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Zero Tolerance:
A Community-Based Program for Glyphosate-Resistant Palmer Amaranth Management

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Herbicide-resistant Palmer amaranth (pigweed) is the greatest pest facing cotton and soybean producers in Arkansas. This weed is resistant to three major herbicide modes of action (WSSA groups) in Arkansas including the dinitroanalines (group 3), acetolactate synthase (ALS) inhibitors (group 2) and glycine (group 9). It has also been confirmed resistant to triazine (group 5) herbicides in Georgia and four (group 27) herbicides in Kansas. When introduced into one square meter of a weed-free field and treated with glyphosate only, glyphosate-resistant Palmer amaranth expanded to infest over 20% of the total field area in less than 2 years after introduction. These results indicate that resistance management options such as a "zero-tolerance threshold" should be used in managing or mitigating the spread of glyphosate-resistant Palmer amaranth (Norsworthy et al., 2014). The University of Arkansas System Division of Agriculture has an extensive research program devoted to identifying more effective programs to control Palmer amaranth (Scott and Smith, 2011). Research has indicated that one weakness in the life cycle of Palmer amaranth is rapid loss from the soil seedbank (Jha et al., 2014); thus a program to promote the elimination of Palmer amaranth seed production and reduce the soil seedbank is critical to success.

Figure 1. This field in eastern Arkansas was completely taken with Palmer amaranth in 2 years.

Zero Tolerance Is Based on Science

Managing Palmer amaranth is a numbers game. Greater than 1.5 million seed were harvested from a single large female plant found growing in a soybean field in Arkansas (Scott and Smith, 2013). Typically, 50,000 to 60,000 seed are produced by Palmer amaranth females competing with dense cotton or soybean stands. Approximately 75%-80% of the seed produced each year is lost due to predation and decay over the first winter (Bagavathiannan and Norsworthy, 2013). Out of the

Figure 2. This pigweed plant produced over 1.5 million seed.

surviving seed, 90% germinate the next year and the other 10% over a 4-year period. Our research indicates that the Palmer amaranth seedbank will be almost completely depleted in 4 years if no additional seed are allowed to enter (Jha et al., 2014).

Why Zero Tolerance? Palmer Amaranth Is a Prolific Seed Producer

Herbicide and cultural practices are available to provide greater than 99% control of Palmer amaranth, but this is not adequate. A conservative example would be that a female plant produces 300,000 seed. Assuming 80% of those seed are lost over the winter, there are 60,000 remaining seed with 90% germination, leaving 54,000 seed to germinate the first year. If 99.9% are killed with an effective herbicide program, 54 escapes are present, of which a percentage of these will be female plants that are capable of producing seed the following year. If these escapes are allowed to produce seed, the field potentially can be completely lost the second year as illustrated by Norsworthy et al. (2014). Again with conservative assumptions of 54 escapes with 35% females, each of which produce on average 300,000 seeds/plant, and assuming 80% loss due to predation and decay, 90% germination of the remaining seed and 99.9% control of germinated seedlings with an effective herbicide program, still 1,020 escapes will be present the second year. Obviously, if a higher percent of the population is female, the females produce more than 300,000 seed each or the herbicide program is less than 99.9% effective, greater numbers of escapes will be present. **This is not sustainable; the seedbank must be managed.**

Zero Tolerance Has Been Successful With Pigweed

Managing escapes is an essential component of sustainable Palmer amaranth management. Spot sprayers and hand weeding have proven to be the most effective means of removing escapes. Escapes include plants on field borders, ditchbanks, turnrows, etc., and removing them prior to forming a seedhead is critical. Seedheads as young as 14 days old may have viable seed and are capable of replenishing the soil seedbank. The Zero Tolerance concept is the only effective way to combat herbicide-resistant Palmer amaranth over time. In fields where farmers have committed to not allowing a single plant to produce seed and were conscious about sanitation from outside sources, seedbanks and the number of escapes have been reduced significantly. The time required to hand chop escapes in one 50-acre cotton field was reduced from 110 hours to 5 hours after one year of zero tolerance. In another field, seed collected from grid sampling was reduced by 65% the first year and was below detectable levels the second year (Ken Smith, personal communication).

Figure 3. Pigweed should be destroyed before it has grown enough to produce thousands of seed. At this size, resistant pigweed will have to be eliminated by hand.

Zero Tolerance Zones

Palmer amaranth seed are predominantly gravity-dispersed but can also be spread by irrigation and other water flow, with the movement of birds and

Figure 4. First Zero Tolerance field – Phillips County – involved stakeholders: county Extension agent, local conservation district rep, NRCS agent, farmer and former Extension weed scientist.

mammals, and through agricultural management practices such as plowing, mowing, harvesting and spreading compost, manure or gin trash (Norsworthy et al., 2009). Infestations from outside the field are a major concern (Bagavathiannan et al., 2013a). Seed are readily moved by water and equipment into clean fields, and viable pollen may move up to 0.25 mile and confer resistance to new areas (Sosnoskie et al., 2012). Turnrows, ditchbanks and adjacent fields can be major sources of seed to move into otherwise clean fields. The advantages of having no Palmer amaranth adjacent to clean fields are obvious. Farmers across the state have begun to capitalize on these advantages and are banding together and making extraordinary effort to ensure no Palmer amaranth produces seed in large land areas. The Zero Tolerance zones range from 8 to over 20,000 acres in size. Growers realize that by keeping their farm clean, they are not only helping themselves but helping their neighbors at the same time. The more neighbors band together and make the commitment to Zero Tolerance, the easier the job becomes for all because there are no seed to disperse. It becomes much easier to keep equipment weed seed-free because there are fewer contaminated fields. The Zero Tolerance concept requires a shift from thinking about economic thresholds as the number of weeds required to reduce yields in the present year to realizing even a single escape will replenish the soil seedbank and intensify required management for the next few years. Zero Tolerance is a practice that is gaining momentum throughout the state and is proving to be the best technique for sustainable management of Palmer amaranth.

Tips and Programs for Achieving Zero Tolerance and Managing Herbicide Resistance

Multiple strategies to control herbicide-resistant weeds should be implemented on an individual field basis (Bagavathiannan et al., 2013b). First, producers should incorporate multiple methods of weed control in their crop planning strategy. Some of the current resistant weed issues can be traced back to several years of monoculture crops. Monoculture can be described as growing the same crop year after year without rotating to a different crop. Producers should consider a rotation in both crop and herbicide tolerance technologies, for example shifting from primarily Roundup Ready crops to Liberty Link or other new technology. Arkansas growers have done a much better job managing glyphosate-resistant Palmer amaranth in Liberty Link cotton and soybeans the last couple of years. Incorporating non-chemical means for weed control such as tillage, cover crops or harvest weed seed management should also be included into a management scheme when possible. In tillage studies, Palmer amaranth seeds lost approximately 30% of their viability after 6 months and had less than 50% viability after a year when buried less than 4 inches deep (Sosnoskie et al., 2013). Double-crop wheat or use of a rye cover crop in combination with a one-time fall deep tillage using a moldboard plow reduced emergence of glyphosate-resistant Palmer amaranth by 95% over a 2-year period in soybeans (DeVore et al., 2013).

Rotating herbicide modes of action during the season in conjunction with crop rotations should also be a high priority due to its effectiveness in reducing the risk for resistance and in lowering the soil seedbank (Neve et al., 2011). Figure 5 illustrates the amount of potential glyphosate-resistant Palmer amaranth seedbank reduction after 2 years of crop and herbicide mode of action rotation. One year of corn (2010) utilizing atrazine (Aatrex) and metolachlor (Dual) followed by one year of Liberty Link soybean using residual herbicides plus glufosinate (Liberty) significantly reduced the Palmer amaranth weed seedbank in just 2 years. Incorporating Zero Tolerance into this system will cost less and decrease the seedbank to very low levels by year 3.

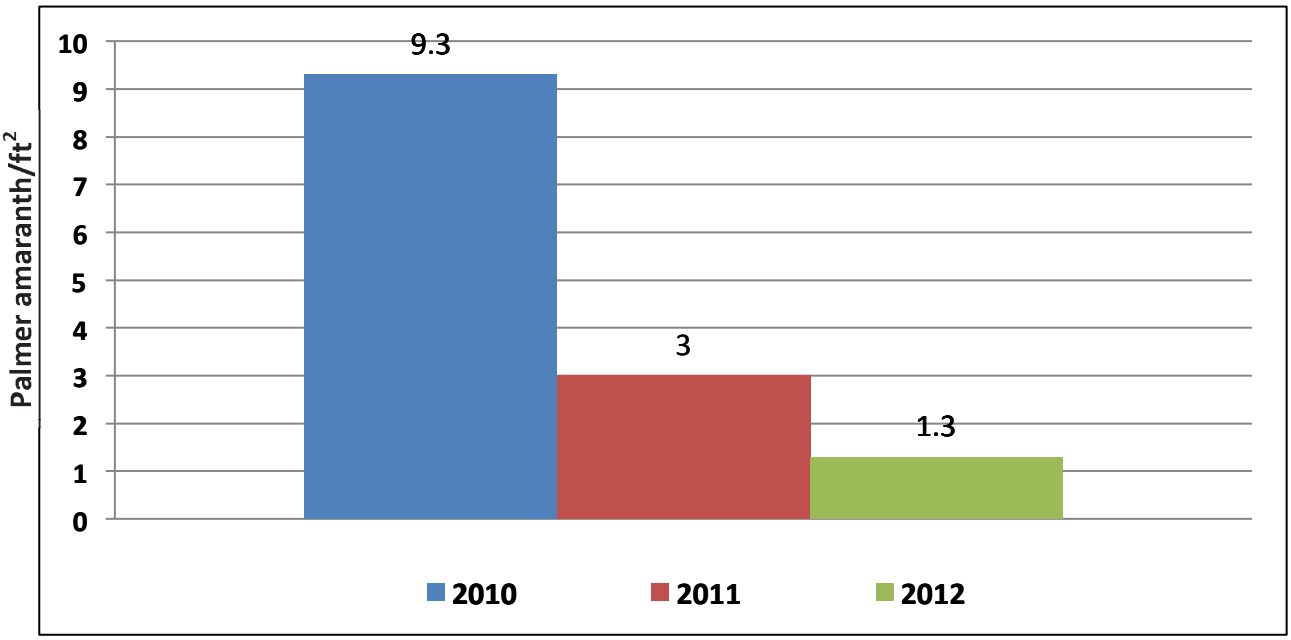

Figure 5. Palmer amaranth seedbank reduction based on soil samples after 2 years of incorporating resistance management and Zero Tolerance strategies. Corn 2010, Liberty Link Soybean 2011 with a final count in 2012.

Herbicide Resistance Management Points for All Crops

1. Crop and technology rotation – Incorporate and rotate new technologies as they become available.

2. Rotate effective herbicide modes of action – At least 3 each year.

3. **Don't let Palmer amaranth go to seed – fields, turnrows, ditchbanks, equipment yards, etc.**

4. Clean equipment often – If purchasing used equipment, clean before use.

Figure 6. Palmer amaranth seed can contaminate many areas of harvesting equipment. Clean equipment often to prevent spread.

5. Manage escapes – If hand removing weeds that already have seedheads, carry out of field, pile and burn.

6. Control late-season flushes that emerge following harvest, especially in corn. This can be done with tillage or herbicides or both.

Keys to Creating a Zero Tolerance Community

1. Start with a strong non-biased "local" leader (county agent) in the agricultural community to pull growers together and hold them accountable.

2. Develop a common goal – AKA eradicate glyphosate-resistant Palmer amaranth.

3. Create an identity – "Zero Tolerance" zones.

4. Base your decisions on scientific data – Show scientific evidence that the concept works such as complete removal of Palmer amaranth will greatly reduce seedbank in 3 years. Focus on all means of removal in fields, turnrows, ditchbanks, equipment, etc.

5. Recognize growers that are leaders in the industry and gain their confidence or "buy in" into the program.

6. Develop leaders in the local farming community – consultants, dealers, industry representatives.

7. Cooperate with NRCS and other state agencies for help with rights of way.

8. Talk about the results (positives and negatives), and get others to talk. The local agricultural communities are very tight knit, and when growers talk, others will listen.

9. Publicize the results with local, regional and national media. These outlets are interested and invaluable in gaining broader acceptance and building momentum for the program.

Developing Zero Tolerance in Clay County, Arkansas

In order for this program to work, there must be cooperation among producers. As with most things, there needs to be a leader. In Clay County, Arkansas, the leaders were the farmers who stepped up and started the program and showed everyone it could be done. The county agent then took the role of a facilitator and started encouraging others to participate and join together through one-on-one visits and presentations at meetings. Most of the time, all it takes is someone telling a producer that they can do a better job if they will just try. If other areas want to have a successful Zero Tolerance program, they must first believe it will work and be willing to work together. If they however do not believe that they can make it work, the program will be doomed from the start.

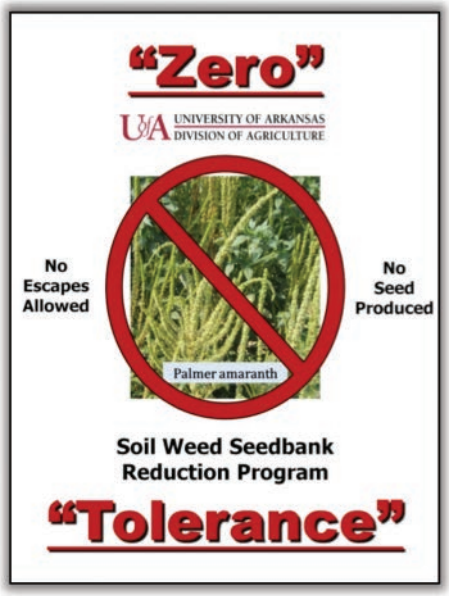

Figure 7. Zero Tolerance identity created for Arkansas.

Successful Practices in Clay County, Arkansas

A total herbicide approach including burndown, preemergence (more than one) and timely postemergence herbicides is a must. After that, cultural practices such as hand hoeing or pulling the Palmer amaranth will be necessary. Once Palmer amaranth has produced viable seed, plants must be taken out of the field and burned. If chopped, plant removal must be below the soil surface or else plants will often regrow. Field evidence has shown that plants completely cut into an inch or so above the ground will sprout and form more of a bush-type plant that will be even more difficult to control. If hand pulled, effort must be taken to totally remove the plant from the ground with no roots remaining attached to the soil or these plants will re-sprout and survive. For those producers that often furrow-irrigate every other row, workers that hand remove Palmer amaranth generally place plants in the dry row middle to minimize risks of these plants sprouting. Even with taking these preemptive steps, if hand-pulled plants receive rainfall shortly after removal from soil or come in contact with irrigation water, they can re-attach to the soil and survive.

Figure 8. Zero Tolerance zone south of Carlisle, Arkansas. Growers in the community banded together to reduce Palmer amaranth populations.

Negative Effects

As with most new programs, there are some obstacles that must be overcome before a successful program can be realized – even a program like Zero Tolerance. Producers at times have struggled with what herbicides are labeled for turnrows, ditchbanks, etc. Glyphosate is commonly applied in mixture with other herbicides for Palmer amaranth control on ditchbanks; unfortunately, glyphosate kills the grasses that form a dense mat, leaving ditchbanks barren which leads to erosion. Removal of grasses also encourages emergence of weeds like Palmer amaranth throughout much of the summer months, which further complicates management on ditchbanks. Extension has recommended that producers use herbicides like Gramoxone or Diquat in hooded sprayers to spray turnrows and ditchbanks and add residual herbicides like Diuron for residual control. These contact herbicides usually only stunt grasses and they regrow and reduce erosion.

Cooperating Agencies

The Extension Service and the Natural Resources Conservation Service have worked together with local commodity boards to encourage funding for programs like Zero Tolerance. Work needs to be done with state agencies like highway departments to see how they too can help reduce the seedbank on rights of way, especially considering that Palmer amaranth is one of the most prominent weeds infesting roadsides in eastern Arkansas (Korres et al., 2015).

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