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Herbicide Resistance: Impact and Management

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Abstract—*The intensive and continuous use of herbicides over the last six decades has resulted in the development and evolution of weeds resistant to the normally phytotoxic chemicals. Herbicide resistant problems are accelerating and consequently management of weeds is becoming increasingly more difficult and complex. India too, despite its very limited use of herbicides by the farmers, is reeling under a grave situation of herbicide resistance in Phalaris minor weed for isoproturon in wheat crop. Continuous use of isoproturon in wheat since last 18-20 years, has resulted in the evolution of resistant biotypes of Phalaris minor. New and high risk herbicides like sulfonylurea and aryloxy phenoxy propionate groups may cause resistance in weeds by 3-5 years of their continuous use. Herbicide resistant weeds threaten the continuous success of herbicide technology to contribute to world crop production. Effective management of herbicide resistance in weeds depends on reducing selection pressure, which of necessity involves reducing the frequency herbicide applied and increasing reliance on IWM practices. Herbicide mixtures, sequences and rotations with different modes of action, crop rotation, IWM and accurate record keeping aid in resistant management.*

1. INTRODUCTION

A wise farmer once said, "If you do anything the same way long enough, it's wrong because things are going to change." This is certainly true when speaking of weeds and herbicide resistance. Herbicide resistance is the inherent ability of a species to survive and reproduce following exposure to a dose of herbicide normally lethal to its wild type. Although herbicide resistance was reported as early as 1957 against 2,4-D from Hawaii, the first report of herbicide resistance was against triazine herbicide in common groundsel and was reported in 1968 from U.S.A. Since then, the number of resistant weed biotypes against various herbicides is on rise. Till recently, 284 biotypes belonging to 171 species have reported resistance against various herbicides [3]. Moreover, the area of land infested with resistant weeds is increasing rapidly.

2. FACTORS DETERMINING THE SELECTION OF BIOTYPES RESISTANT TO HERBICIDES

2.1 Selection pressure

It is assumed that a small number of plants in any weed population is naturally resistant to a given herbicide and that repeated application of that herbicide will allow these plants to survive and set seed. Over a period of several such selections the resistant biotype can dominate the weed population [5].

2.2 Herbicide persistence in soil

Herbicides with long residual effect exert selection pressure on weed populations longer than herbicides that easily dissipate in soil. This is probably one of the reasons why weed populations resistant to a group of herbicides as new as the sulfonyl ureas have been found. If the herbicides is not very persistent, the seed bank in the soil may decrease the probability of proliferation of the resistant biotypes by keeping an elevated population of susceptible individuals that germinate and reproduce once the herbicide has lost its biological effect.

2.3 Site of action

Products that are highly active at a single site of action are the most likely to have resistant biotypes to appear. Inhibitors of aceto lactate synthase and acetyl CoA carboxylase are highly susceptible to resistant development [4].

3. IMPACT OF HERBICIDE RESISTANCE

Herbicide resistance typically increases production costs and limits options for herbicides, cultivation and rotations. With regard to the magnitude of this phenomenon and its worldwide distribution, it should be stated that in 2006 there were 311 resistant biotypes from 183 species, including 110 dicots and 73 monocots which affect approximately 270 000 fields.

The main groups of herbicides causing the most problems of resistance are currently the ACCase inhibitors, s-triazines and ALS inhibitors. Similar behaviour is also shown by the group of glycines, concretely glyphosate [2-7]. Glyphosate resistance is especially important as a highly effective compound due to its worldwide use, and due to the serious problems that its resistance may cause in the management of genetically modified crops.

4. RESISTANCE RISK ASSESSMENT

There are several factors to consider when evaluating herbicide resistance risk. Some of these relate to the biology of the weed species in question, others relate to particular farming practices [6]. Some examples are given below:

4.1 Number or density of weeds

As resistant plants are assumed to be present in all natural weed populations, the higher the density of weeds, the higher the chance that some resistant individuals will be present.

4.2 Natural frequency of resistant plants in the population

Some weed species have a higher propensity toward resistance development; this relates to genetic diversity within the species and, in practical terms, refers to the frequency of resistant individuals within the natural population.

4.3 Seed soil dormancy potential

Plant species with a longer soil dormancy will tend to exhibit a slower resistance development under a selection pressure as the germination of new, susceptible, plants will tend to dilute the resistant population.

5. CROP MANAGEMENT PRACTICES WHICH MAY ENHANCE RESISTANCE DEVELOPMENT

5.1 Frequent use of herbicides with a similar site of action

The combination of ‘frequent use’ and ‘similar site of action’ is the single most important factor in the development of herbicide resistance.

5.2 Cropping rotations with reliance primarily on herbicides for weed control

The crop rotation is important in that it will determine the frequency and type of herbicide able to be applied. It is also the major factor in the selection of non-chemical weed control options. Additionally, the cropping period for the various crops will have a strong impact on the weed flora present.

5.3 Lack of non-chemical weed control practices

Cultural or non-chemical weed control techniques, incorporated into an integrated approach is essential to the development of a sustainable crop management system.

Table 1: Assessment of the risk of resistance development per target species

Management option	Risk of Resistance		
	Low	**Moderate**	**High**
Herbicide mix or rotation in cropping system	> 2 modes of action	2 modes of action	1 mode of action
Weed control in cropping system	Cultural, mechanical and chemical	Cultural and chemical	Chemical only
Use of same mode of action per season	Once	More than once	Many times
Cropping system	Full rotation	Limited rotation	No rotation
Resistance status to mode of action	Unknown	Limited	Common
Weed infestation	Low	Moderate	High
Control in last 3 years	Good	Declining	Poor

6. PREVENTION AND MANAGEMENT OF HERBICIDE RESISTANCE

The prevention of resistance occurring is an easier and cheaper option than managing a confirmed resistance situation. Experience has shown that simply changing herbicides is not enough to overcome resistance in the mid to long term and that a sustainable, integrated system needs to be developed which is appropriate for the farm in question.

Integrated Weed Management is defined as the use of a range of control techniques, embracing physical, chemical and biological methods in an integrated fashion without excessive reliance on any one method. The following information outlines the three key areas of weed management: crop management, cultural techniques and chemical tools which, when employed in a rotational and integrated approach will help to reduce the selection pressure on any weed species and hence significantly reducing the chance of survival of resistant weeds.

6.1 Rotation of Crops

The principle of crop rotation as a resistance management tool is: to avoid successive crops in the same field which require herbicides with the same site of action for control of the same weed species. Crop rotation allows the following options: 1) Different crops will allow rotation of herbicides having a different site of action. 2) The growth season of the weed can be avoided or disrupted. 3) 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. 4) Crops also differ in their inherent competitiveness against weeds. A strongly competitive crop will have a better chance to restrict weed seed production.

6.2 Cultural Techniques

Cultural (or non-chemical) weed control methods do not exert a chemical selection pressure and assist greatly in reducing the soil seed bank. Cultural techniques must be incorporated into the general agronomy of the crop and other weed control strategies. Some of the cultural measures for weed control could include: 1) cultivation or ploughing prior to sowing to control emerged plants and to bury non germinated seed 2) delaying planting so that initial weed flushes can be controlled with a non selective herbicide 3) using certified crop seed free of weed 4) post-harvest grazing, where practical 5) stubble burning, where allowed, can limit weed seed fertility 6) in extreme cases of confirmed resistance, fields can be cut for hay or silage to prevent weed seed set.

6.3 Herbicide rotation and herbicide mixtures

Herbicide rotation or mixtures refers to the rotation or mixtures of Herbicide Site of Action against any identified weed species. When planning a weed control program, products should be chosen from different site of action groups to control the same weed either in successive applications or in mixtures [1].

A general guideline for the rotation of chemical groups should consider:

1) Avoid continued use of the same herbicide or herbicides having the same site of action in the same field, unless it is integrated with other weed control practices

2) Limit the number of applications of a single herbicide or herbicides having the same site of action in a single growing season

3) Where possible, use mixtures or sequential treatments of herbicides having a different site of action but which are active on the same target weeds

4) Use non-selective herbicides to control early flushes of weeds (prior to crop emergence) and/or weed escapes

We can conclude that rotation of herbicides alone is not enough to prevent the development of resistance. To retain these valuable tools, the chemical rotation explained must be employed in association with at least some of the other weed control measures outlined. Mixtures can be a useful tool in managing or preventing the establishment of resistant weeds. For chemical mixtures to be effective, they should:

1) Include active ingredients which both give high levels of control of the target weed; and,

2) Include active ingredients from different site of action groupings

7. CONCLUSION

How quickly the resistant weed species will revert to "natural levels" within the population, if ever, will depend on a number of factors such as the relative fitness of the resistant versus susceptible biotypes, the weed's germination pattern and the weed's reproductive capabilities. It is only through the development and implementation of an integrated weed management program utilizing as wide a variety of weed control practices as are economically feasible that the problem can be effectively managed or prevented. Steps towards the management of herbicide resistance 1) Assessment of risk through a cropping system checklist 2) Evaluation of options (including costs) to be adapted to local conditions 3) Implementation of a sustainable weed control program 4) Rotation of crops to enable a variety of weed control options 5) Rotation of cultural practices to lower the reliance on herbicides 6) Rotation of herbicide site of action to reduce the likelihood of resistance to a specific product group in this heading, they should be Times 11-point boldface, initially capitalized, flush left, with one blank line before, and one after.

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