BEST MANAGEMENT PRACTICES FOR WEED MANAGEMENT (adapted from the Herbicide Resistance Action Committee (HRAC) guidelines at: HRAC website > Home)

GENERAL PRINCIPLES (HRAC website > Home):

The general principles of herbicide resistance management are:

(1) Apply integrated weed management practices. Use multiple herbicide mechanisms-of-action with overlapping weed spectrums in rotation, sequences, or mixtures. (Integrated weed management practices include the combination of cultural, mechanical, and chemical weed control practices such that selection pressure from one method or any one herbicide is minimized.)
(2) Use the full recommended herbicide rate and proper application timing for the hardest to control weed species present in the field.
(3) Scout fields after herbicide application to ensure control has been achieved. Avoid allowing weeds to reproduce by seed or to proliferate vegetatively. (Scouting fields regularly to identify weeds and map their distribution will assist in developing management strategies.)
(4) Monitor site and clean equipment between sites.

For annual cropping situations also consider the following:

- Start with a clean field and control weeds early by using a burndown treatment or tillage, in combination with a pre-emergence residual herbicide, as appropriate.
- Use cultural practices such as cultivation and crop rotation, where appropriate.
- Use good agronomic principles that enhance crop competitiveness.

DISCUSSION:

Integrated Weed Management (IWM) is defined as a diversified weed management approach that uses information on the biology and ecology of the weed(s) to select from available control techniques, embracing cultural, chemical and/or mechanical methods in an integrated fashion without excessive reliance on any one strategy. (Note: Weed Scientists also use the term diversified weed management to describe this approach.)

The goal of integrated/diversified weed management is to manage weeds in a sustainable way in order to maximize crop productivity, prevent weed escapes, and ultimately reduce the size of the soil seed bank. Therefore, growers should start with weed-free fields, and maintain them as weed-free fields, to reduce the potential for herbicide resistance to evolve and to reduce weed seed-production, including fields with suspected herbicide resistant weed biotypes. Regular scouting and proper weed identification are critical elements of effective IWM programs which cannot be over-emphasized. It is important to recognize that weed populations will adapt to any weed management tactic that is used recurrently and where it is the only tactic used to manage weeds.

IWM programs need to be developed based on understanding the weed life cycle, growth characteristics, and population densities of the weed species identified in the field. Preventing the evolution of herbicide resistant biotypes by using a combination of cultural, herbicide, and mechanical
tactics is generally easier and more economical than managing a confirmed herbicide resistance situation. Experience has shown that simply changing herbicides after resistance has evolved to a product or mechanism of action (MOA) is not enough to create a long-term sustainable weed management system; thus a diversified approach must be adopted which is appropriate for the farm in question. Better still is to adopt (IWM) proactively, prior to the evolution of herbicide resistant weed biotypes. Examples of each method follow:

1. **Cultural practices**: manage the crop to enhance productivity and competitiveness;
   (a) control weeds around fields, maintain and clean field equipment
   (b) remove weeds that establish in a field after harvest
   (c) carefully monitor fields during the growing season and remove weeds prior to setting seed
   (d) use cover crops, crop rotation, and rotate planting dates
   (e) remove weeds with post harvest stubble burning (where allowed).

2. **Herbicide practices**: apply herbicides with different mechanisms of action in mixtures, sequential timings (pre followed by post) or alternating products with different MOAs across a crop rotation.

3. **Mechanical practices**: preplant, in-crop, and/or post harvest tillage.

The following is additional information on key weed management practices that may be used in an integrated/diversified approach to reduce the selection pressure from recurrent tactics on any weed species – hence significantly reducing the chance of survival of herbicide resistant weeds. Growers should consult their local extension recommendations and Natural Resources Conservation Service (NRCS) office to develop a management plan that will provide effective weed management without compromising conservation programs.

**ROTATION OF CROPS**

Crop rotation as a resistance management tool allows one to: (1) integrate different cultural practices which can influence weed population diversity and density, and (2) facilitate the use of alternative herbicide mechanisms of action for control of the same weed species across multiple cropping seasons.

Crop rotation allows the following options:

- Different crops will allow rotation herbicides with different mechanisms of action.
- The growth season of the weed can be avoided or disrupted when crops with different planting/harvest dates are grown.
- Crops with different sowing times and different seedbed preparation can facilitate use of a variety of cultural techniques to manage a particular weed problem.
- Crops also differ in their inherent competitiveness against weeds. A highly competitive crop will have a better chance to restrict weed seed production.

**HERBICIDE MIXTURES, SEQUENCES AND ROTATION**

Herbicide rotations, sequences or mixtures should include herbicides with different mechanisms of action that are each active against identified target weed species. Experience has shown that simply
changing herbicides after herbicide resistant biotypes have evolved does not provide a long-term sustainable weed management system. A diversified (IWM) approach specifically developed for the farm or field in question that includes herbicide rotation or mixtures as well as other tactics must be adopted.

The Weed Science Society of America (WSSA) has prepared a table that classifies herbicides according to mechanism of action (Weed Science Society of America). When planning a weed control program, proper weed identification is the key to success of the program. After consulting with state extension personnel or qualified advisors, herbicides should then be chosen from different mechanism of action groups to control the same weed with sequential applications or mixtures of these herbicides, unless otherwise directed. Classification of herbicides according to mechanism of action is in itself NOT a recommendation of which herbicide to use. This system does not account for efficacy on individual weed species or on herbicide resistance risk assessment, but is solely based on chemical mechanism of action. This mechanism of action table should be used as a tool to help select herbicides from different mechanism of action groups, so that appropriate mixtures or rotations can be included within an IWM system.

General guidelines for managing herbicide uses are:

- Avoid continued use of the same herbicide or herbicides having the same mechanism of action in the same field, in a single growing season or across years, unless it is integrated with other weed control strategies (including the use of herbicides with different mechanism(s) of action and/or mechanical methods of weed control).
- Where using herbicide mixtures, sequential treatments, or rotation of herbicides having a different mechanism of action, it is important that each is active on the same target weeds.
- Use non-selective or selective herbicides to control early flushes of weeds (prior to crop emergence) and/or weed escapes.
- Follow herbicide label use instructions carefully. This especially includes the use of recommended rates and application timing for the target weeds.
- Routinely monitor results of herbicide applications, and note any trends or changes in the weed populations present.
- Maintain detailed field records so that crop and herbicide history is known. Records should also include a history of weed identification, population density, and distribution; along with a record of treatment effectiveness.

Identification of the problem

A herbicide may not provide acceptable control for a number of reasons besides the presence of resistant weed species. Ensure that the proper rate was applied and the environmental conditions and weed growth stage were appropriate for that application. Herbicides may fail due to application to drought-stressed weeds, due to rain soon after application, lack of rainfall for incorporation, or other
 factors. Work with a weed scientist at your land grant university to verify the presence of herbicide-resistant weed species.

**What to do in cases of confirmed herbicide resistance**

In cases where a control failure has been confirmed as a herbicide resistant biotype, immediate action is recommended to limit further seed production. The degree of the action will depend on the crop developmental stage in the field and the density and distribution of the problem weed.

Some options to consider:

- Destroy and remove the remaining weeds from the field, particularly if the population is growing in patches, and limit build-up and spread of seed in the soil.
- Limit the field-to-field movement of herbicide resistant weed populations by cleaning all equipment to avoid transfer of the herbicide resistant weed seed.
- Avoid using the herbicide to which resistance has been confirmed, unless used in conjunction with additional herbicides that have different mechanisms of action and demonstrated efficacy on the herbicide resistant weed population.
- Select fields with confirmed herbicide resistant weeds for rotation to another crop or set these fields aside for the following cropping season.
- Seek advice from the local cooperative extension office for assistance in long term planning of weed control in these fields.

Once herbicide resistant weed numbers are reduced, implementation of a diversified weed management system as outlined in this document, will ensure that crops can continue to reach high levels of productivity in the fields in question.

A case study analysis carried out in England (ref. Orson and Harris, 1997) identified that the evolution of herbicide resistance can be categorized into stages, each stage requiring a new intensity of management. These management levels naturally carry a cost over that which is considered as the standard farming practice. An example cited in the case study is the option of delayed planting. While this is a very effective tool for managing weed numbers, the cost of doing so, if yield is reduced, can be significant.

The possible increased costs incurred to manage herbicide resistant weed populations must be measured against the impact of NOT applying these measures. In extreme cases, the rapid increase of herbicide resistant weeds will also severely affect crop yields and may eventually impact land value itself.

Key to the measurement of the cost of herbicide resistant weed management is the inclusion of several variables such as, but not limited to, crop yield potential, commodity prices, local costs of various techniques such as tillage, the weed species, and the soil type, among other issues. This means that a cost evaluation can only be accurate on a local level and extrapolation from or to other situations can offer principles but not the specific detail.
Notes: This paper was prepared by Jill Schroeder and John Soteres September 17, 2010. It was reviewed by members of Global HRAC, members of WSSA S-71 Committee and other university weed scientists attending a NACD hosted symposium in Little Rock, AR in August, 2010.

If you have questions, contact Jill Schroeder (jischoe@nmsu.edu) or John Soteres (john.k.soteres@monsanto.com).