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MANAGING HERBICIDE RESISTANCE

Alan C. York
NC State University
Raleigh, NC

Herbicide resistance is defined as the inherited ability of a biotype of a weed to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. In layman's terms, it means a population of weeds that were once controlled by a given herbicide can no longer be controlled by that herbicide at normal use rates.

Herbicide resistance was first reported in 1957, and many resistant biotypes have since been discovered. Worldwide, there are at least 304 biotypes within 182 species resistant to one or more herbicides. In the United States, there are at least 107 biotypes within 63 species resistant to one or more herbicides. Even though herbicide resistance is not a new problem, it has taken on increasing significance for cotton growers because of changes in cultural practices and weed management programs over the past decade. Of particular significance is the widespread adoption of Roundup Ready technology and the increased acreage devoted to reduced tillage. The diversity once present in weed management programs (preplant tillage and conventional seedbed preparation, two to three preplant incorporated and preemergence herbicides, multiple directed herbicide applications, multiple cultivations) has been greatly reduced as growers have moved toward no-till and heavy reliance on glyphosate. Examples of resistance to some of the older chemistries used in cotton include common cocklebur resistant to organoarsenical herbicides (MSMA and DSMA), goosegrass, johnsongrass, and Palmer amaranth resistant to dinitroaniline herbicides (such as Prowl and Treflan), and johnsongrass resistant to ACCase inhibitors (such as Poast and Fusilade). These problems occurred in the Southeast and Midsouth primarily in areas where cotton was grown continuously and where these herbicides were used year after year.

Weed scientists are becoming increasingly concerned with resistance to particular modes of action (defined as the mechanism by which herbicides kill plants). One such mode of action is the ALS (acetolactate synthase) inhibitors. There are a number of herbicides within four chemical classes [imidazolinone, sulfonylurea, pyrimidinyl(thio)benzoate, and triazolopyrimidine] that kill plants by inhibiting ALS. These herbicides are registered for use in corn, soybean, peanut, small grains, pastures and forages, and several vegetable crops. Two ALS inhibitors, Staple and Envoke, are used in cotton. Resistance to ALS inhibitors developed quickly (in some cases in as little as 3 or 4 years) and is widespread, both in terms of geography and weed species. In the United States alone, ALS resistance has been reported in 38 species. Of primary concern in the Cotton Belt is ALS resistance in cocklebur and *Amaranthus* species (pigweed species). ALS resistance in cocklebur and *Amaranthus* has been reported in eight cotton-producing states. ALS resistance is particularly a concern in Palmer amaranth in the southeastern states. Palmer amaranth is one of the most troublesome weeds in cotton in the Carolinas and Georgia, and it is also found in most other cotton-producing states. The extent of the resistance in the Carolinas and Georgia is unknown primarily because essentially every acre of cotton is treated with glyphosate, and glyphosate normally controls this weed well. The resistance in these states is most likely widespread.

The other mode of action where resistance is of utmost concern is the EPSPS (5-enol-pyruvylshikimate-3-phosphate synthase) inhibitors; glyphosate is the only EPSPS inhibitor currently on the market. Glyphosate resistance has been reported in common ragweed in Arkansas and Missouri, Italian ryegrass in Oregon, Brazil, and Chili, rigid ryegrass in California, Australia, and South Africa, goosegrass in Malaysia, buckhorn plantain in South Africa, hairy fleabane in Spain and South Africa, and horseweed in the United States. Glyphosate-resistant horseweed has been reported in 13 states, with six of those being cotton-producing states. It has been particularly troublesome in no-till cotton in Tennessee and Arkansas. Resistance spread rapidly, primarily because the seed are very light and have adaptations for easy dispersal by wind. Fortunately, glyphosate-resistant horseweed can be managed if its presence is known ahead of time. Research in Tennessee has shown good control by dicamba applied as a component of an early burndown program followed by a residual herbicide such as Cotoran (with Gramoxone as needed) at planting to control late-spring emerging plants. Options to control glyphosate-resistant horseweed in emerged Roundup Ready or conventional cotton are very limited.

Concerns with weed resistance in cotton were elevated to a new level in 2005 when Dr. Stanley Culpepper, University of Georgia, confirmed glyphosate resistance in Palmer amaranth in central Georgia. Resistance is thought to occur in several fields in North Carolina, and efforts are underway to confirm it. Suspicious populations also exist in Tennessee and South Carolina. Glyphosate resistance in Palmer amaranth is a very serious concern considering that Palmer amaranth is one of the most common and most troublesome weeds in cotton in the Southeast and that essentially every acre of cotton is planted to a Roundup Ready variety. The problem is further exasperated by ALS resistance in Palmer amaranth. Staple is the only postemergence option growers have to control glyphosate-resistant Palmer amaranth in Roundup Ready or conventional cotton, and resistance to Staple is thought to be rather common.

Glyphosate resistance in Palmer amaranth is expected to spread rapidly. Palmer amaranth is a dioecious species, meaning there are separate male and female plants. Cross pollination is a requirement in this species. Culpepper has already shown that crosses between glyphosate-resistant males and susceptible females result in glyphosate-resistant offspring. That is evidence that the trait is carried by pollen, hence spread will be limited only by the distance pollen can move and remain viable. Low frequencies of hybridization among *Amaranthus* species has been noted, hence it is quite possible that glyphosate resistance may be transferred to other pigweed species.

Growers, and often those who advise growers, have been rather complacent in regards to herbicide resistance management. They have become accustomed to having new chemistries enter the market on a regular basis. Hence, when resistance to a particular herbicide became a problem, growers simply switched to another herbicide without addressing the reasons for resistance developing with the previously used product. This complacency worsened with the introduction of Roundup Ready technology. The agricultural community was told that weed resistance to glyphosate was highly unlikely. While many scientists didn’t really believe that, growers adopted Roundup Ready technology in a wholesale manner and have relied heavily on glyphosate for weed management in cotton for the past eight years. Now that glyphosate resistance is a reality, resistance to all chemistries becomes of greater concern because other chemistries will be needed to deal with glyphosate-resistant weeds. Growers must be aware that no new herbicide modes of action are expected in the foreseeable future. Because of the economics of the marketplace, industry has greatly curtailed herbicide discovery efforts for cotton and other agronomic crops. Lack of new modes of action means efforts must be made to prolong the useful life of currently available chemistries.

Herbicide resistance results from selection pressure exerted on rare resistant individuals that exist naturally in the population. Prior to exertion of selection pressure, resistant individuals exist in very low frequencies. One resistant plant in a population of one million plants of that species is a common frequency. If a herbicide to which those rare individuals are resistant is used, the susceptible majority is controlled and it is primarily the resistant biotype that produces seed to replenish the seed bank. If that same herbicide, or another herbicide with the same mode of action, is used frequently, resistant individuals will increase in frequency until much of the population is comprised of the resistant biotype. The number of cropping seasons required for resistance to build to levels that result in a weed control failure depends upon a number of factors. It may take 15 or more seasons for a significant problem to develop, or it may take only three or four seasons.

It is much easier, and usually more economical in the long run, to avoid resistance than it is to deal with resistance once it has become entrenched. A management program aimed at avoiding resistance must focus on reducing selection pressure on any resistant individuals that may exist in the population. Reducing reliance on herbicides is the best way to reduce selection pressure. Growers may be able to capitalize on cultural practices that reduce reliance on herbicides. For example, a competitive crop requires less protection from weeds. Hence, good agronomic practices that favor establishment and early development of the crop will be beneficial in resistance management. This includes practices such as good fertility and control of nematodes, seedling diseases, and early season insects. Reducing row spacing, where practical, can also give the crop a competitive edge over weeds. Other cultural practices that may be applicable in specific situations include use of a heavy cover crop to suppress weeds and long rotations with a perennial forage crop.

Mechanical control, both preplant tillage and in-crop cultivation, can be an excellent component of a resistance management program because it reduces reliance on herbicides. Most growers, however, have opted to reduce or eliminate tillage in an effort to reduce costs. Herbicide resistance could force growers to return to tillage.

Any practice that reduces reliance on herbicides will be beneficial in resistance management. However, herbicides will continue to be the backbone of cotton weed management programs. Hence, it is important that growers focus on ways to better use herbicides with an eye towards resistance management. To this end, growers need to seek diversity in the herbicide modes of action used and also use multiple modes of action. Where economic conditions allow, crop rotation can be an excellent component of a resistance management strategy if one avails himself of the opportunity rotation provides to use different modes of action. Rotating Roundup Ready cotton with Roundup Ready corn or soybean will be of little benefit if one continues to rely heavily on glyphosate in all crops in the rotation. Rotating Roundup Ready cotton with conventional corn or soybean forces one to break the glyphosate cycle. Liberty Link cotton, in areas where adapted varieties are available, affords another opportunity to introduce different chemistry into a system.

Growers should realize that some modes of action are inherently at greater risk for resistance than others, and thus frequent use of those products should be avoided. The ALS inhibitors are a prime example. A cotton grower who plans to use Staple or Envoke in cotton should limit the use of other ALS inhibitors in crops rotated with cotton.

Whether rotating crops or growing continuous cotton, the herbicide program within a crop should be based on multiple modes of action rather than reliance on a single mode of action. This can be accomplished in cotton through the use of preemergence herbicides followed by postemergence herbicides and tank mixtures of herbicides having different modes of action.

Information on herbicide modes of action is readily available online and also in state extension service publications. An excellent web site is www.plantprotection.org.

An example of a resistance management strategy based upon multiple modes of action is the program promoted in Georgia and the Carolinas for Roundup Ready cotton. In addition to the normal use of glyphosate, growers are asked to include two of the following three options in their management programs: a residual preemergence herbicide, such as Cotoran, Prowl, or Treflan; Dual Magnum tank mixed with glyphosate applied overtop; and a residual herbicide, such as Caparol, Direx, Suprend, or Valor, applied at lay-by in mixture with MSMA or glyphosate. The suggested program does not include Staple or Envoke primarily because of the widespread problems with Palmer amaranth. Glyphosate resistance in Palmer amaranth is expected to spread quickly, and Staple (or to a lesser extent Envoke) will be the only postemergence overtop option to control glyphosate-resistant Palmer amaranth in Roundup Ready cotton. With ALS-resistant Palmer amaranth already a concern, the intent is to reduce further selection pressure for ALS resistance in an attempt to maintain Staple as a viable option to control glyphosate-resistant Palmer amaranth where it occurs.

Early detection of possible resistance is also an important component of a resistance management strategy. It is important to detect resistant weeds as early as possible and take appropriate steps to eliminate them before they spread. Unfortunately, there are no quick, in-field assays to determine herbicide resistance. The usual course of action is to collect seed, grow seedlings in a greenhouse, treat them with the herbicide in question, and compare the response to that of a known susceptible biotype. That requires time and, hence, does not resolve the immediate question at hand. However, thorough examination of the problem will usually provide a reasonably good indication as to whether or not resistance is likely a problem. Growers should realize that most weed control failures are not due to resistance. Thus, before assuming resistance, first eliminate other potential causes for the weed control failure. These causes include things such as improper application or use of an inadequate rate, lack of timely rainfall or irrigation to activate preemergence herbicides, failure to apply postemergence herbicides timely, failure to obtain adequate spray coverage with postemergence herbicides, weeds under stress when treated postemergence, wash off of postemergence herbicides, and weed emergence after application of non-residual herbicides. Once such potential causes for weed control failure are eliminated, there are three good indicators of herbicide resistance. One indicator is poor control of a given species by a herbicide that normally controls that species well but good control of other species. A second indicator is patchiness of the weeds. If the problem is detected early, resistant weeds will usually be confined to spots in the field. The third indicator is dead and live plants of the same species intermingled. If one or more of these indicators is observed and the field has a history of use of the herbicide in question, or other herbicides with the same mode of action, then the problem may indeed be resistance. Steps should be taken immediately to eliminate seed production and to prevent spread to other farms.