PART XII
Herbicide Considerations

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Management of herbicide resistant weeds

Since the initial development of selective herbicides in the late 1940's, farmers have relied heavily on these materials to provide effective and economical control of weeds. Herbicide use has allowed tremendous advances in our agricultural productivity. The relatively recent development of resistance in various weed species to commonly used herbicides represents one of the most serious threats to profitable agronomic crop production. Many factors involving the characteristics of both the target weed and the herbicide determine whether resistance will occur, and the rate at which resistant species develop. The following is a brief discussion of the factors involved in the development of herbicide resistance, and appropriate methods for management of resistant weeds.

Resistance, as defined by the Weed Science Society of America, is the naturally occurring inheritable ability of some weed biotypes within a population to survive a herbicide treatment that would, under normal conditions of use, effectively control that weed population. The genetic change which confers resistance to certain members or biotypes within a given weed species is naturally occurring, and can allow those weeds to survive a herbicide application in a number of distinct ways. The most common mechanism for resistance is alteration of the target enzyme site of herbicide binding. In the susceptible species, the herbicide would bind to an enzyme in such a manner as to prevent its catalyzation of a necessary metabolic reaction, thereby causing death of the plant. In weeds with the altered binding site, however, the herbicide cannot bind, and the reaction proceeds without deleterious effect on the plant. Increased herbicide metabolism also accounts for herbicide resistance in some weeds, in which the herbicide is rapidly degraded to nontoxic forms in the resistant biotype but is retained primarily in its toxic form in the susceptible biotype. A third resistance mechanism involves enzyme amplification or overproduction in the resistant biotype, wherein increased levels of the enzyme allow a requisite reaction to proceed at a normal rate despite the presence of the herbicide.

Many factors determine the likelihood of the development of resistance in a weed species to a specific herbicide. Herbicides with high specificity in mode of action provide a much greater potential for resistance. Where alteration of the target site is the mechanism for resistance, and the herbicide is specific to inhibition of a single enzyme, simple single gene mutations can result in resistant individuals. Conversely, herbicides with broader effects on multiple sites or functions provide relatively little potential for the development of resistance. Herbicide persistence also affects the potential for the development of resistance, because the length of time that the selection pressure is present directly influences the likelihood that resistant individuals will be identified. Continued use of the same herbicide, or herbicides with the same mode of action, also dramatically increases the potential for resistance.

The potential for resistance is also determined by characteristics of the weed species. Species with high seed production and rapid turn over of the weed seed bank in the soil are most likely to develop resistance. The rate of resistance development is also determined by the extent to which a mutation which confers resistance is distributed throughout the population prior to initiation of the selection pressure via the herbicide. Fitness of the resistant individuals also determines the extent to which this biotype will become a constraint to production, where a less fit resistant biotype will pose a lesser threat to production than a resistant biotype with fitness similar to or exceeding that of the susceptible biotype.

In Virginia, triazine resistant pigweed is currently the most prevalent herbicide resistant weed species. This problem arose due to an altered target site and reduced susceptibility of this pigweed biotype to triazine herbicides including atrazine, simazine (Princep), and cyanazine (Bladex). The resistant pigweed biotype spread rapidly in western and southwestern Virginia due to continuous no-till corn production and continuous use of atrazine plus simazine. The resistant biotype has subsequently spread across Virginia, but this eastward movement was slowed by the fact that the corn/soybean rotation common in eastern Virginia introduced alternative rotational herbicides. Other resistant weed species confirmed in Virginia include triazine resistant common lambsquarters, imazethapyr

(Pursuit) resistant pigweed, diclofop (Hoelon) resistant annual ryegrass, and sethoxydim (Poast Plus) resistant johnsongrass. It is important to note that these weeds may also exhibit resistance to other herbicides in the same chemical family or in the same mode of action group.

Herbicide resistant weed species must be managed with a combination of herbicidal, cultural, and mechanical weed control techniques. Crop rotation, where appropriate, is critical to successful resistant weed management, as it may allow the use of a more competitive crop or a crop whose life cycle and associated management and harvest procedures disrupt the life cycle of the resistant species. Most critical to resistant weed management, however, is herbicide rotation. Whether in a continuous crop, or in a crop rotation, herbicide rotation must be employed to prevent the development of new herbicide resistant weed species or to manage existing weed species. Rotation of herbicides with differing modes of action and with high efficacy on the target species will prevent a resistant biotype from developing to the point that it constrains production. Combination of herbicides within an application or within a growing season is also effective for resistant weed management, where combinations of differing modes of actions will control an existing resistant biotype as well as prevent the development of new resistant species. As stated, the use of herbicides with high specificity in terms of mode of action increases the likelihood of the development of resistance. Herbicide rotations or combinations involving two herbicides with modes of action with this degree of specificity should be avoided if possible due to the possibility of the development of resistance to both compounds (multiple resistance).

Chemical combinations or rotations employed without knowledge of the mode of action of the herbicides being used cannot constitute meaningful resistance management. The Pest Management Guide for Field Crops, VCE Publication 456-016, contains tables which relate the active ingredients in all recommended single ingredient and prepack herbicides for agronomic crops, as well as tables relating the mode of action of each herbicide and its effectiveness on individual weed species. Taken in total this information can easily be used to formulate effective programs for the management of resistant weed species.

Rainfree Periods for Post Emergence Herbicides

Information as a guide to pre-pack herbicide mixes, guide to single active ingredient herbicides, and herbicide recommendations are available in The Pest Management Guide for Field Crops, VCE Publication 456-016 which is revised annually.

The table below is included in this reference publication because rainfall is difficult to predict in our environment, especially in the summer. The table shows the critical time between application and rainfall varies from only 30 minutes to eight hours.

Rainfree Periods for Postemergence Herbicides

Herbicide	Hours	Herbicide	Hours
Accent	4	Harmony Extra	3
Aim	1	Hoelon	Not specific
Assure II	1	Hornet	4
Ally	4	Laddok S-12	8
Atrazine	1-2	Liberty	4
Banvel	4	Liberty ATZ	4
Basagran	8	Lightning	1
Basis	4	Marksman	6
Basis Gold	4	Northstar	4
Beacon	4	Peak	4
Bladex	1-2	Permit	4
Blazer	6	Pinnacle	1
Buctril	1	Poast Plus/Poast	1

Rainfree Periods for Postemergence Herbicides (cont)

Herbicide	Hours	Herbicide	Hours
Bugle	1	Pursuit	1
Celebrity Plus	4	Raptor	1
Clarity	4	Reflex	1
Classic	1	Resource	1
Cobra	30 minutes	Roundup Ultra	1-6
Concert	1	Scepter	
2,4-D Amine	6-8	Scorpion III	6
2,4-DEster	1-2	Select	1
2,4DB	6	Shotgun	4
Distinct	4	Stellar	1
Exceed	4	Stinger	6-8
Extrazine II	1-2	Storm	8
Flexstar	1	Synchrony	1
Fusilade	1	Touchdown	4
Fusion	1	Tough	1-2
Gramoxone Extra	30 minutes		