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Herbicide Resistance in Weeds and its Management

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SUMMARY

Even though herbicides provide efficient and cost-effective weed control resistance will make them obsolete, if they are overused. Herbicide resistance is the acquired and inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. Altered site of action and change in any of the processes that intervene in the herbicide action are the two mechanisms of herbicide resistance. Management strategies (alternative herbicides, herbicide mixture, crop rotation and other agronomic practices) providing the crop with a competitive edge over weeds be the first line of defense in controlling weeds to avoid herbicide resistance and enhance sustainability of the production weed.

INTRODUCTION

Herbicides helped the farmers to control some of the noxious pests and thus reduced the yield loss caused by them at an affordable cost. But there are some disadvantages like development of resistance against these pesticides in targeted organisms was the most prominent among them. Herbicide resistance was reported as early as 1957 against 2,4-D from Hawaii (Hilton, 1957), in day flower (*commelina diffusa*) plant but the first confirmed report of herbicide resistance was against triazine herbicide in common groundsel (*Senecio vulgaris*) and was reported in 1968 from U.S.A. (Ryan, 1970). Since then, the number of resistant weed biotypes against various herbicides is on the rise. Till recently, 383 biotypes belonging to 208 weed species (122 dicots and 86 monocots) are spread over 570,000 fields of the world. Infestation of isoproturon R population caused >65% wheat grain yield reduction with the recommended rate of isoproturon (1000 g ha^{-1}) application. Continued reliance on isoproturon after the evolution of resistance resulted in a heavy build-up of *Phaloris minor* populations, as competition from other weeds was removed and caused heavy yield losses.

The evolution of herbicide resistance

Two theories have been suggested to explain how gene mutations causing herbicide resistance, the gene pool theory, and the selection theory.

Gene pool theory:-

It is based on the idea that herbicides act as mutagens *i.e.* plant mutates as a result of herbicide treatment due to which the genetic background of the plant changes there is little evidence supporting this theory.

Selection theory

Most widely accepted theory, which states that in any population of weeds, there will be some plants that can naturally tolerate a particular herbicide *i.e.* one or more individuals in a population will be resistant because of natural variation. Selection pressure is directly proportional to the efficacy of the herbicide (Wrubel and Gressel, 1994).

Herbicide Resistance Management

Proactive management practices

i) Cultural practices

Crop Rotation : Growing the same crop every season will invite same inputs including herbicide because of the same ecological culture. Crop rotation allows the following options:

• Different crops will allow rotation of herbicides having a different site of action.
• The growth season of the weed can be avoided or disrupted

• Crops with differing sowing times and different seedbed preparation can lead to a variety of cultural techniques being employed to manage a particular weed problem.
• Crops also differ in their inherent competitiveness against weeds. A strongly competitive crop will have a better chance to restrict weed seed production.

Close spacing and higher seed rate: Higher seed rates and close row spacing may allow less weeds to grow and competing ability in favour of crop.

Proper time of sowing: Early sowing of crop e.g. wheat favors initial growth and crop competitiveness against weeds.This is more important under rice-wheat cropping system because *Phaloris minor* germinates more profusely during last week of November to December and even January. Therefore, sowing of wheat in the last week of October to second week of November will be of enormous help in combating the emergence and early growth of *Phaloris minor* in particular and other weeds, in general. Early sowing of wheat can easily be possible under zero-tillage.

ii) Mechanical: weed control may include inter-row cultivation, preplant tillage, hand rouging etc. Cultural control may be an important part of reducing the over reliance on herbicides. This includes using varieties or hybrids that are more competitive, seeding in narrow rows or planting cover crops.

iii) Herbicide mixtures and rotation

- Use herbicides only when necessary
- Use the recommended rate
- Use herbicide mixtures that include 2 or more herbicide groups
- Rotate herbicides between herbicide groups
- Use of herbicides with short residual life if we are using herbicides having long residual life then the selection pressure will be more. So use herbicides having short residual life. Also, if we are increasing the dose of herbicide the residual period will be high. So use the recommended dose.
- Herbicide mixtures and herbicide rotation strategies work on the premise that if a weed carries the genes to resist 1 group of herbicides, an alternate herbicide group will kill it.

The difference between the two approaches is that herbicide mixtures kill the resistant weed using many active ingredients in the same season. Rotating herbicides controls the resistant weeds in the years when effective herbicide groups are used with the goal of reducing the resistant weed population. It is concluded that mixtures are more effective than rotations in mitigating the resistance evolution.

Reactive management practices:-
Mechanical options

- Control of weed escapes and sanitation of equipment to prevent spread of resistant weeds:
- Scout the fields for resistant weeds. Post harvest grazing, where practical.
- Stubble burning, where allowed, can limit weed seed fertility. In extreme cases of confirmed resistance, fields can be cut for hay or silage to prevent weed seed set.

Herbicide options

- Apply the most effective post emergence herbicide with a different mechanism of action.
- If low level herbicide resistance has been identified and no other options are available, apply the maximum labelled rate of the same post emergence foliar herbicide

Mechanism of Herbicide resistance

Mechanisms of herbicide resistance can be broadly grouped into two categories (Dekker and Duke, 1995).

Non target site mechanism/exclusionary

Those that exclude the herbicide molecule from the site in plants where they induce toxic response. In exclusionary resistance mechanism the herbicide is excluded from the site of action in many ways.

(a) Differential herbicide uptake: In resistant biotypes the herbicides are not taken up readily due to morphological uniqueness like overproduction of waxes, reduced leaf area etc.

(b) Differential translocation: In resistant biotypes the apoplastic (cell wall, xylem) and symplastic (plasma lemma, phloem) transport of herbicide is reduced due to different modifications.

(c) Compartmentation: Herbicides are sequestered in many locations before it reaches the site of action or it gets attatched to cell wall where it exerts no effect e.g. some lipophilic herbicide may become immobilized by partitioning into lipid rich glands or oil bodies

(d) Metabolic detoxification: Herbicide is detoxified at a faster rate before it reaches the site of action. The biochemical that detoxifies herbicides can be grouped into four major categories: oxidation, reduction, hydrolysis, and conjugation. Three enzyme systems are known to be involved in resistance due to increased herbicide detoxification.

- Glutathione-s-transferase that detoxifies atrazine.
- Aryl-aylamidase that detoxifies propanil.
- Cytochrome P450 monoxygenase is responsible for resistance to inhibitors of ACCase, ALS and PSII in a number of grass weed species.

Target site mechanism

Altered site of action:

Site of action is altered in such a way that it is no longer susceptible to the herbicide *e.g.* In *Lactuca sativa* biotypes which are resistant to sulfonylurea herbicides, the ALS enzyme which is the site of action of herbicide is modified in such a way that herbicide can no longer bind with the enzyme and inactivate it.

Site of action overproduction:

This causes the dilution effect of the herbicide. Here the site of action is overproduced so that the herbicide at its normal rate of application will not be able to inactivate the entire enzyme produced. Some glyphosate-resistant Palmer-amaranth has been shown to express increased levels of herbicide-susceptible EPSPS target-site protein. This case is the only known example of this type of mechanism.

CONCLUSION

Genetic variation is almost always present in plant population. Given the existence of genetic variation, sufficient duration and intensity of selection will likely result in the development of resistance. Herbicide resistance cannot be avoided as it is a random chance. Rotational use of herbicides and herbicide mixtures are the main components of management strategies. Adoption of an integrated weed management approach would help to manage resistant weeds.

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