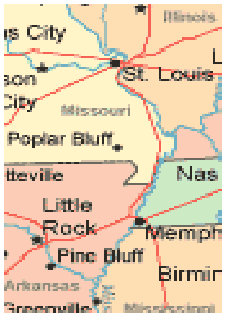
U.S. EPA Tour of Weed Resistance Management Challenges in Missouri, Illinois, and Arkansas
August 15-17, 2011

Background:

The U.S. Environmental Protection Agency (USEPA) and Weed Science Society of America (WSSA) have developed an active dialogue over the recent years on issues pertaining to 'biotech' crops and herbicide-resistant weeds. Some groups have argued that since weeds have evolved resistance to glyphosate [N-(phosphonomethyl)glycine], the primary herbicide used in the development of soybean, cotton, and corn (Roundup Ready® varieties) in the U.S., that biotechnology has failed and that regulatory procedures pertaining to biotech crops should be re-examined to prevent future failures. Furthermore, some groups have suggested that glyphosate-resistant weeds are "super weeds", and their impact will spread and compromise native ecosystems. However, growers are faced with producing crops after the evolution of weed populations that are resistant to glyphosate and other herbicides commonly used to manage these weeds. The evolution of weeds with multiple herbicide resistance has made producing crops economically an increasing challenge for producers. The debate on these critical issues facing agriculture has received the attention of the special interest groups, the agricultural industry, regulatory agencies, academia, and the general public because highly visible media outlets have covered the topic.

WSSA has recently arranged tours for government officials in other areas of weed management such as aquatic weed problems in the waterways of Florida and weed management challenges in irrigation canals, rangeland, and riparian areas of New Mexico (http://www.wssa.net/WSSA/EPAliaison/index.htm). These tours have been extremely successful in achieving the goal of increasing awareness on the subject at hand so more educated discussions can be at the heart of providing any solutions to the challenge being faced. With similar objectives, a field tour was organized for U.S. EPA representatives to observe and discuss the problems with and management of glyphosate-resistant weeds that are now infesting Arkansas, Illinois, and Missouri among several other states. Participants included representatives from all of the divisions within the EPA Office of Pesticide Programs (OPP), USDA Office of Pest Management Policy, and the Weed Science Society of America. Other individuals who participated on the tour included crop consultants, agronomists from agricultural chemical retailers, farmers, and representatives from the United Soybean Board and the Illinois Soybean Association. The deliverables of this project were the creation of knowledge and appreciation for the weed management challenges being faced and any limiting factors in bringing new solutions to growers.



Area covered during the 2011 Herbicide Resistance Tour.

Tour Objectives:

1) Familiarize participants with the scope and impact of herbicide-resistant weeds in corn, soybean and cotton production systems, specifically weeds resistant to glyphosate but also weeds resistant to multiple herbicide mechanisms of action.

2) Share the current state of our scientific knowledge on the problem including the plant biology/ecology, practical field management solutions, awareness and education within the agricultural community, and grower adoption of best management practices for managing weed resistance.

3) Provide a first-hand experience of the diversity of crop production systems implemented by growers that can influence which tactics are practical for adoption by them as well as any other limiting factors that would prevent them from being able to properly address the problem while maintaining a profitable farm enterprise.

Day 1, August 15: Participants met in Columbia, MO at 1:00 p.m.

Missouri tour (Host – Kevin Bradley; University of Missouri)

Stop -1: The group was introduced to the problem growers are facing with a visit to a commercial field near Columbia, MO. The field had been continuously planted with soybeans for 20 years and was infested with common waterhemp (waterhemp; *Amaranthus rudis* Sauer) that had evolved resistance to multiple postemergence herbicides. The field had been sprayed in 2011 with three applications of a PPO-inhibiting herbicide [WSSA Herbicide Mechanism of Action Classification (MOA) Group 14 http://wssa.net/Weeds/Resistance/WSSA-Mechanism-of-Action.pdf] and three applications of glyphosate (MOA Group 9) with little success. No postemergence herbicide options in soybean remain for controlling the waterhemp with multiple herbicide resistance in this field. The grower had planned to apply a preemergence herbicide on these fields but, due to the number of acres under production and weather conditions, had not been able to make the application in a timely manner. Dr. Bradley, Steve Cromley (agronomist with MFA agricultural retailer), Andy Schmidt (agronomist with Winfield Solutions), and Brian Francis (agronomist with Ricketts Farm Service, not pictured), all of whom are involved with implementing weed management strategies in Missouri agriculture, were present to discuss this site and the situation as it stands on a state-wide level. At this site, the group primarily discussed how management of herbicide resistance is impacted by land ownership. Approximately 60% of the agricultural land in Missouri is leased by the producer. The structure of lease agreements (cash versus shares and short term versus long term lease agreements) as well as the goals of the land owner both impact the options for weed management available to the producer, including crop rotation.

Soybeans infested with a waterhemp population resistant to multiple herbicide mechanisms of action including ALS-inhibitors (MOA Group 2), PPO-inhibitors (MOA Group 14), and glyphosate (MOA Group 9 EPSP synthase inhibitor).

Stop -2: The field site near Madison, MO contained a natural infestation of glyphosate-resistant giant ragweed (*Ambrosia trifida* L.). Glyphosate-resistant giant ragweed populations are not currently a widespread problem throughout the state; however, University of Missouri researchers are concerned that this weed could be one of the next major weed problems to contend with in corn and soybean production fields. This stop included a discussion of the field plot research conducted by the University

of Missouri weed science research program. The goal of the study was to develop management strategies for this weed before it becomes a widespread problem in production fields. The field research featured successful and failed herbicide programs for the management of glyphosate-resistant giant ragweed. Successful programs included herbicides with an alternate mechanism of action, such as 2,4-D [(2,4-dichlorophenoxy)acetic acid; MOA Group 4], dicamba (3,6-dichloro-2-methoxybenzoic acid; MOA Group 4), and saflufenacil [N'-[2-chloro-4-fluoro-5-(3-methyl-2,6-dioxo-4-(trifluoromethyl)-3,6-dihydro-1(2H)-pyrimidinyl)benzyl]-N-isopropyl-N-methylsulfamide; MOA Group 14], that were applied prior to soybean planting as a "burndown" herbicide application. As a large majority of giant ragweed germination will typically occur prior to planting soybeans in the Midwest, the importance of utilizing herbicides other than glyphosate in the burndown application and starting with a weed-free environment were discussed. Additionally, Dr. Bradley discussed the utility of glufosinate [2-amino-4-(hydroxymethylphosphinyl)butanoic acid; MOA Group 10] and glufosinate-resistant (Liberty-Link®) soybeans as a tool to manage glyphosate-resistant giant ragweed.

Dr. Kevin Bradley discusses the potential problem that glyphosate resistant giant ragweed will pose to soybean growers in Missouri. He is standing in front of a plot that had been sprayed with two sequential applications of glyphosate at the proper growth stage.

The group traveled to Fairview Heights, IL and spent a pleasant evening discussing the events of the day over dinner.

Day 2, August 16

Illinois tour (Host – Bryan Young; Southern Illinois University)

Stop-3: The group traveled to a glyphosate-resistant waterhemp field site near Red Bud, IL. At this site the group was joined by the grower, Dave Reinhardt, and Dale Burmester (Gateway FS, chemical retailer, pictured below with Dr. Bryan Young) who have been involved with the historical weed management practices at this site, along with representatives from the United Soybean Board (Richard Joost) and the Illinois Soybean Association (Dan Davidson, Dean Campbell, Wendel Lutz). This site included a large demonstration of grower-applied strategies and some small plot research conducted by Southern Illinois University. The site is also infested with glyphosate-resistant horseweed (*Conyza canadensis* (L.) Cronq.) that had been managed fairly effectively in 2011 and was not the focus

for research. However, the group did discuss the challenges of timing management practices when both horseweed and waterhemp infest a field. Horseweed emerges in both the fall and early spring while waterhemp is a warmer season annual that begins to emerge in late April and continues to germinate through July in Illinois. The growers all have similar tools available for managing these glyphosate-resistant weeds; however, they experience different levels of success due to weather, variations in soil type, and differences in farm size that affects their ability to treat weed populations at the proper growth stage. Many growers will manage horseweed in the fall so they can concentrate their efforts in the spring on managing waterhemp.

Stop-4: The discussion moved from the field site to a conference room at a local agricultural chemical retail facility (Gateway FS, Red Bud Elevator). Dr. Bryan Young (standing in photo at left) presented information on the development and spread of herbicide-resistant waterhemp in Illinois. The problem began in the 1990's when waterhemp populations evolved resistance to the triazines (MOA Group 5 Photosystem II-inhibitors) and ALS-inhibiting herbicides (Group 2), followed with resistance to the PPO-inhibiting herbicides (Group 14) by 2000, and glyphosate (Group 9) in 2005. In addition, single populations have also evolved resistance to multiple herbicides over this same period resulting in populations resistant to herbicides with four or five different mechanisms of action. The group discussed the management tools that are available currently, including glyphosate- and glufosinate-resistant crop technologies, preemergence herbicides (some requiring incorporation), postemergence herbicides, crop rotation (emphasizing the benefit of planting corn with the application of atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine; MOA Group 5] for waterhemp control), and tillage. A number of tools are available but none are the complete solution to this complicated problem. The group discussed yield potential of varieties, availability of conventional varieties of soybean (some are available, in certain markets), whether all registered products are available to all growers, the potential benefits versus risks associated with the dicamba and 2.4-D stacked gene technologies currently under development, the impact of tillage on conservation programs, and the connection with the university extension service and expertise. The link with extension has changed because fewer agents are available leading to less information flow between the grower/retailer and the university. However, the group agreed that there is a tremendous need for continuing education on identification and management of resistance, particularly for consultants and field scouts. The challenge for consultants is that the variability from farm to farm makes it very difficult to develop solutions and impossible to make blanket prescriptive management recommendations. The group discussed whether there is potential for university scientists to develop a decision tree to assist growers and consultants with management of this issue; the challenge would be how to translate the complicated blend of experience and problem solving into a decision tree model that would be effective and useful.

The group left the facility to travel through SW Illinois to observe the frequency and extent of commercial fields with weed escapes. They stopped for an excellent lunch of barbeque in Murphysboro, IL (17th Street Bar and Grill, 214 N.17th Street, Murphysboro, IL 62966), where they were joined by Scott Martin, a District Conservationist with Natural Resources Conservation Service (NRCS). Scott discussed the work that NRCS is doing to assist growers with refining their conservation crop plans to address resistance management. He also indicated that growers are quick to use tillage to remedy any challenging weed populations prior to planting that cannot be controlled with glyphosate.

After lunch, the bus departed for Arkansas, traveling through an area (East Cape Girardeau, IL) with several years of history with glyphosate-resistant horseweed and waterhemp. The area has a high frequency of continuous soybean production due to river flooding.

Arkansas tour (Hosts – Jason Norsworthy and Ken Smith; University of Arkansas)

Stop-5: The discussion shifted to issues related to the problems and solutions surrounding glyphosate-resistant Palmer amaranth (*Amaranthus palmeri* S. Wats.) infestations in Arkansas cotton production. The bus arrived at the Rector Convention Center in Rector, AR for a round-table discussion with Dr. Ken Smith, Andy Vangilder (county agent), and growers Richard Simmons, Mike Morgan, Gregg Sain, Harold Dills, and Danny Holifield. Drs. Norsworthy and Smith gave a short introduction and some demographics of Arkansas agriculture with emphasis on management of Palmer amaranth. The growers discussed the challenge of implementing the weed control practices that are needed to manage glyphosate-resistant Palmer amaranth including herbicides applied five to eight times over the season: one or more burndown applications prior to planting (no-till) along with treatments at-planting, early postemergence, postemergence, and as hooded treatments. In addition, the growers still must use hand labor to remove glyphosate-resistant Palmer amaranth or other glyphosate-resistant weeds from fields at a cost that can exceed $100/acre for the hand labor alone. They were candid in saying that the only reason they could afford the complex weed control required for Palmer amaranth suppression was the fact that cotton prices are currently high; if cotton prices go down, they will face great economic difficulties. The group also discussed the reliability (or lack thereof) of soil-applied herbicides as well as the pressure we are placing on some very old chemistry (PPO-inhibitors, MOA Group 14, and acetamides, MOA Group 15), the current availability of suitable varieties with the glufosinate-resistant technology, whether all registered herbicides are available in all markets, and the potential benefits versus concerns associated with the new dicamba and 2,4-D stacked gene varieties that are under development.

The tour moved on to visit cotton fields that had been recently hand-weeded, fields that had been lost due to inability to control the Palmer amaranth infestations, and some fields where paraquat (1,1'-dimethyl-4,4'-bipyridinium ion; MOA Group 22) had been applied with a ropewick as a salvage treatment. Dr. Jason Norsworthy (second from right in photo) and Andy Vangilder showed the group how fields are furrow-flood irrigated and how laying the poly-tube that carries irrigation water breaks the barrier of soil applied herbicide to allow Palmer amaranth emergence at the edge of the fields.

Dr. Ken Smith explains the challenges of effectively using hoe crews to remove Palmer amaranth from a production field, beyond the economic cost. Among the challenges includes timely removal prior to flowering as well as removing the plant below the lowest nodes to ensure that the plant does not re-sprout in the field. Stem diameters can exceed several inches which increases the challenge of effective physical removal of the plant.

Dinner (steaks and chops) was provided at the Hunts Duck Club, Jonesboro, AR.

The group was joined for dinner by Jim Carroll (farmer, United Soybean Board), Chuck Farr (consultant), Pace Hindsley (farmer), and Stewart Weaver (farmer). Jim Carroll discussed the concerns of the United Soybean Board as well as the personal challenges he and his neighbors are facing in the fight against Palmer amaranth. He also thanked the group for the dialog with the governmental agencies that can help with the resistance issues. Stewart and Pace discussed the Palmer amaranth situation on their farms as well as their communities. Chuck Farr commented about the role consultants play in Arkansas agriculture and his challenges with pigweed.

Day 3, August 17

The day began early with a meeting in the hotel conference room where Jason Norsworthy led a group discussion with a focus on glyphosate-resistant Palmer amaranth. Pace Hinsley and Stewart Weaver explained their herbicide programs in cotton and soybean to the group. Pace grows mainly cotton and some soybean while Stewart grows a rotation of cotton, grain sorghum, and soybean on his properties. Both growers have been working with Ken Smith to implement the 'Zero Tolerance' program for reducing the Palmer amaranth seedbank developed by the University of Arkansas. The program has been shown to reduce the soil seedbank of Palmer amaranth by 90 to 95% over two years. However, due to the cost and logistical difficulties (intensive management is required to remove all Palmer amaranth plants prior to flowering), the number of fields that they can effectively manage in this way is limited. In addition, the producers brought up the fact that resistant seed is continually moved throughout the region in commercial combine operations as well as gin trash, in spite of efforts to clean seed. The group discussed the fact that practices continue to evolve as both the university weed scientists and producers learn from their efforts. The growers rely on the university scientists and extension professionals to keep them informed regarding what to look for and what practices to try in their production systems. Unfortunately, tillage is becoming a more common practice again in the region because of the Palmer amaranth problem; however, NRCS has a pilot program in three states, including AR, to implement resistance management programs that preserve conservation programs and provide incentives to growers. Jason Norsworthy presented research information that showed the potential benefit of deep tillage followed by a cover crop in reducing Palmer amaranth emergence in a field situation.

Stop-7: The tour concluded with stops at several field sites showing the challenges faced by growers and consultants who must manage Palmer amaranth. A particular challenge for the producers is managing

the Palmer amaranth that infests field edges and ditches throughout the region. The weed germinates throughout the summer and produces seeds within weeks of emergence. The cost of continually cleaning the ditches and field roadsides is born by the grower with no economic return. Jason Norsworthy discussed the current strategies (mowing, herbicide applications with hooded sprayers) for removing the weed. Harold Coble asked whether they had looked at the potential for using fluridone [1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone; MOA Group 12] for weed control in the ditches. This led to an extensive discussion during the remaining field stops remembering that fluridone had been evaluated in the 1970's for its potential as a cotton herbicide; it was very effective in controlling many weeds in a terrestrial setting. However, the projected cost of the treatment as well as rotational restrictions limited its potential and fluridone was never commercialized for cotton. The university and USDA weed scientists decided to follow up and determine the feasibility and efficacy of including fluridone as a management tool for Palmer amaranth in cotton production systems or ditches.

The final stop of the day was at a field site planted with a conventional cotton variety and infested with Palmer amaranth. The grower achieved similar control of Palmer amaranth in this field as in fields planted with glyphosate-resistant cotton varieties.

Cotton field infested with Palmer amaranth. The red flag signifies that a conventional variety of cotton was planted in this field. This is part of a University of Arkansas program called 'Flag the Technology'; field flags are colored to identify the crop technology in order to prevent misapplication of herbicides and warn of sensitivity to off-target drift.

The group departed their Arkansas and its hosts for the Memphis airport where they thanked their Missouri and Illinois hosts and departed on afternoon return flights.

WSSA herbicide resistance tour participants on August 17 (front row L to R): Mike Barrett, WSSA President; Stewart Weaver, Arkansas farmer; Jill Schroeder, WSSA Subject Matter Expert to EPA; Kevin Bradley, University of Missouri; (middle row L to R): Carissa Cyran, EPA Pesticide Re-Evaluation Division; Melanie Biscoe, EPA Pesticide Re-Evaluation Division; Maggie Rudick, EPA Registration Division; Lee Van Wychen, WSSA Director of Science Policy; (back row L to R): Ken Smith, University of Arkansas; Jason Norsworthy, University of Arkansas; Dan Kenny, EPA Registration Division; Derek Berwald, EPA Biological and Economic Analysis Division; Bill Chism, EPA Biological and Economic Analysis Division; Julie Langsdale Van Alstine, EPA Health Effects Division; Harold Coble, USDA Office of Pest Management Policy; Bryan Young, Southern Illinois University; Brian Kiernan, EPA Environmental Fate and Effects Division; Grant Rowland, EPA Registration Division; Mike Mendelsohn, EPA Biopesticides and Pollution Prevention Division.

Summary:

Several different aspects and observations of managing herbicide-resistant weeds were openly discussed throughout the tour. Biological and ecological descriptions of the specific weed species and the evolution and spread of glyphosate resistance was provided by the university faculty along with reasoning as to why the *Amaranthus* species (Palmer amaranth and common waterhemp) arguably pose the greatest threat to crop production compared with other glyphosate-resistant weed species that have already been confirmed. The inclusion of corn in the crop rotation was commonly cited as a means of improving management of these weed species by having access to a broader group of herbicide mechanisms of action, especially the use of atrazine. In fact, the importance of atrazine in providing greater control of problematic weeds and improved overall sustainability of weed management was a repeating theme from the growers and crop consultants across the geographies traveled. The importance of both old and new herbicide chemistry to manage herbicide resistance was also emphasized as well as the need for continued herbicide discovery efforts for the development and commercialization of novel herbicide mechanisms of action. In addition, the development of new crop traits such as those imparting resistance to dicamba, 2,4-D, glufosinate, and HPPD-inhibiting (MOA Group 27) herbicides were also viewed as important tools for future weed management in spite of the challenges, such as the mitigation of off-target drift, that may be associated with some of these technologies.

In some instances, cropping decisions for individual fields were being influenced specifically by government programs such as federal crop insurance. The role of these government programs on the potential for influencing grower behavior and the evolution and spread of glyphosate-resistant weeds or soil conservation was discussed. The group also emphasized the importance of continuing education on how to manage herbicide resistant weeds for consultants and dealers, including the need for mechanism of action information (MOA group number) on all herbicide labels. The MOA group number on labels helps practitioners use the resistance management information provided by university extension educators. When all chemical means of weed management were exhausted, growers, in some areas, resorted to tillage for weed management which threatened soil conservation. In other areas, growers implemented hand-weeding crews to manually reduce the amount of glyphosate-resistant weed seed production as a long-term management strategy. The tour brought to light the dependence of growers on effective herbicides for successful weed management and how other non-chemical means such as cultural practices and crop rotations will be needed to supplement herbicides in future weed management strategies to enhance the sustainability of the system.

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Respectfully submitted,
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