Wheat, *Phalaris minor*

**Introduction**

Globally, wheat (*Triticum aestivum* L. emend. Fiori & Paol.) is the most important crop grown on an area of 217.8 mha (Knoema, 2022) with production of 794.6 mt (FAO, 2023). Ever since the green revolution started, wheat productivity has improved tremendously but due to the yield stagnation and increasing population scientist are predicting a need for second green revolution or more precisely ever green revolution to support the need of the ever-increasing population of the world which is expected to become double by 2050, or an alternative to that could be the resource management by reducing the losses. Among all the agents that cause reduction in the yield weeds causes the highest reduction in the crop yield i.e. it attributes to around 37% reduction to the yield of the crop (Das, 2015), thus effective weed management, will not only increase productivity but also the profitability of the farmers, with
the most efficient control being the use of herbicide molecules. From the various literature available online it is clearly evident that the first herbicide came into use during 1940’s and was welcomed by farmers with open arms, and over the years it has replaced other traditions methods of weed control, now it is impossible to think of crop production without the use of herbicides, because these are efficient, time saving, cost effective, energy saving and easiest method to control weeds when compared with the others (Chhokar and Sharma, 2012). Although efficient it also has a downside to it, that is its unjust or indiscriminate use due to faulty spray technology practices can lead to the development of herbicide resistance in weeds such case was reported by (Malik and Singh, 1993) that *Phalaris minor* has become resistant to isoproturon which otherwise was quite effective in controlling it, in addition to this it also has detrimental effect on the soil health, thus it is safe to say that it is a double-edged sword. Lately weeds like Phalaris has become a major constraint to wheat’s productivity, causing large amounts of losses in wheat grain yield, affecting farmers profitability, and now the presence of herbicide resistance only adds to the menace.

**Extent of Losses**

The extent of crop loss caused by *Phalaris minor* varies from 10 to 100 per cent. In many areas of Haryana and Punjab infestation of this weed may be anywhere between 200 to 3000 plants/m² and farmers are forced to harvest their green wheat crop as fodder. A total of 8-50% reduction in the wheat yield is observed when there are around 50-500 *Phalaris* plant/m² (Khera *et al.*, 1995 and Singh *et al.*, 1999), in addition to this a higher population of 2000 plants/m² may result in the complete crop failure, many such instances were recorded in many parts of Haryana and Punjab and as such farmers were forced to either plough the crop for sowing alternate crop or use it as a fodder (Malik and Singh, 1993, 1995). Whereas population of 20 plants of Phalaris minor/m² have almost negligent effect on the wheat yield (Singh *et al.*, 1999). When weeds emerge earlier than the crop, yield reduction up to50% or even more can occur. Grassy weeds at a population of 25/m² removed at least 10 kg N in the unfertilized plots and 29 kg N in the plots fertilized with 125 kg N/ha (Malik and Singh, 1995). Farmers are not aware about the alternative strategies to control weeds and diseases. Herbicides/pesticides are being used without bothering for their residual effects, which may be disastrous for health as well as for the environment. Keeping these losses in mind effective weed management strategies should be adopted to improve the crop production and profitability of the farmers.

**Herbicide Resistance development in Phalaris minor in India**

With the increased irrigation facilities rice-wheat system became dominant system in northern plains and this mono-cropping combined with mono-herbicide led to the evolution of isoproturon resistance during mid 1990’s and this was the first herbicide resistance case in India reported from CCS HAU.

In addition to this *Phalaris minor* is well suited in rice wheat system because its seed can withstand the anaerobic conditions created during puddling where as many weeds such as wild oats lose their viability under puddle conditions, also the sowing time was slightly delayed to first fortnight of November when it germination is high because it prefers low temperature and high soil moisture, also this weed sheds major proportion of seed just before the wheat is ready for harvesting and rest of the seed contaminate the produce during threshing which is the source of infestation for the coming years when farmers use this own contaminated seed. Now this contaminated seed is fed to the animals then it passes through the alimentary canal of the animal and then reaches the FYM pits through the animal waste used for manure production and when this FYM is added to the fields it only adds to the already abundant seed bank of *Phalaris minor* in the fields.

Moreover, sub-optimal performance of sand or urea mixed application of isoproturon, over spraying also increased the *P. minor* population.

All these aforementioned factors which increase the infestation of Phalaris favoured the evolution of isoproturon resistance, because of heavy selection pressure there are more chances of evolution of herbicide resistance. It was the first case of herbicide resistance in India and was only noticed when it spread over large areas in Haryana and Punjab and caused gigantic losses to the yields of wheat and barley.

All these aforementioned herbicides in the table have become ineffective and are only effective in synergistic combination with other herbicides like pyroxasulfone etc.
During mid 1990’s there was no safer alternative herbicide option that was available for farmers use, although farmers used metribuzin initially to tackle this problem, but the problem of herbicide resistance led to the diversification of cropping system in Haryana and Punjab, as a result farmers adopted sunflower which reduced *Phalaris* infestation, and the 3 alternative herbicides (clodinafop, sulfosulfuron and fenoxaprop) were recommended in 1998 to deal with the isoproturon resistant *Phalaris*. The majority of the farmers at that time accepted clodinafop and sulfosulfuron for *Phalaris minor* control. In addition, zero tillage technology which was being demonstrated at farmer field also helped in reducing *P. minor* infestation (Chhokar et al., 2007), and farmer accepted zero tillage because the saving on tillage cost were diverted for the purchase of new herbicide which were 3 to 4 times costlier than isoproturon. Zero tillage in synergy with new herbicide drastically reduced the *Phalaris* seed bank in Haryana and Punjab and the productivity which was stagnant due to *P. minor* started increasing.

The large scale uses of 2,4-D along with isoproturon also increased the selection pressure due to elimination of competition from broadleaf weeds. Another reason for this could be the adoption of high yielding dwarf varieties of wheat which are less competitive as compared to their wild counterparts.

Table 1 clearly depicts that apart from single site resistance *Phalaris* has also developed multiple herbicide resistance against various MOA of herbicides some of them are also depicted in the table above.

### Management of Resistance Population

Owing to increased selection pressure there has been development of cross as well as multiple herbicide resistance in weeds (Yu and Powles, 2014 and Valverde, 2003). Now factors like concentration, amount and interval of application of herbicide affects the expression of gene conferring for the resistance in weeds i.e. the frequency of the gene causing resistance increases, so it is advised that in order to prevent resistance farmer should change cropping pattern and follow herbicide rotation, herbicide mixture etc.

So, efforts should be made to reduce the selection pressure which can be achieved by inculcating different means of weed control along with the herbicides, Following methods can be employed to control or manage resistant weed population:

1. **Cropping System:** Adoption of different cropping system also helps in controlling the weed population, for example inclusion of an intercrop gives very less space for the growth of the weed and hence helps in reducing the weed population, crop that has allelopathic effect on weed is found to be more effective in reducing weed growth and their population example. or including *Trifolium* once in 3 years or including sugarcane or sunflower also helps in reducing the weed population.

2. **Crop rotation:** Changing the cropping pattern,

<table>
<thead>
<tr>
<th>Phalaris Species</th>
<th>Name of the Country</th>
<th>First Case</th>
<th>Mode of Action</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Phalaris minor</em></td>
<td>Australia</td>
<td>2012</td>
<td>ALS</td>
<td>Heap, 2021</td>
</tr>
<tr>
<td></td>
<td>India</td>
<td>1991</td>
<td>ALS</td>
<td>Raghav et al., 2018; Malik and Singh, 1995 and Raghav et al., 2016.</td>
</tr>
<tr>
<td></td>
<td>Iran</td>
<td>2004</td>
<td>ALS</td>
<td>Gherakhloo et al., 2012</td>
</tr>
<tr>
<td></td>
<td>Israel</td>
<td>1993</td>
<td>ALS</td>
<td>Tal et al., 1996</td>
</tr>
<tr>
<td></td>
<td>Mexico</td>
<td>1996</td>
<td>ALS</td>
<td>Cruz et al., 2015</td>
</tr>
<tr>
<td></td>
<td>Pakistan</td>
<td>2015</td>
<td>ALS</td>
<td>Yasin et al., 2011</td>
</tr>
<tr>
<td></td>
<td>South Africa</td>
<td>1999</td>
<td>ALS</td>
<td>Pieterse and Kellerman, 2002</td>
</tr>
<tr>
<td></td>
<td>United States</td>
<td>2001</td>
<td>ALS</td>
<td>Dhawan et al., 2012</td>
</tr>
</tbody>
</table>

ALS = Acetolactate synthase, ACCase = Acetyl CoA Carboxylase, APP = Aryloxy Phenoxy Propionate, CHD = Cyclohexanedione, PPZ = Phenyl Pyrazoline, PS II = Photosystem II, \(\checkmark\) = Resistant, \(\checkmark^*\) = Moderately Resistant.
i.e., the type of crops or crop grown on the same field is known as cropping pattern, this will disrupt the conditions favourable for weed growth and will ultimately affect their population for example as observed in northern India Phalaris dominates the rice-wheat system as during wheat it has favourable environment for its growth and development, while during Kharif season most of the paddy is sown by transplanting in the puddle soil which is favourable for the survival of the seeds of Phalaris as puddling places the seeds of Phalaris to be placed deep in the soil which otherwise would be exposed to the scorching heat of the sun and would ultimately lose their viability.

3. Tillage crop establishment method: summer deep ploughing after rabi season exposes weeds seed to the sun and as a result they get destroyed this is known as Khurra-Bakhroni or growing of low land rice also reduces the weed (Shakrawar et al., 2018)

4. Chissling: Snobar and Haddad, 1998 and Brenzil et al., (2006) demonstrated that inter-cultural practices using implements like chissler can yield a comparable grain yield to the herbicide treated plots, however a wider row spacing is a prerequisite for the effective mechanical weed control.

5. Tillage crop establishment method: summer deep ploughing after rabi season exposes weeds seed to the sun and as a result they get destroyed this is known as Khurra-Bakhroni or growing of low land rice also reduces the weed (Shakrawar et al., 2018)

6. Flaming: dredging and flaming is a common method to control aquatic weeds, but it can also be used to control terrestrial weeds. (Brand et al., 2007 and Holmoy and Netland, 1994).

7. Hand Hoeing: According to Dhiman et al. (1985) hand weeding or hand hoeing at 20 and 40 days after sowing was found effective in reducing Phalaris population and increasing grain yield of wheat by 26% against 41% obtained by chemical weed control.

8. Conservation agriculture: adoption of zero tillage helps in reducing the weed problem in wheat (Chhokar et al., 2012)

9. Herbicide rotation: Prevent the use of herbicides that have the same MOA for the control of a particular herbicide, season after season as this is the reason for induction of the resistance in the weeds. So, the herbicides can be substituted with a herbicide of another MOA group. This will prevent the development of a resistant weed population. Example: - Using pyroxasulphone, metribuzin etc in place of Isoproturon to control Phalaris minor, which has otherwise got resistant to isoproturon (Chhokar and Sharma, 2012).

10. Mixture application: Herbicides can also be applied in a mixture containing two or more herbicides effective on targeted weed species. And this method is more effective than herbicide rotation, similar mixture can be identified for wheat.

11. It has been surveyed that the herbicides belonging to groups AC Case and ALS are prone to resistance evolution especially in developing countries. So, their use should be done keeping that in mind and after consulting the experts or the other agencies like KVK’s, research organisations etc. (Valverde, 2003).

12. Use of integrated weed management: -Under the circumstances when grassy weeds particularly Phalaris minor is causing serious threat to the wheat productivity, the only option left is to adopt integrated approach for the control of weeds. This can be achieved by judicious use of chemicals, diversification of rice-wheat se-

<table>
<thead>
<tr>
<th>Table 2. Herbicide resistant P. minor and the possible effective alternative options in wheat</th>
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<tbody>
<tr>
<td>Herbicide resistance in P. minor</td>
</tr>
<tr>
<td>Isoproturon</td>
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<tr>
<td>Clodinafop</td>
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<td>ALS inhibitor (Sulfosulfuron, Mesosulfuron + Iodosulfuron and Pyroxsulam)</td>
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<tr>
<td>Photosynthesis-II inhibitors, ALS inhibitor, ACCase inhibitors</td>
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quency, adopting proper tillage practices including closer spacing and using suitable wheat varieties. Example atrazine @ 1.00 kg ha⁻¹ + HW, 2 HW and paddy straw mulching, producing grain yield of (203.48 g, 188.34 g and 186.82 g) respectively, as compared to un-weeded plot (68.30 g) (Rai et al., 2018).

Conclusion

From the above discussed information we can conclude that the indiscriminate use of the herbicides should always be avoided. And the chemicals should be applied according to the recommended dose and over-dosage and under-dosage should be avoided. With that being said it was evident from the study that ineffective or poor spray technology was the reason for the development of multiple herbicide resistance, thus dissemination of proper. Moreover, the use of integrated weed management should be promoted as it is environment friendly and efficiency is more than any single mode of control. Now as the potential yields of the crops have stabilized and cannot be increased any further, and the land resources are also limited so better resource management strategies need to be developed (like weed control, use of modern tillage etc.). Hence developing a better weed control method will help in eliminating the competition proposed by the weeds to the crops and will ultimately help in increasing the productivity and profitability of the wheat crop. Hence improved agronomic measures/practices are the prerequisite to this modern age to deal with the needs of the increasing population. But with the development of the herbicide resistance, it seems to be a herculean task, as large number of losses are caused by the weeds. Hence better weed management practices will help in increasing the yield of the crop even further and will also reduce the uncertainty in the yield of the crop.

References