

Management alternatives for *Phalaris minor* in the rice–wheat cropping system

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Wheat is the second most important staple food after rice for the Indian population. Wheat crop is infested with diverse grasses and broadleaved weeds. Amongst these, Phalaris minor has evolved multiple resistance against many commercial herbicides leading to weed control failures and crop yield losses. Alternate herbicides should be used in rotation, sequence or mixture to reduce the selection pressure, and evolution of herbicide resistant weeds. For this, farmers must be made aware about the alternate herbicides and their mechanism of action. Further, prevention of weed seed replenishment should be part of weed control programmes to reduce the soil weed seedbank. Non-chemical methods such as cultural and physical weed control along with herbicide stewardship guidelines need to be designed for management of herbicide resistant weeds.

Keywords: Cultural control, Herbicide resistance, Integrated weed control

WEEDS cause maximum yield losses in crop production and are considered a major biotic stress in crop production. Weed flora in cropped fields is highly diverse, encompassing grasses, sedges, and broadleaved weeds. Weeds compete with crops for light, water, and nutrients, and can drastically reduce crop yields and quality. It would be very challenging to feed the ever-growing population with current agricultural practices and increasing threats of climate change, water scarcity, and reduction in farm holding size.

In north-western Indo-Gangetic Plains of India particularly Punjab, the rice–wheat cropping system is a dominant cropping system. In this system, *Phalaris minor* is the most troublesome and dominant grass weed in wheat fields. *Phalaris minor* is morphological alike to wheat plant until flowering stage, thus, very difficult to identify at early growth stages that makes it challenging to remove manually within wheat rows. It emerges in multiple cohorts with its emergence

start in November and later cohorts emerge with subsequent irrigation in the winter season. A season-long infestation of *P. minor* can reduce wheat yield by up to 80% depending on density, agronomic management practices, edaphic and environmental factors. Also, *P. minor* seeds get accumulated in upper soil profile (0–10 cm depth) during puddling process in transplanted rice system that might have resulted into more weed population in subsequent wheat crop.

Herbicide resistance in *P. minor*

Farmers control *P. minor* mainly with herbicides due to ease in their use, efficacy and economics of weed control. Further, use of herbicides is necessary to control it in wheat due to its morphological similarities with wheat. The broad-spectrum herbicide such as isoproturon was used for controlling *P. minor* in the mid-1970s. There was wider adoption of isoproturon in the 1980s, and after its continuous use for 10–15 years, *P. minor* populations evolved resistance in the early 1990s

in Haryana and later in Punjab. Till date, there are eleven confirmed unique cases of herbicide resistance in *P. minor* on a global scale.

To tackle this havoc situation, four new herbicides, clodinafop, fenoxaprop and tralkoxydim, belonging to HRAC 1 (Inhibition of Acetyl CoA Carboxylase) along with sulfosulfuron (HRAC; 2 Inhibition of Acetolactate Synthase) were recommended as an alternative for its control in 1997-98. At present, there are confirmed reports of multiple resistance (against two or three modes of action) in *P. minor* populations against clodinafop, fenoxaprop (HRAC 1), sulfosulfuron (HRAC 2) and isoproturon (HRAC 5). Further, there are reports of evolution of herbicide resistance in other weeds such as *Avena ludoviciana*, *Chenopodium album*, *Polypogon monspeliensis* and *Rumex dentatus*. However, *P. minor* is the most problematic weed, having evolved resistance to several herbicide classes including standalone application of clodinafop, sulfosulfuron, mesosulfuron plus

Table 1. Confirmation of unique cases of *Phalaris minor* resistant to different mechanisms of action

Year, reported for first time	Country	Crop	Mechanism of action
1991	India	Wheat	PSII inhibitors (HRAC 5)
1993	Israel	Wheat	ACCase inhibitors (HRAC 1)
1994	India	Wheat	-
1996	Mexico	Wheat	-
1999	South Africa	Pastures and wheat	Multiple resistance to two sites of action: ACCase inhibitors (HRAC 1); ALS inhibitors (HRAC 2)
2001	United States	Onion	ACCase inhibitors (HRAC 1)
2004	Iran	Winter wheat	
2006	India	Wheat	Multiple resistance to three sites of action: ACCase inhibitors (HRAC 1); ALS inhibitors (HRAC 2); PSII inhibitors (HRAC 5)
2012	Australia	Wheat	ACCase inhibitors (HRAC 1)
2013	India	Wheat	ALS inhibitors (HRAC 2)
2015	Pakistan	Wheat	ACCase inhibitors (HRAC 1)

Note: Adapted from Heap (2026)

iodosulfuron, pinoxaden, clodinafop plus metribuzin and metribuzin.

Management of herbicide-resistant *P. minor*

To manage weeds effectively, resistant weeds and faulty spray application technology should be differentiated by carefully monitoring visual rating for weed control. Various cultural, mechanical and chemical weed control can be employed to control herbicide-resistant *P. minor* populations.

Cultural and mechanical methods: The selective stimulation of crop growth can be done by adopting good agronomic practices for raising a crop. Crop rotation is the principal component of weed management programmes to control crop-associated weeds. The selection of quick growing cultivars along with closer spacing and high seed rate can help in covering the land quickly and will leave less space for weeds to come. *Phalaris minor* can be effectively controlled by altering sowing time of wheat crop. Further, fertiliser and water can be applied selectively to crop to facilitate the crop growth while discouraging the weed growth. Narrowing the row spacing to 15–18 cm from 20–22.5 cm leaves less space and limited resources for weeds.

The physical/mechanical methods such as interculture, hoeing and hand weeding is labour-intensive and costly.

- **Crop rotation:** The fields having history of heavy infestation of *P. minor* and other weeds, the rotation of wheat with berseem, sugarcane or potato for 1–2 years significantly reduces infestation of weeds. In case of berseem, multiple cutting does not allow weed seed production and reduce the weed seedbank from the soil. Similarly, in sugarcane, the weed seed production is restricted by herbicides and repeated interculture. In mustard, early sowing, smothering effect and early maturity of crop reduce *P. minor* establishment. In potato, the alternate herbicides use, digging operations and early maturity of crop does not allow the weed to set seeds.
- **Sowing at end-October:** Optimum temperature for *P. minor* germination is 15–20°C. In fields having history of *P. minor* infestation, early sowing of wheat during last week of October to first week of November would escape the first cohort of *P. minor* which emerge with the crop and give

intense competition during initial crop growth stage. During this period, the temperature is not optimum for *P. minor* germination.

- **Zero till sown wheat:** Wheat can be sown with zero/minimum tillage and infestation of weeds especially *P. minor* is very less due to minimum disturbance of soil.
- **Paddy straw as mulch:** Crop residue management is a big challenge in agriculture globally. The surface retention of rice residue in between wheat rows will suppress the emergence of *P. minor* along with other direct and indirect effects on soil moisture, temperature, and carbon sequestration. After rice harvest, sowing of wheat can also be done with Happy Seeder/Smart Seeder/Surface seeding-cum-mulching technique in residue-retained fields without tillage. Sowing with these techniques significantly reduce the germination and emergence of weeds. Uniform retention of paddy straw layer with thickness of 3–4 inches act as mulch on soil surface that prevents the germination and/or emergence of weeds.
- **Soil/dust mulching:** Weed seeds, present near to the soil surface, require moisture for germination. Thus, if we



Plant of *Phalaris minor*

allow surface soil to dry up before seedbed preparation, it will reduce weed incidence significantly, especially first cohort of weeds. For this, apply pre-sowing irrigation to allow weed seeds to germinate. Later, weed seedlings are killed with shallow tillage without disturbing the lower deep soil which retains adequate moisture for germination of crop in the soil. The dried surface soil acts as soil/dust mulch and do not allow the germination of weeds from the soil surface.

- **Raised bed sowing:** The infestation of weeds is less in wheat sown on raised beds than the crop sown with conventional method. The upper surface of raised beds dries up quickly which prevent weed seed germination. Further, planting of wheat on raised beds can help in ease of mechanical interculture operations.

Chemical methods: Weeds evolve herbicide resistance after continuous use of single herbicide. Use of herbicide rotation or mixture is a one of principal stewardship guidelines to delay this evolution. Further, herbicides should be used as pre-emergence (at the time of sowing for prevention of emergence of weeds) or as post-emergence (before or after first irrigation to manage emerged weed seedlings). The use of pre-emergence herbicides is the best strategy to control resistant *P. minor* populations. In conventional

Table 2. Herbicides available for control of *Phalaris minor*

Herbicide mechanism of action	Chemical class/family	Herbicides (Examples)	Time of application
Acetyl CoA Carboxylase inhibitor (HRAC 1)	Aryloxyphenoxy propionate	Clodinafop, diclofop, fenoxaprop	Post-emergence
	Cyclohexanedione	Tralkoxydim	–
	Phenylpyrazoline	Pinoxaden	–
Acetolactate Synthase inhibitor (HRAC 2)	Sulfonylurea	Sulfosulfuron, iodosulfuron	Post-emergence
Microtubule Assembly inhibitor (HRAC 3)	Dinitroaniline	Pendimethalin	Pre-emergence
PSII inhibitors (HRAC 5)	Substituted ureas	Chlorotoluron, isoproturon, metoxuron	Pre- and early post-emergence
	Triazine	metribuzin, terbutryn	
Phytoene Desaturase inhibitors (HRAC 12)	Pyridine carboxamides	Diflufenican	Pre-emergence
Deoxy-D-Xylulose Phosphate Synthase inhibitor (HRAC 13)	Isoxazolidinones	Bixlozone	Early post-emergence
Protoporphyrinogen Oxidase inhibitor (HRAC 14)	N-phenylphthalimides	Flumioxazin	Pre-emergence
Very Long-Chain Fatty Acid Synthesis inhibitors (HRAC 15)	Chloroacetamide	Pyroxasulfone	Pre-emergence
Lycopene Cyclase (HRAC 34)	Diphenylethers	Aclonifen	Pre-emergence

till sown wheat, application of pendimethalin or pyroxasulfone or premix of pendimethalin + metribuzin or aclonifen + diflufenican + Pyroxasulfone as pre-emergence herbicide within two days after sowing in good soil moisture will keep the wheat fields free from *P. minor* for first 25-30 days.

For achieving excellent weed control, herbicide should be applied in well prepared field that is free from clods and have good

soil moisture. For weed control in Happy seeder sown wheat, any one of the pre-emergence herbicides may be applied just before sowing by mixing with basal dose of urea (broadcast the mixture). The herbicide spray technology is of paramount importance to achieve full weed control. Pre-emergence herbicide can be applied with Lucky Seed Drill which sow wheat and spray herbicide simultaneously. In soil/dust mulch condition, when soil surface is dry, pre-emergence herbicide is not recommended for application as proper soil moisture is the pre-requisite for activation of pre-emergence herbicides. Herbicides provide best weed control when applied in a field having good soil moisture. Presence of excess soil moisture at the time of herbicide application also causes toxicity to crop plants (e.g. in case of iodosulfuron, metribuzin, bixlozone, aclonifen, diflufenican, etc.).

The timing of application of post-emergence herbicide is also very crucial, and herbicide should be applied at the proper weed growth stage for the management of *P. minor*



Wheat field infested with *Phalaris minor*



Heavy infestation of *Phalaris minor* in wheat field at later stage

in wheat. Further, post-emergence herbicides should be applied in a sunny day after dew is cleared off from leaves, and first and second irrigation should be relatively lighter for getting best results from herbicides. To preserve these herbicides for future use and for sustainable weed control, proactive management strategies and

herbicide stewardship guidelines are needed to be followed.

Integrated weed management: It is crucial to adopt integrated weed management (IWM) practices including agronomic practices, physical methods and herbicide use to manage the herbicide-resistant weeds. The quarantine measures should be taken for wheat seed

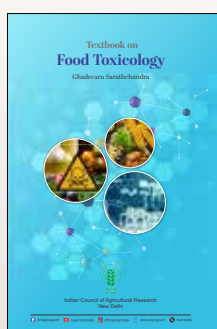
procurement to prevent weed seed dispersal and dissemination. Thus, use of weed-free crop seeds is the crucial preventive weed control strategy. Further, weeds should be uprooted before setting of seeds to prevent weed seed rain. *Phalaris minor* can be targeted for harvest weed control approaches as it retains a substantial proportion (74%) of its seeds until wheat harvest. Early sowing of wheat in residue retained fields is the best IWM approach in which there is >80% reduction in the *P. minor* density.

SUMMARY

Farmers should have knowledge about mode of action of herbicide to be used so that proper herbicide rotation or mixture can be applied to control the resistant *Phalaris minor*. Further, adoption of multiple approaches comprising of herbicide use along with crop rotation, competitive cultivars, more seeding rate, narrower spacing, stale seed bed, advance sowing, conservation tillage, and weed seed free crop seed is the key for sustainable weed management.

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