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Herbicide Resistance and Its Management Strategies - A Review

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Abstract

Due to their improved effectiveness and ability to save time, herbicides are the most widely used and effective weed control methods. However, prolonged use of herbicides brought about several issues, including environmental risks, shift weed in shift flora, and weed resistance. Herbicide resistance is one of the most significant issues worldwide today, out of all of these issues. The use of herbicides with extensive residual periods and a lack of rotation of the herbicide are the primary causes of herbicide resistance. Herbicide resistance is a global occurrence, and the number of resistant weed biotypes is alarmingly growing. In 252 plant species, there are already 480 occurrences of herbicide resistance. Weed herbicide resistance should be reduced since it is a significant barrier to food security. We could more effectively handle it if we thoroughly understood resistance development. Integrated weed management techniques, such as crop and herbicide rotations, herbicide combinations, and cultural, mechanical, and biological methods of weed control, can control the herbicide resistance problem.

Keywords: *Weeds; Herbicide; Herbicide Resistance; Cross resistance*

Introduction

Weeds infest crops and reduce crop yield. Weed infestation affects almost all crop production systems. Grasses, broad-leaved weeds , and sedges constitute the weed flora of crops and cropping systems. They may be perennial, biennial or annual. Farmers use several management strategies to control weeds. They include cultural practices, chemical methods , and manual or mechanical weeding. The most successful way to manage weeds has been to use herbicides. Most of the troublesome weeds in various crops have been successfully controlled with various herbicides from various chemical groups and modes of action. Herbicide resistance, a global issue and a challenge for both the farming community and weed researchers, has been brought on by the prolonged use of herbicides (Singh *et al*., 2020).

A weed or crop biotype's inherent ability to survive and reproduce after exposure to a herbicide dose to which the original population was susceptible is known as herbicide resistance (Duary, 2008). The herbicide 2, 4-D caused wild carrots to show the first evidence of resistance. Common groundsel resistance to triazine herbicides was the first incidence of herbicide resistance that was confirmed. The level of resistance has increased globally throughout time. They have been reported globally from 66 different countries.

A total of 250 species, including 145 dicots and 105 monocots, have become resistant to 160 different herbicides with different modes of action (Heap, 2016). The community develops resistance biotypes as a result of repeated and intensive use of herbicides with similar modes of action in crops and cropping systems over time. The production systems are gradually threatened as the resistant biotypes gradually acquire multiple forms of resistance. The most significant herbicide-resistant plant species among the weeds include *Lolium rigidium, Avena fatua, Amaranthus retroflexus, Chenopodium album, Elusine indica, Echinocloa crussgalli,* and *Phalaris minor,* according to reports from around the world.

Types of Herbicide Resistance

One or more weed plant species develop herbicide resistance at a specific location where herbicide is applied. Generally, when the herbicide is used on a particular weed, it also affects nearby species of weeds. Herbicide resistance is developed in weed plants due to repeated application of herbicide, and weed plants are no longer affected by herbicide. Only when the herbicide site of action does not react to any chemical applied doe's resistance in weed plants begin to appear. Herbicide has an impact on several areas of a weed plant, affecting its ability to grow and other processes. Protein cells, enzymes, and cellular mechanisms that involve cell division and elongation are the sites of herbicide action. Herbicide resistance is a mutative reaction in which several genetic characteristics are changed (Powles and Yu, 2010).

Herbicide resistance generally can be classified into two types based on the mode of action of herbicides and the process by which it affects the weed species (Kim *et al*., 2015).

1. Cross resistance:

This type of herbicide resistance is only effective against individuals of the same class of herbicides. One herbicide from a group or multiple herbicides from the same group can exhibit cross-resistance. Cross resistance is modifying a weed plant's genetic expression in response to different herbicides. It speaks towards how weed plant species' genetic expression adapts to an applied herbicidal dose. Aceto lactase synthase (ALS) enzyme, which causes resistance in weed species, is attacked by the selection pressure of herbicide on the target site (Vargas and Wright, 2004). Cross-resistance is a significant indication that limits the mechanism of herbicide action inside the species of weed plants, as a consequence. It is a significant phenomenon that raises further concerns about agricultural productivity losses and agricultural production. There will be a significant loss in agriculture economics and productivity if this resistance lowers herbicides' ability to control weeds.

The use of herbicides to generate resistance in seeds and pollen grains has the advantage of cross resistance (Hall *et al*., 1994). The undifferentiated behaviour of weed plant species that continue to survive the impact of any herbicide on a piece of land is considered herbicide resistance. Herbicide resistance decreases crop plants growth and reduces crop productivity. Cross resistance further can be grouped into two categories:

- Target site cross resistance
- Non target site cross resistance

The development of resistance at the aforementioned site of action is facilitated by herbicide cross resistance in weed plant species. Using this herbicide cross-resistance mechanism is crucial when conducting scientific and experimental work. If herbicides limit the weed control actions in weed plant species, manufacturers of agricultural and other agrochemicals will suffer a significant economic loss. Scientists from all around the world will find it difficult to reach their full potential and productivity in terms of crop growth and output due to herbicide resistance.

Target Site Cross Resistance

When the herbicide's action site is altered, cross-resistance of the herbicides at the target site results. The biochemical site of herbicidal action in the various kinds of weed plants belongs to a particular chemical class that influences the site of action. The crop plant species are impacted by the target site cross resistance, preventing the biochemical site of action of comparable herbicides. Not all classes and mechanisms of herbicides exhibit this kind of resistance. Although it deals with the same mechanism of action as a herbicide, target site cross-resistance does not stimulate all herbicidal classes.

Non-target site cross resistance:

Non-target site cross resistance is linked to the different herbicidal classes along with the way they affect plants. This ross resistance, rather than the target site enzymes facilitating the resistance, is the method of action of different herbicides. Cross-resistance on non-target sites occurs when a herbicide's mode of action becomes resistant.

2. Multiple Resistances:

The site of action of herbicides inside weed plants can change, leading to several resistances to them. The primary cause of herbicide resistance in weed plants evolving is farmers' ongoing use of herbicides at doses below those suggested by the manufacturer, which either directly or indirectly breeds resistance in certain weed plant species. The alteration in the herbicide site of action cause the multiple resistances.

This sort of resistance occurs when weed plants exhibit resistance to several herbicides' sites of action. Herbicide resistance is created through various selection processes for herbicides, including ALS and acetyl-CoA carboxylase, ACCase inhibitors (Won *et al*., 2015).

When a weed species exhibits resistance to one herbicide and another when that herbicide is used in the field, the weed plant develops resistance to both of those herbicides to differentiate the selection pressure. A weed plant species' method of action and application reveals whether it is resistant to one or more herbicide classes. A weed species can use two or more resistance pathways to gain resistance to different herbicide classes. Both target and non-target site resistance mechanisms are a part of multiple resistance. It is exceedingly challenging to control weed plant species that use both mechanisms within the same species (Powles and Preston, 2016).

The most problematic and challenging to control weed plant species are those that have multiple resistances. They are extremely herbicide resistant and interfere with the growth and development of agricultural plants. The existence of one or more resistance mechanisms within a population is how the idea of multiple resistances in weed plants is expressed. Multiple herbicide classes are resistant to weed species, which also exceed crop plants in terms of growth ability. It is easy to resist an herbicide when a population of weeds has one or more resistance mechanisms.

The growth and yield of crops are significantly impacted by multiple resistances, which carry out resistance mechanisms against numerous herbicides. As a result, one or more herbicides are resisted by one or more resistance mechanisms within each plant population in both the target and non-target sites of the weed population. The resistance grows in both the target and non-target sites, making weed population control extremely challenging (Brattsten *et al*., 1986).

Management of herbicide resistantce:

If herbicide resistance has been identified or strongly suspected, different strategies need to be included in weed control.

It is safest to stop using herbicides with the same action mode. However, the herbicide is still the greatest option for comprehensive weed management because it frequently continues to be effective against a wide variety of weeds. If it is decided to keep applying the herbicide, there are numerous options:

- Using a combination or pre-pack of a herbicide tank with at least one mechanism of action known to suppress the resistant weed for proactive (pre-plant or pre-emergence) weed control.
- Only applying post-emergence herbicides in tank combinations or pre-packs that have at least one recognised mode of action for controlling resistant weeds.

Plants and weeds are difficult to identify in the initial stages of plant growth because they have a lot of the same physical characteristics. For example, the presence of *Phalaris minor* weed will make hand weeding in wheat less efficient. However, using machines to weed is expensive, and managing the workers is difficult. Thus, one efficient way for weed management, particularly in wheat crops, is the use of herbicides.

Rotating among several herbicide modes of action helps slow the emergence of weed resistance. For example, the population of *Phalaris minor* may become resistant to the new class of herbicides if two different modes of action of herbicides are used. In 1995, the Punjab and Haryana region developed three herbicides to combat resistant biotypes: fenoxaprop, clodinafop, and sulfosulfuron (Malik and Singh, 1995)

These herbicides are commonly used in areas affected by herbicide resistance because they are highly effective in controlling *Phalaris minor*. For the majority of weed species, these herbicides are very effective. After consistent use for 8 to 10 years, these begin to exhibit resistance. After consistent treatment for nearly 8 years, these alternative herbicides are exhibiting resistance (Kwon *et al*., 2015). When these herbicides are ineffective at controlling the weed population in wheat crops, another class of herbicide called pinoxaden might be employed in their place. Pendimethalin is now frequently used to suppress *Phalaris minor* in wheat crops.

The *Phalaris minor* population in wheat crops is also controlled with various herbicide mixes. To suppress the weed population of *Phalaris minor* and other weed species, herbicidal formulations such as mesosulfuron + iodosulfuron, fenoxaprop + metribuzin, etc. are used. These provide effective weed control, particularly in reducing the prevalence of *Phalaris minor* in agriculture fields. Metribuzin is a herbicide that inhibits photosystem II and is efficient in reducing herbicide resistance in the population of *Phalaris minor* (Goggin *et al*., 2016). However, if this herbicide is applied after a rain, the crop may suffer damage. As a result, some species or kinds of wheat become poisonous, which can harm the wheat crop. Different herbicide mixes are available, however due to the presence of sensitive wheat varieties in the field, their usage is not widespread. They might have an impact on the wheat crop's development in the field.

Metribuzin can be used with fenoxaprop-p-ethyl, however this combination is not commonly used due to its toxicity. PBW 550, HD 2967, and HD 2854 are a few of the herbicide-sensitive cultivars.

Conclusion

Weeds use many kinds of strategies to avoid the harmful effects of herbicides. When compared to target site resistance mechanisms, the NTSR (Non target site resistance) mechanisms use more complicated pathways since they combine variations from multiple physiological processes. Understanding NTSR mechanisms in greater detail can provide much-needed additional details on the procedures needed to combat herbicide resistance. These findings can considerably advance our understanding of the mechanism of action of these herbicides and help to clarify the concept of herbicide resistance. These results can also be used to increase the efficacy of herbicides and develop better strategies for managing populations that are resistant to herbicides.

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