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# Managing Herbicide Resistance: The Role of Extension

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## Abstract

The rapid evolution of herbicide resistance poses a significant threat for conventional agricultural practices. In practice, herbicide resistance seems to be a very complicated problem to deal with. Extension can play a significant role in managing herbicide resistance educating farmers on the main advantages and disadvantages of the available methods aiming to control and minimize herbicide resistance.

This could be achieved by redirecting the educational efforts more towards the principles of weed biology and integrated weed management, teaching farmers how to learn, paying attention to the basic prerequisites for the new control methods and providing precise information about the economic usefulness of each proposed method.

## Introduction

The occurrence of herbicide-resistant weeds has become a common and almost worldwide phenomenon, particularly the last few years, due to the continuous use of herbicides as the main method of weed control, in combination with monoculture cropping systems (Shaner, 1995).

Such cropping systems, developed since the discovery of selective herbicides, rely mainly on high efficacy and cost effectiveness of herbicides for maximum crop productivity and intensive use of land.

However, the strong selection pressure imposed to weed populations by the continuous use of herbicides has resulted in development of resistance. Herbicide resistance poses a major threat to conventional agricultural practices as, to date, more than 250 weed biotypes in 50 countries have been reported to be resistant to one or more than one herbicide(s) (Heap, 2002).

Herbicide resistance is expected to strongly affect weed management strategies in the future (Duke, 1997). How herbicide resistance will ultimately influence agriculture may depend on many factors and may vary considerably with crop and location.

It is evident, however, that when resistance has been extensively developed, weed management with certain herbicides becomes inadequate and different herbicides or other methods of weed control should be adopted. This may have a great impact on the agriculture of an area (Peterson, 1999). Farmers, on the other hand, do not seem to rapidly adopt new weed management strategies to delay the development of resistance.

On the contrary, they tend to continue with a successful herbicide program until it fails and only when resistance to herbicides fully occurs they adjust their weed management practices accordingly (Pannell and Zilberman, 2001).

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**Managing Herbicide Resistance: a Complicated Problem to Solve**

Various management strategies have been proposed for the control of herbicide resistance (Friesen et al., 2000). Among them, the most common are:

- Herbicide rotation,
- Herbicide mixtures,
- Herbicide-resistant crops,
- Cultural weed control practices such as cultivation, delayed sowing, crop rotation, set aside, and competitive crops.

These strategies, however, may be difficult to implement, ineffective in practice, or in many cases more costly for the farmer to use.

***Herbicide Rotation.***

Different herbicide programs are not always effective either because current herbicide alternatives are less effective than those already used or because alternatives are often more costly to use. New herbicides may provide effective options for control of herbicide-resistant weeds, but the cost is often equal to or greater than the cost of the available products. Furthermore, new chemistry is developed slowly.

***Herbicide Mixtures.***

Mixtures may theoretically be very useful tools for managing herbicide resistance when they meet several criteria (Wrubel and Segel, 1994). It is, however, rather difficult to find herbicides with the proper efficacy, persistence, and mechanism of action to be partners in mixtures for managing resistance. Furthermore, convincing farmers to use mixtures that probably would increase management cost without immediate benefits in weed control is also questionable.

***Herbicide-Resistant Crops.***

The introduction of genetically modified crops (resistant to herbicides) has provided new alternatives for the management of herbicide-resistant weeds. However, besides the controversy about the effects of such crops on human health and the environment, the use of herbicide resistant crops may lead to volunteer control problems (weedy crops), new weeds through introgression and to similar shifts in weed species biotypes in the future as a result of the intensive herbicide use and selection pressure (Lotz et al., 1999). Furthermore, the increased cost of this new technology may be also critical.

***Cultural Methods.***

Cultural methods such as soil cultivation, delayed sowing, crop rotation, set aside, and competitive cultivars can be effective options for management of herbicide resistance, although implementation of these practices is often dictated by personal preferences and factors other than herbicide resistance. In particular, we may consider the following:

- Delayed sowing may reduce the need for herbicide use and, therefore, to reduce the selection pressure imposed by herbicide applications by allowing weed control before crop establishment. This alternative, however, may be ineffective in practice when competition occurs from other weeds normally emerging later in the growing season or when crop growth is not favoured by delayed sowing (Boerboom, 1999; Nalewaja, 1999).
- The limit in adapted crops in certain areas often restricts the use of crop rotation as a method to manage herbicide resistance. Furthermore, crop rotations are dictated solely by profit potential and not management of herbicide-resistant weeds. Thus, the loss in profitability from growing the competitive crop is often of greater concern for the farmer than the possible development of resistance.
- Set aside suspends the herbicide treatment at least for a year and, therefore, it can considerably delay the appearance of herbicide resistance. This method, however, is restricted by the intensive use of land and also by the farmer's demand for high and immediate profit. It would be rather difficult, therefore, to adopt as a preventive measure for managing herbicide resistance, unless high weed densities occur (Richter et al., 2002).
- Increasing the ability of crops to compete against weeds, through either enhancing crop tolerance or crop interference to weeds, provides an attractive option to current weed control practices (Pester et al., 1996). Although research has revealed differences in weed competitiveness among crop cultivars, the

development of such cultivars with increased competitive ability against weeds has been very slow. The complexity of weed-crop interactions may be considered a major reason for this delay. Traits of the competitive crops may vary considerably among weed densities and production systems. The wide range of weed species and weed densities, which are most often spatially and temporally variable, may significantly influence performance of competitive crops across an area.

It is evident from all the above that managing herbicide resistance is a very complicated problem. There are many ways for weed management to aim at minimising the development and spread of herbicide resistance. All methods, however, may be useless, unless they are practiced in the field, monitored for effectiveness, and applied properly by the farmer for best results. Furthermore, the economics of each alternative should be investigated.

**The Role of Extension: Outlining the Main Objectives**

Extension services have always been an important source of agricultural information and a successful disseminator of information to farmers (Rogers, 1983). They have been the main agency helping farmers make rational use of the existing agricultural technology to improve productivity and income.

Extension specialists and private consultants deal with weed control practices on a day-to-day basis, as such extension services have been one of the few sources of reliable information about weed management practices for farmers.

Extension can play an important role in managing herbicide resistance. Its primary role is to provide accurate information to the farmers on various topics, including herbicide resistance and also to educate growers on the most effective means of managing and preventing herbicide resistance. Collection, evaluation, summarizing, and also dissemination of the available information is, therefore, important. Extension agents can provide specialists and researchers with valuable information on farmers' needs, as well as feedback on the effectiveness of new weed control methods.

On the other hand, the role of extension is not confined only to a distributive mechanism of the available information. Extension can also help researchers develop the most environmentally, socially, and economically sound technologies.

Often, new technologies must first be modified to fit well the diverse climatic, ecological, and particularly, socio-economic conditions. Extension can help in turning basic scientific advances into useful technologies for farmers by working closely with university scientists and industry.

**The Role of Extension: Redirecting Educational Efforts**

Changes in agriculture have altered the role of extension activities, particularly in weed management education. Concerns about common weed control practices have increased the consideration of new weed management strategies. These changes have created a chance for extension to redirect its educational efforts towards the principles of weed biology and integrated weed management, spending less time on herbicide evaluation and recommendation.

The increased dependence on herbicides has increased the demand for this type of information. Focusing on weed biology allows the connection between fundamental biology and practical weed control. One consequence of the one-dimensional management programs is rapid shifts in weed populations. Providing an understanding of the biological bases for these shifts in weed populations prepares for the development of management programs that will provide adequate control of the new weed problems and reduce the likelihood of continued shifts in weed populations.

Educators should pay attention to basic prerequisites for applying any new weed control method for managing herbicide resistance, taking into account the special conditions for each case. As mentioned above, each proposed method has limitations to be effectively applied. University specialists and researchers should not assume that farmers always know what they are doing. Often, educators assume that learners' level of knowledge is higher than it actually is.

In many instances, l*earning how to learn* would be much more important for farmers than learning new research findings. Attention must be given to the current levels of knowledge and competence to develop the special skills required for the new weed control methods.

Educators should also include precise information about economic usefulness of each method. Profits are a major reason for adopting or rejecting any innovation. Risk, opportunity costs, production possibilities, as well as competing production practices can dramatically impact a farmer's adoption decision.

Several useful tools can be used to disseminate weed biology and management related information. Information about weed biology usually comprises a significant part of the information presented at traditional extension meetings, with the remainder of time spent discussing specific control tactics (herbicides, tillage,

etc). Extension bulletins on topics such as herbicide resistance, competition between crops and weeds, weed seed banks, and timing of weed emergence can be a useful source of information. Posters, computer software programs, and web pages have also been used to disseminate weed biology information.

In particular, the internet can be an effective way of implementing Extension Service training (Lippert and Plank, 1999). With the abundance of sources for herbicide information, there is a niche for extension to provide the knowledge required to improve weed management systems used in agriculture.

In the long run, this information should have much greater impact on the decision making process of persons involved in weed management, than simply providing information concerning specific control tactics, such as herbicide selection, etc.

Given the complexity of finding the most appropriate way to manage herbicide resistance on a case-by-case basis, extension services can and should play a significant role educating farmers.

This may require major changes in the extension organisations, including a retraining of their staff, the use of different sources of information than those on which one relied in the past and a change in extension methods.

Apart from the main advantages and disadvantages of the available means of managing herbicide resistance, extension services can help farmers not only to choose and implement the most appropriate and cost-effective method for their particular scenario, but, where appropriately structured can also help them to modify their behaviour from solely depending on herbicides towards more sustainable practices.

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