Innovations in Cotton Weed Management

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The development of herbicide resistant weeds in southeastern U.S. cotton fields presents serious challenges to cotton producers across the country. The number of herbicide resistant weed populations has steadily increased for over the last 40 years and the number of glyphosate resistant weed populations has increased dramatically since 1996 to 21 resistant weed biotypes in early 2012 (11 grass and 10 dicot species). The current status of herbicide resistant weed populations worldwide can be found at www.weedscience.org. Palmer amaranth (carelessweed, pigweed, *Amaranthus Palmeri*) resistant to glyphosate, the active ingredient in Roundup products, is the most widespread and difficult to manage in cotton due to its fast growth rate and prolific seed production. This weed can increase production costs as much as \$100 to \$200 per acre through increased costs for chemical, hand labor, fuel and equipment.

Common cotton production practices in western states such as tillage, furrow irrigation, in-season cultivation and diverse crop rotation sequences have delayed the development of herbicide resistant weeds in the west. Western farmers have the opportunity to be proactive and adopt management practices that can avoid or delay the development of herbicide resistant weeds. The concept of diversity is the key to managing herbicide resistance in weeds. No-till cotton farmers that used only postemergence glyphosate (e.g., Roundup) sprays for weed control were the first to develop glyphosate resistant Palmer Amaranth populations.

Diversity means using a combination of tactics to reduce the selection pressure imposed by any single weed control practice. Diversity means using mechanical, cultural and biological practices in addition to herbicides. Diversity in herbicide use is achieved by applying several herbicides in a season that have different mechanisms of action but will control the same target weed or weeds. The development of herbicide resistance can be delayed and perhaps avoided by using a few or several of the tactics listed in **Table 1**. One of the best ways for western cotton producers to increase their diversity of herbicide use is to apply preplant-incorporated residual herbicides such as trifluralin or pendimethalin at the beginning of the season. Another is to continue to use tillage; both preseason tillage for field preparation and in-season cultivation for weed control.

Preemergence herbicide experiments conducted in 2004 to 2008 at the University of Arizona Maricopa and Safford Agricultural Centers (MAC and SAC) investigated the early season weed suppression of Palmer Amaranth (AMAPA) and ivyleaf morningglory (IPOHE) resulting from different methods of applying pendimethalin and trifluralin in RR Flex cotton and Liberty Link cotton. The herbicides were simultaneously applied to flat ground (i.e., broadcast) and incorporated with a field cultivator or were applied with a roto-mulcher following listing (i.e., bed formation). When applying the herbicides with the mulcher, TeeJet XR8001VS or XR8015VS 80 degree flat fan nozzles were mounted to spray a band that was 50% of the row spacing centered on the listed bed and the rate in the sprayed band was double the broadcast rate of the treatments applied with the field cultivator. Thus, after the mulcher incorporated the herbicides and redistributed the soil, the herbicide rates were comparable on a broadcast area basis.

The preplant incorporated (PPI) application of pendimethalin with a field cultivator prior to bed formation provided excellent control of Palmer amaranth (AMAPA) and suppression of ivyleaf morningglory (IPOHE) in terms of both reduced weed density and slower growing weeds. These two effects resulted in a longer early season topical glyphosate or glufosinate application window and improved weed control later in the season. For example at MAC in 2005 at 34 DAP (days after planting), AMAPA plants were 6.8 cm tall with 8.8 leaves per plant and there were 205 plants m^{-2} in the absence of pendimethalin compared to plants that were 2.5 cm tall with 6 leaves per plant with a density of 5.2 plants m^{-2} in the presence of pendimethalin (1.06 kg/ha). Similarly, at 34 DAP, IPOHE plants were 4.8 cm tall with 4 leaves per plant and there were 48 plants m^{-2} in the absence of pendimethalin compared to plants that were 2.0 cm tall with 2 leaves per plant and a density of 13.3 plants m^{-2} in the presence of pendimethalin. The effects of pendimethalin on weed size resulted superior Palmer amaranth control after early season topical herbicide applications and in greater suppression of ivyleaf morningglory after two sequential postemergence herbicide applications (either glyphosate or glufosinate).

In a dry-plant experiment at MAC in 2008, the control treatment not treated with a dinitroaniline herbicide contained 85 and 79 AMAPA and IPOHE plants m^{-2}, respectively, 40 DAP (i.e., after the germinating irrigation). Treatments that had pendimethalin (0.92 kg/ha) or trifluralin (0.7 kg/ha) applied with the field cultivator had 0.2 and 0.2 AMAPA plants m^{-2} and 37 and 18 IPOHE plants m^{-2} at 40 DAP, respectively. Similarly, treatments that had pendimethalin (0.92 kg/ha) or trifluralin (0.7 kg/ha) applied with the roto-mulcher after bed listing had 0.8 and 1.3 AMAPA plants m^{-2}, respectively, and 27 and 35 IPOHE plants m^{-2} at 40 DAP, respectively. The herbicide treatments had significantly fewer weeds compared to the control but the differences in AMAPA and IPOHE densities as a function of herbicide application method (field cultivator versus roto-mulcher) were not significantly different. Thus, in furrow-irrigated cotton production systems, growers can eliminate a preplant pass across cotton fields by combining preemergence herbicide applications with roto-mulching that is necessary as a part of bed formation thereby reducing crop production costs.

Another tactic that can be used to reduce the risk of developing or selecting for herbicide resistant weeds is secondary tillage or in-season cultivation for weed control. Previous precision tillage research conducted in Arizona cotton in the 1990s prior to development of GPS-RTK systems determined the equipment needed (e.g., articulated electro-hydraulic quick-hitch and wands that sensed location of cotton plants/seed-line) and documented the benefits in terms of improved weed control, faster operating speeds, reduced operator fatigue and reduced costs. However, the system had limitations including that it could not be used until cotton stems could withstand the force applied by the wands (i.e., about 1 foot tall) and that equipment maintenance and training workers proved be too difficult for most adopters of the system.

The maturation of GPS-RTK tractor auto-steer technology and widespread availability provide growers with an opportunity to increase the use of steel and reduce the reliance on postemergence herbicides. When this technology is used for all field operations (i.e., listing, roto-mulching, bed-shaping and planting) growers have precise knowledge of the location of the cotton seed-line (i.e., the A-B line) and this information can be used to conduct precision in-season tillage for weed control. In small cotton (2 to 4 leaf) a rigid, 3-tool-bar cultivator frame with two disk-stabilizers mounted on the rear bar can be used with the following tools (front to back): disc openers, banana knives (facing away from the crop row and mounted on the front of the middle bar) and Alabama sweeps. The disk openers should cut a shallow slot that the banana knives run in to avoid moving surface soil around the cotton seedlings and damaging their stems. Typically the uncultivated band around the seed line in coarse texted soils is 5 to 6 inches.

Precision tillage and in-row weeding can be conducted with tools such as Bezzerides Spring Hoe weeders or Torsion Bar weeders in bigger cotton with several inches (>3") of woody bark at the base of the stem (normally cotton > 1 foot tall). A rigid 3-bar cultivator frame with two disk-stabilizers can be used with the following tools (front to back): disk openers, beet knives (mounted on the front of the middle tool bar) with the points facing the crop row and the vertical shank away from the crop row, Bezzerides Torsion Bar Weeders mounted on the back of the middle bar) with Alabama sweeps on the rear bar. A typical gap between the ends of the beet knives is 3 to 4 inches and they should run about 2 inches deep to undercut the roots of weeds. The torsion bar weeders are set to slightly overlap the cotton seed line and run about 1 to 2 inches deep. Fertilizer injection knives can also be mounted on the front of the rear tool bar and a tank and pump system mounted on the cultivator to simultaneously cultivate and side-dress nitrogen fertilizer in one pass through the field. Special clamps may be needed in the latter situation to provide enough room for the tools on the rear bar.

Precision tillage can be combined with the use of postemergence herbicides sprayed in narrow bands to reduce the amount of herbicide used and the consequent selection for herbicide resistant weeds since steel is non-selective. Keys to making precision tillage work are an understanding of the GPS-RTK system and the use of disk stabilizers on the cultivator so that the soil engaging tools do not twist the tractor on its radial tires and cause "cultivator blight". The 3-

point hitch sway blocks must be used to lock the cultivator into position directly behind the tractor so there is no sideways motion and yet allow the cultivator to be lowered to the appropriate working depth. The beet knives and torsion bar weeders should be running about two inches below the soil surface during operation. Stable depth control is best achieved with gauge wheels.

Additional tactics that can reduce the selection for herbicide resistant weeds is to choose and use herbicides with different mechanisms of action and to use the full labeled dose of herbicide when spraying. (A ***herbicide mechanism of action is the biochemical site within a plant with which a herbicide directly interacts.***) The Weed Science Society of America (WSSA), the EPA and primary herbicide manufacturers have collaborated to develop a mechanism of action group numbering system for herbicides (see the WSSA website; http://www.wssa.net/Weeds/Resistance/index.htm and click on the link for "WSSA Classification of Herbicide Mechanism of Action). These group numbers are on most major manufacturer labels but not yet on all generic herbicide labels. Using herbicides with different trade names but the same group number is NOT using herbicides with different mechanisms of action and will not reduce the risk of developing herbicide resistant weeds. The development of Liberty Link Cotton which is resistant to glufosinate (Liberty) and GlyTol cotton that has resistance traits for both glyphosate and glufosinate provide growers with an alternative to continuously using glyphosate herbicides in cotton production.

When spraying weeds the full label rate specified on the label should be used. As defined by the Weed Science Society of America the "***full labeled rate" is the rate or range of rates set by a manufacturer that consistently provides effective control of a weed species across growth stages and site conditions***. Using low herbicide rates repeatedly over time can lead to the evolution of a herbicide-resistant weed population by allowing some treated plants to survive, reproduce and disperse seed. As defined by the WSSA, a ***"low rate" is a rate applied below the labeled rate that may provide effective control at an individual location, but will not provide consistent control over a wide range of conditions***. Weeds may be exposed to low rates due to: 1) the intended use of low rates, 2) spraying plants larger than those recommended on the label, 3) inadequate spray coverage of weeds because of size, density and/or crop cover, and 4) errors in sprayer calibration, faulty equipment, or mixing errors.

Table 1. Weed management tactics that can delay the development of herbicide resistance.

Tactic	Strategy	Action
Herbicide	Use multiple herbicides with different mechanisms of action	**MIX: t**ank mix herbicides with different mechanisms of action and spray them together. For example, mix prometryn with glyphosate when making post-directed sprays midseason.
		SEQUENCE: use a sequence of herbicides with different mechanisms of action. For example, use a residual "yellow" herbicide (trifluralin or pendimethalin) preplant incorporated followed by postemergence herbicides or use a residual herbicide at layby.
		ACROSS SEASONS: use different herbicide mechanisms of action across seasons. For example, grow Liberty Link Cotton one year followed by Roundup Ready Flex Cotton the next year.
Mechanical	Use steel to kill weeds; steel kills both herbicide susceptible and resistant weeds (*clean implements between fields*)	**PRE-PLANT:** use primary tillage to prepare fields for planting and start the season with a clean field.
		IN-CROP CULTIVATION: use steel to kill weeds that may have escaped chemical treatment and maintain a clean furrow.
		IN-ROW WEEDING: when cotton has several inches of bark at the base of the stem, consider using precision guidance and in-row weeding tools such as Bezzerides Spring Hoe Weeders or Torsion Bar Weeders.
		POST-HARVEST: use tillage at the end of the season to kill surviving weeds.
		HAND-ROGUEING: use hand labor to remove weeds from fields before they set seed.
Cultural and Biological	Maximize crop growth and competition against weeds; minimize pollen and seed movement	**CROP ROTATION:** rotating crops exploits differences in tillage practices, crop competitiveness and herbicide choices for controlling weeds.
		PLANT POPULATION: an optimum crop plant population maximizes competition against weeds.
		ROW SPACING: Narrower rows result in more rapid shading of the furrows; wider rows require longer periods of weed control.
		COVER CROPS: cover crops planted before the primary crop may suppress weed growth through physical presence or release of allelochemicals that affect weed germination and growth.
		SANTITATION: remove weeds growing around field margins or borders to prevent pollen movement between resistant and susceptible plants. Prevent movement of weed seeds and vegetative propagules (e.g., tubers and rhizomes) between fields by cleaning equipment.