

Multiple herbicides resistance

in *Phalaris minor*: Extent and management

Prabhu Lal Jat, Rajesh Kumar Meena, Hardev Ram, Govind Makarana and Rakesh Kumar^{1*}

ICAR-Agronomy Section, National Dairy Research Institute, Karnal, Haryana 132 001

Wheat (Triticum aestivum L.) is the number one cereal crop of the World both in area and production. During the crop season of 2020, it covered worldwide 225 million ha area and produced 766 million metric tonnes with a productivity 3,404 kg/ha. India, China and UK are the World leaders in area, production and productivity of wheat, respectively. In India, it is grown in the area of 30.20 M ha with a production 107 million metric tonnes and productivity of 3,566 kg/ha in 2020. Among the different wheat growing states Uttar Pradesh, Punjab and Haryana covered the highest area and production of wheat, however, the highest productivity was recorded in Punjab.

Key words: Herbicides resistance in *Phalaris minor*, Indo-Gangetic plains, Wheat

Introduction

After the Green revolution, production of wheat increased day by day due to higher adoption rate of chemical fertilizer, insecticide and herbicides. The Indo-Gangetic plains cover the maximum wheat area, unfortunately, here wheat is grown under monocropping system of rice-wheat (10.5 M ha areas), which leads to incidence of insect, pest and weeds. The average yield losses in wheat are caused by weeds is around 25-30%.

The critical period of crop-weed competition in wheat is 30-45 days after sowing. Wheat crop is dominated by various types of weed flora viz. *Phalaris minor* (satellite weed), *Avena fatua* (associate weed), *Carthamus oxycantha*, *Convolvulus arvensis* (objectionable weed), *Sorghum halepense* (horrible weed), *Cynodon dactylon*, *Cyperus rotundus* and *Chenopodium album*.

Phalaris minor L. (Little seed canary grass, guli danda, mandusi and kanaki) is a satellite and associate weed of wheat and belongs to the gramineae family. This weed normally

germinates along with the wheat. During the initial stages of crop growth, their morphology features closely resembles with wheat seedlings so it is difficult to differentiate them. Little seed canary grass is an annual grassy and most

troublesome weed in rice-wheat cropping system of Indo-Gangetic plains. In north-west India especially Punjab, Haryana and Uttar Pradesh, canary grass created a huge problem because it's early maturity than wheat and having prolific seed production capacity.



Fig. 1. Wheat field infested with *Phalaris minor* near Karnal

Changes in weed flora over time

Weed flora in wheat changes markedly over time. In 1960's, *Carthamus oxycantha* was the major weed of the wheat. In early 1970's with the introduction of high yielding dwarf varieties which need assured irrigation, and high doses of fertilizers lead to the replacement of broad-leaf weeds by *Phalaris minor* and *Avena ludoviciana*. *P. minor* became predominant weed of rice-wheat cropping system.

Herbicide resistance

It is the inherent ability of a weed to survive and reproduce following exposures to a dose of herbicide normally lethal to wild type. Broadly, it can be classified into three types viz. 1. Single resistance: Weed shows

resistance due to continuous exposure to the same herbicide, e.g. *Phalaris minor* show resistance to isoproturon due to its continuous use, 2. Cross resistance: It evolves when weed biotype is found resistant to more than one herbicide species, all of which possessed the same mode of action, e.g. weed resistance to imidazolinone often shows resistance to sulfonylurea, and 3. Multiple resistances: It evolves when individual weed species shows resistance to different chemical classes of herbicides having a different mode of phytotoxic action, e.g. *Lolium rigidum* shows multiple resistances against various groups of herbicides.

Reasons for herbicides resistance in *Phalaris minor* are, continuously cultivation of wheat under rice-wheat monocropping system, repeated application of similar modes of action herbicide on weed population with their unknown quantity, accelerated use of the same herbicides year after year without practising herbicide combinations, herbicide rotation and integrated weed management and non-availability of high yielding weed resistant varieties of wheat.

Evolution of Isoproturon resistance in *Phalaris minor*

Dependence on single herbicide or herbicides with the same mode of action can lead to the evolution of resistance and a shift in weed flora towards difficult to control weeds. Introduction of high yielding dwarf varieties during the early sixties that require a high dose of fertilizers and assured irrigation create an ideal condition for the build-up of *Phalaris minor*. Phenyl urea herbicide isoproturon was recommended for the control of broad spectrum weeds including *P. minor* in mid-1970. It was widely used during the 1980's and effectively controlled *P. minor* until the early 1990's. Its high adoption is due to its cost effectiveness, wider application window, flexibility in method of application, and broad spectrum weed kill. Continuous uses of isoproturon in the rice-wheat system for more than a decade lead to the evolution of resistance in *Phalaris minor* in early 1990's. Very heavy

infestations of this weed (2000-3000 plants/m²) were reported from many areas. The resistance has spread to more than 1.0 M ha of the predominant R-W cropping system, posing a serious threat to the sustainability of this system. In a natural population, exists both susceptible and resistant plants, repeated use of the same herbicide will expose the weed population to selection pressure leading to an increase in a number of resistant individuals in the population. Development of isoproturon resistance in *P. minor* in Haryana was the first case of herbicide resistance in India and in the World. The resistant biotype of *Phalaris minor* requires 3-15 times higher doses of isoproturon for weed control, which was not economical and unsafe for the wheat crop.

Multiple resistances in *phalaris minor*

After the development of isoproturon resistant *Phalaris minor*, alternate herbicides such as clodinafop, fenoxaprop and sulfosulfuron provided excellent control for several years, but their continuous use for 6-7 years *P. minor* show resistance to them as well. Hence *P. minor* shows multiple resistances against three modes of actions: photosynthesis at PS-II site, acetyl CoA carboxylase (ACCase) and acetolactate synthase (ALS) inhibitors. The main reason for the rapid evolution of resistance in *P. minor* is due to monocropping (rice-wheat), using the same herbicide and underdosing. If the problem of resistance is not tackled, it may pose threat to the sustainability of the rice-

wheat cropping system.

Mechanisms of herbicide resistance in weeds are important for selecting alternate herbicides for the management of resistant weeds. Herbicide resistance in weed is due to various mechanisms such as increased rate of herbicide detoxification, decreased rate of herbicide activation or sequestration (compartmentation) of herbicide away from the target site. *Phalaris minor* shows resistance to isoproturon due to its enhanced degradation. The enhanced degradation in *P. minor* is due to N dealkylation and ring alkyl oxidation by NADPH-cytochrome P450 monooxygenase.

MANAGEMENT OF MULTIPLE HERBICIDES RESISTANT POPULATIONS

Cultural/Ecological control

Competitive and high yielding varieties: Grow those varieties of wheat which will quickly establish, having early vigour and high tillering capacity enhances the competitiveness of wheat against weed. Adopt varieties like HD 3086, PBW 677 and HD 2967 which are more vigorous and more spreading in nature. Pure and certified crop seeds that do not contain any weed seeds.

Stale seedbed: It is a technique in which pre-sowing irrigation is given to the field and left the field for about a fortnight so that weeds can emerge. After that weeds are killed by non-selective herbicide (Paraquat, glyphosate) or removed by tooth harrow/cultivator. Two or three flushes can be done which reduces the seed bank of weed in the soil.

Table 1. Alternative and mixture herbicides recommended for control of isoproturon resistant *Phalaris minor* in India.

Herbicide	Mode of action	Dose (g/ha)	Water (liters/ha)	Time of application
Pendimethalin	Microtubule formation inhibitor	750	500-600	Pre-emergence
Trifluralin	Microtubule formation inhibitor	1200	500-550	Pre-emergence
Clodinafop-propargyl	ACCase inhibitor	60	250-300	Post-emergence
Fenoxaprop-p-ethyl	ACCase inhibitor	100	200-300	Post-emergence
Sulfosulfuron	ALS inhibitor	25	200-250	Post-emergence
Mesosulfuron + iodosulfuron	ALS inhibitor	14.4	200-250	Post-emergence
Metribuzin + fenoxaprop-p-ethyl	PS II inhibitor + ACCase inhibitor	275	250-300	Post-emergence

Planting time and rate of sowing: Sowing of wheat in the first fortnight of October than recommended time of sowing usually favours wheat's initial growth and competitiveness. Early sowing of wheat reduces *Phalaris minor* infestation because the warmer temperature is not favourable for the germination of this weed. Higher seed rate 150 kg/ha reduces biomass of *P. minor* by more than 40% and increased biomass yield of wheat compared to sowing at seed rate 100 kg/ha.

Crop rotation: Rotating with different life cycle crops helps in disrupting the weed cycle. Inclusion of fodder crops such as berseem in the cropping system significantly reduces the seed bank of *Phalaris minor* within three years.

Crop residue management: In rice-wheat cropping system, straw of rice is usually burned because the straw is not fed to the animals. It has been found that burning stimulates the *Phalaris minor* seeds to grow in larger population in wheat. Hence residue burning should be avoided and retained residue on soil surface which acts as mulch and reduces the germination of *Phalaris minor* and other weeds.

Mechanical and manual approaches

Tillage practices: Furrow irrigated raised bed system is an effective method of non-chemical weed control particularly *Phalaris minor*. Zero tillage which requires higher dose of herbicide may aggravate the resistance problem. Increasing use of herbicide in zero tillage kills susceptible populations completely and the resistant population grows more luxuriantly in absence of competition. Similarly, minimal/reduced tillage favours quicker development of resistance.

Soil solarisation: Soil solarisation for minimum of 2 weeks during hot summer months is efficient to control weeds.

Harrowing: Mechanical weeding by tooth harrow at the early stage of wheat preferably before first irrigation or a week after first irrigation. This followed by post-emergence herbicides at 35-40 DAS



Fig. 2. Pre-emergence herbicide application

give an effective option to reduce resistant *P. minor* problem.

Manual weeding: Hand weeding/hoeing by experienced labourers or farmers following after first and second irrigation may be useful. As the weeds are morphologically similar to crop, it is very difficult to identify and remove them.

Biological approaches

Many insects feed on weeds; fungi causes disease and deleterious *Rhizobacteria* colonize in the root rhizosphere of weeds. Example, *Trichoderma viridae* has been observed to control *P. minor* selectively through colonization in roots.

Chemical approaches

Alternate herbicides: Once the resistance is confirmed, effective alternate herbicides should be recommended. In India, several alternative herbicides such as clodinafop-propargyl (topic 15 wettable powder), sulfosulfuron (leader 75WDG), fenoxaprop-p-ethyl (puma Super), and diclofop-methyl (illoxan) have been used to control isoproturon resistant *P. minor* effectively. However, their continuous use for 8-10 years, resistance now confirmed. Pinoxaden (axial 10EC) which is also a group herbicide still control some populations where clodinafop and fenoxaprop are no longer effective. Microtubule formation inhibitors such as pendimethalin and trifluralin have

been introduced for the control of *P. minor* (Table 1).

Herbicide mixture: Two or more herbicides having a different modes of action, different degradation pathway, similar persistence, and similar target weed group specificity should be selected for the mixture to reduce selection pressure for resistance development. Some herbicide mixtures such as mesosulfuron + iodosulfuron and fenoxaprop + metribuzin were also introduced for controlling resistant *Phalaris minor* (Table 1).

Herbicide rotation: Recommended alternate herbicides with a different

modes of action should be rotated preferably once in every 3 years instead of using the same herbicide again and again.

Integrated weed management (IWM)

Integration of chemical, cultural and mechanical methods to achieve effective weed control with reduced dependence on herbicides. The uses of IWM play an important role in managing weed populations below the threshold levels and delay resistance development in weeds.

CONCLUSIONS

Weed infestation especially, *Phalaris minor* is one of the main biotic constraints in wheat production and productivity. For *P. minor* control most of the farmers depend on herbicides due to cost and time effectiveness compared to manual weeding. Herbicide use is increasing dramatically in different crops and this trend is expected to continue. Continuous use of the same herbicide having same mode of action in monoculture has been a major cause of the occurrence of herbicide resistance. The evolution of herbicide resistant weeds is a threat to wheat sustainability. Long term strategies to manage herbicide resistant weeds should include integration of non-chemical methods with chemical for sustainable wheat production.

¹Principal Scientist (Agronomy).
*Corresponding author e-mail: drdudi_rk@rediffmail.com