



2023-2024 WSSA Standing Committee Report

Committee Code and Name: E-12b Herbicide Resistance Education

Committee Chair: Jill Schroeder

Committee Members, 2023 (includes sub-committee members)

- Amy Asmus
- Michael Barrett
- David Ervin
- George Frisvold
- Todd Gaines
- Raymond Jussaume
- Andrew Kniss
- Ramon Leon
- Gray Turnage
- Jill Schroeder
- Francois Tardif
- Lee VanWychen
- Muthu Bagavathiannan
- David Shaw
- Katie Dentzmann
- Ian Burke
- Aaron Hager
- Bill Chism
- Amber Pelon (student representative)
- Clint Pilcher (ESA representative)
- Mark VanGessel (EPA liaison)
- Lindsay Haines (NRCS)
- Kelly Tindall (EPA)
- Cameron Douglass (USDA-OPMP)
- Craig Alford (HRAC)
- Caren Schmidt (Public Awareness)
- Lynn Sosnoskie (Extension)
- Caio Brunharo (Herbicide Resistance)
- Emily Unglesbee (Communications Specialist)
- Neil Hoffman and/or Rebecca Fletcher (APHIS - (Ex off))

Board Coordinator: Lynn Sosnoskie

Committee Members Rotating Off: Raymond Jussaume

Recommended Replacements/Additions: ???

2024 Plan for Committee Activities

Goals for 2024:

- **Transdisciplinary conference proposal** – Develop a conference grant proposal for submission to Pest and beneficial species program with NIFA. The funds would support a conference designed to engage the pest management community and agencies in a discussion about the changing rural landscape and resulting challenges to communication, community collaboration and information exchange; what new tools do educators need to be able to maintain their effectiveness in this changing environment.
- **Revisit/revise and update Norsworthy paper on BMPs** – Ian Burke is working with Jason Norsworthy to recruit a team to update the BMP paper.
- Amy Asmus and Katie Dentzman are working with the Iowa Pest Resistance Management Program (IPRMP) group. Members of this committee will collaborate with the Iowa project when possible and will look to learn from this group as a case study in community engagement.
- PNW community efforts are continuing.
- Continue work on developing the resistance management assessment framework; goal would be to have a framework that regions/locales can use in their discussions and to refine crop specific resistance management tools. HRAC needs to be involved in this effort.
- Continue to engage with federal partners and other professional organizations.
- Continue to communicate with the WSSA-Endangered Species and Herbicide Resistance Committees with goal to complement activities and avoid duplication of efforts.

Recommendations for Board/Society Action:

Funds requested for 2024:

- The committee requests to spend up to \$10,000 to support activities that could not be undertaken due to COVID-19 in 2022 that carried into 2023. A subcommittee of committee members (see meeting notes of June 6, 2023 meeting attached below) decided that the funds are best spent to review and update the Norsworthy BMP paper. A budget for this activity is in progress. The board will be kept apprised of proposed activities with requests for approval.

Other requests for the Board:

- Consider developing additional mechanisms to remain in a leadership position addressing and articulating the complex issues impacting agriculture and natural resources because of pest resistance.
- Feedback on directions the committee is taking, on partnerships being developed, and on the published material we have developed.
- The PPDC Resistance Workgroup recommended to EPA that pesticide label reform is needed to address resistance issues. The E-12b committee requests that the Board support the label reform movement by ensuring stakeholder input to the ongoing work and small sub-groups that are moving forward based on the workgroup recommendations.

Summary of 2023 Activities

Goals for 2023:

- Complete the crop advisor survey and finalize the report.
- Amy Asmus and Katie Dentzman are working with the Iowa Pest Resistance Management Program (IPRMP) group. Members of this committee will collaborate with the Iowa project when possible and will look to learn from this group as a case study in community engagement.
- PNW community efforts (add descriptors) are continuing.

- Continue work on developing the resistance management assessment framework; goal would be to have a framework that regions/locales can use in their discussions and to refine crop specific resistance management tools. HRAC needs to be involved in this effort.
- Continue to engage with federal partners and other professional organizations.
- Engage communication specialist to learn more about how to frame issues.
- Continue to communicate with the WSSA-Endangered Species and Herbicide Resistance Committees with goal to complement activities and avoid duplication of efforts.

List the committee's accomplishments (since the last annual meeting):

1. A subcommittee including met in Atlanta, GA on June 6, 2023 with the following goal: Where did we start, what have we learned, and what are the next steps that our HRE committee can catalyze/facilitate realistically? Notes from the meeting are attached at the end of this report.
2. **Pacific Northwest RM programs:** Ian Burke. Grain grower groups from the PNW worked to establish permanent funding to support RM research and outreach. The program has launched with initial proposal development for research programs.
3. **Newsletter article:** Aaron Hager – recommendations to Manage Herbicide-Resistant Weeds: It is not as easy as Some Believe. Attached at the end of the report.
4. David Shaw, Amy Asmus and Jill Schroeder have continued to have virtual conversations with Cameron Douglass (USDA-OPMP) and Lindsay Haynes (USDA-NRCS) to discuss ways that WSSA can assist NRCS with resistance training efforts.

Publications:

Shaw, David, Amy Asmus, Jill Schroeder and David Ervin. 2023. **Changing the Paradigm for Pesticide Resistance Management.** Pest Management Science (wileyonlinelibrary.com) DOI 10.1002/ps.7709

Dentzman, Katherine. 2023. **Perspectives of Certified Crop Advisors on pesticide resistance management.** Crops & Soils 56(4): 30-34.

Dentzman, Katherine. (2023). **Barriers to the Effective Management of Herbicide-Resistant Weeds: Perspectives from Crop Advisors.** Outlooks on Pest Management, 34(5), 194-198.

Hollis, Joe, Katherine Dentzman, and J. Arbuckle 2023. **Farmers' Attitudes and Behaviors Related to Weed and Herbicide Resistance Management.** Extension Bulletin SOC 3108 available at: <https://store.extension.iastate.edu/Product/16896>

Frisvold, G., C. Agme, D. Ervin, J. Allen, S. Askew, R. Bowling, ... & M. Bagavathiannan. 2023. **Extension event attendance increases adoption of weed management practices by sports field managers.** *Weed Technology*, 1-32. Doi:10.1017/wet.2023.66

McCurdy, J. D., Bowling, R. G., de Castro, E. B., Patton, A. J., Kowalewski, A. R., Mattox, C. M., Brosnan, J. T., Ervin, D.E., Askew, S. D., Goncalves, C. G., Elmore, M. T., McElroy, J. S., McNally, B. C., Pritchard, B. D., Kaminski, J. E., & Bagavathiannan, M. V. (2023). **Developing and implementing a sustainable, integrated weed management program for herbicide resistant *Poa annua* in turfgrass.** *Crop, Forage & Turfgrass Management*. <https://doi.org/10.1002/cft2.20225>

What information was posted on the WSSA website?

- Nothing new at this time.

What amount of funds were requested? How much was spent?

- WSSA funding in the amount of \$10,000 was requested. The funds will be spent to bring the authors together to revise and update the Norsworthy paper.

What was the impact of the committee activities/accomplishments on the following: membership, publication, policy, legislation, and/or education?

- Herbicide resistance has received substantial attention from a number of federal agencies, as well as Capitol Hill. WSSA has been placed in a prominent leadership role because of our efforts.
- Educational products have been used extensively for training purposes. We have partnered with a number of commodity groups to extend our reach.
- Many members have been involved in committee and subcommittee activities and have engaged with new groups of stakeholders. The activities have engaged audiences (examples include AAAS and NAS) that were not aware of resistance as an issue comparable to the antibiotic resistance that has been an issue of great concern to these scientists. A number of additional members have been involved in 2022.
- EPA and USDA agencies continue to look to WSSA as the authoritative source for technical information and education in regards to herbicide resistance management strategies.
- Members of the Entomology Society of America have been engaged as a partner to continue collaboration and partnership on resistance outreach activities.
- The PNW has been working with local partnership NRCS reps to brainstorm outreach and education, as well as designing a herbicide resistance program for integration into their current Conservation Activity Plan program. The IMRMP has been pursuing similar work with the Iowa State NRCS, and continues to develop plans for communication, outreach, and economic impact assessments.

What is the current state of the committee's projects and activities?

I. Herbicide Resistance Education Sub-committee discussion – June 6, 2023 Atlanta, GA

Attending: Amy Asmus (retail business owner/CCA/farmer), Phil Banks (consultant), Michael Barrett (WS faculty), Nick Bergmann (human geographer), Ian Burke (WS faculty), Bill Chism (retired EPA), Katie Dentzman (rural sociologist), David Ervin (environmental economics), David Shaw (WS faculty), Jill Schroeder (retired WS faculty, USDA)

Action Items:

- 1- 2024 symposium proposal – The Changing Rural Landscape: Have we changed how we communicate?** [proposal was not successful, and ideas from this proposal and the transdisciplinary workshop concept will be incorporated into a conference grant proposal for submission to NIFA programs.]
- 2- Transdisciplinary workshop proposal** – Katie did one with ESA, will share information and we will develop a proposal for WSSA. This could serve as a roadmap to take to other agencies/work training opportunities. [possible incorporation into conference program]
- 3- Revisit/revise and update Norsworthy paper on BMPs** – Ian Burke will lead effort after consultation with Jason Norsworthy and recruit a writing team and lead author. Potential to spend WSSA allotted funds to support a face-to-face meeting after 2024 annual meeting.
- 4- Work through PPDC workgroups to enhance facilitation with federal agencies.** Amy and David with Jill support as needed. [continuing work]
- 5- Talk to Jim Kells about how to bring workforce training initiatives into NIFA programs** – facilitating community engagement. David and Jill to discuss with Jim. [outcome of discussion will be to develop a conference proposal as outlined above]

Agenda: The group considered the following questions to focus our discussion. Overall – we wanted to address the following goal: Where did we start, what have we learned, and what are the next steps that our HRE committee can catalyze/facilitate realistically? We were mindful of the fact that weed management/HR

management is a local issue and that the HRE committee is a few individuals working from a national perspective.

Harold Coble sent the following input for us to consider before we met to have this discussion:

My thoughts on HR are as follows:

- 1. I think we (all involved, not just this group) need to better educate the folks who give recommendations directly to growers. Amy probably will have some comments on this subject. Chemical dealers and distributors have the final contact with growers and many are directly involved with decisions on what products growers use. Extension to a lesser degree in most states along with bankers. Maybe a concerted effort is called for here.*
- 2. We need to make sure all herbicide companies are telling the same story related to HR. I know of some company sales reps who talk the talk until it comes to their company's product, but then come up with a scenario that makes it OK to still use their product when there may be resistance to that product in the weed population. I don't know the solution to this issue, but maybe EPA can be involved.*
- 3. We cannot give up on educating growers. They have a lot on their minds, and continued educational efforts may be warranted.*

Schroeder asked David Shaw to start the June 6 discussion by describing how the HRE committee was formed and our initial activities between 2010 and 2014 when we held the HR Summit 2 at National Academy of Science in Washington, D.C.

Meeting discussion questions included:

Section 1: Where did we start and what we have learned (about 3 hours). Below is a list of recommendations that came out of the Summit and were listed in the paper that D. Shaw wrote for the special issue of WS (Shaw, D. 2016. Weed Science 64 special issue). **Have we fulfilled any of these recommendations and, if so, how? What have we learned? The group was asked to please come prepared to share updates – consideration of what have we done since 2014!**

Recommendations – 2014 Summit:

- Increase awareness that everyone engaged with agriculture has a role in managing herbicide resistance and accountability for that role.*
- Develop a herbicide resistance management certification program for weed management decision makers and advisors.*
- Reduce regulatory barriers to herbicide resistance management; e.g., conservation compliance.*
- Establish prototypical, community-based area-wide herbicide resistance management programs for specific threats; e.g., Palmer amaranth in Iowa.*
- Communicate the effect of herbicide resistance management on short- and long-term farm profitability.*
- Implement programs for scouting and controlling weed escapes.*
- Provide short-term financial incentives to reduce the cost of developing and implementing field-by-field herbicide resistance management plans.*
- Market-promote consistent and scientifically sound herbicide resistance management programs.*
- Incentivize innovation in nonchemical weed management practices.*

Questions to consider for this section:

- What did HR/resistance management look like when we started this journey in 2010?
- What have we accomplished since 2010?
 - What have we learned?
- Who have we listened to and what have we learned from them?
 - Have we successfully engaged these groups? In what way?

Section 2. What has changed (about 2 hours)? Consider the 2014 recommendations listed above; what has changed based on what we have learned since then as well as the state of HR?

Questions to consider:

- What does HR/resistance management look like now?
 - What has changed?
- How do we continue to engage/follow up on what we have learned since 2014?
- Who do we still need to listen to and engage?
- What other weed/pest/crop management or environmental/regulatory issues have arisen that will impact HRE and HR management?

Section 3. Where do we go from here? (about 3 hours) Questions to consider:

- What do we need to continue work on and what should be set aside by our group?
- What is our role going forward?
 - Who else needs to be part of our effort going forward?
 - How do we engage/recruit these groups?
- What are the next steps that we can realistically take to move this group effort forward?
- What does success look like for HR management?
- What does success look like for us as the HRE core group?

Discussion Notes – June 6, 2023 after the background was presented by D. Shaw and A. Asmus (who shared what growers and advisors were facing and why they could not “just do what we academics said they needed to do to address resistance”).

Discussion of progress and concerns since 2014:

Amy Asmus – she sees that growers know what herbicide resistance is and have generally adopted at least one or two BMPs. However, they still do not recognize that prevention (of resistance or movement of seed etc.) is a solution. Currently, resistance is no longer a quick fix for her as an advisor. She counsels(?) the growers to add resistance management (RM) to their practice but then has to go back and find new/alter solutions to other management problems that arise because of the change in weed management. (Sometimes the management does not come easily in a jug and growers are more reluctant to implement IPM strategies that may take longer and don’t show immediate results.)

Bill Chism - EPA was on notice in 2014 that they had to do something so they didn’t have to remove chemistry due to lack of performance because of resistance. This led to the development of the 2 PR notices that were published. Currently, he has observed that industry is putting more resources into development of GM crops rather than developing new pesticides.

Dave Ervin – Chairing the 2010 National Research Council “The Impact of Genetically Engineered Crops on Farm Sustainability in the United States” was his introduction to the issue of HR. Mike Owen, Iowa State University, was instrumental (and forceful!) in his education on the topic. One of the four principal recommendations of that consensus report states “Federal and state government agencies, private sector technology developers, universities, farmer organizations, and other relevant stakeholders should collaborate to document emerging weed-resistance problems and to develop cost effective resistance-management programs and practices that preserve effective weed control in herbicide-resistant crops. The group that David Shaw pulled together to plan and carry out the summits responded to this charge and the current group with Jill in charge continues in the vein of assembling key stakeholders to innovate HRM. Dave E has subsequently, as a result of collaborative interdisciplinary research, learned that HR is not limited to production agriculture but is a broad issue for any environment where weed management is needed (e.g. turf). He has been part of the effort to understand and bring awareness of the issue to the turf industry.

Phil Banks – the concern is that growers/managers are still looking for the new silver bullet (techno-optimism) and have less concern for the ramifications of the problem. Resistance to glyphosate really highlighted the problem with the silver bullet mentality. Now with the Dicamba crops, it seems that users don’t care about the collateral damage.

Ian Burke - Weed Science is missing the fact that effective chemical weed management is a fundamental tool for climate issues – cannot achieve soil health initiatives without effective weed management. WSSA is meeting an opportunity with messaging on this issue with the agencies. In addition, HR and weeds as a barrier to trade is a major issue for US export markets – weed seed, particularly, HR weed seed, contamination of grain or seed is a major concern for export markets. Tolerance for weeds on a field by field basis needs to change – we need to consider these additional problems as we move forward, including where we need to embrace a Zero tolerance approach.

Amy Asmus – the mind set of the grower is on the economics of field; they make decisions based on a one to three year loss to yield.

Ian - Ian also asked, How do we change the mindset of the grower from yield loss economics, to market loss economics?

Katie Dentzman – ag economists have done a great deal of modeling work to develop decision support tools for growers. These are rarely used in practice due to all of the constraints of production decisions.

Ian – The issue of GMO wheat escapes in the PNW – three events led to the close of markets in Europe too all U.S. wheat exports.

Katie – when considering community based management, techno-optimism leads to lack of agency/sense of control over HR issue. Growers have no other option based on their operation size, etc. She found that through her work that growers wanted to know what neighbors are doing and that the more they talk, the more they move toward community. She has worked with Iowa growers on building community projects – they had great momentum but now all activity has stopped. The support group is dropping off due to retirements/new jobs etc. and the momentum for working together on this has ceased. She has a grant to study the community success which has changed to understanding why the community approach is no longer working. Lack of rural vitality is one reason, farmers are stretched too thin.

Nick Bergmann – as a human/rural geographer, he brings a different perspective to the discussion. From his work in the PNW he questions how much more farmers mentality (common theme is that they just need to work differently) can change with regard to HR. We may need other structural approaches – how can the system adapt to assist the farmers. He also suggested that community-based projects can be very helpful and thinks it would be useful to study these groups across the U.S. to compare/contrast what strategies work.

Katie – found from survey work that universities do not usually hear the complaints about performance and that consistent messaging is still an issue.

Question for Katie – Who else do we need to listen to – she has interviewed and surveyed farmers and advisors. We agreed that we need to hear from industry, especially sales; retailers; federal agencies; university extension.....

Ian – PNW – who should they survey? -to measure progress? – those in support/advisory roles such as NRCS? **Perhaps what would be helpful is to map, through successive surveys, the network of communications.**

Katie – she is interested in hearing more about barriers to deal with farmers and understanding the complexity that farmers deal with. She is hopeful about the shifts she has observed within weed science and entomology – an increasing recognition of issue that farmers face.

Amy – she thinks they hear from growers by meeting customers where they are at and communicating to understand and work from where they are at. Questions where they can have the greatest impact – which customers are the social influencers who will share that knowledge beyond her business?

Katie – her biggest ‘a-hah’ moment from her survey work was that she heard from certified crop advisors that what is important are the things they can control. These advisors feel more empowerment over their response to the issue than growers who tended to embrace techno-optimism.

Nick- he is thinking about community from the framework of co-production of knowledge by growers/advisors. He thinks that the approach within the community based participatory framework is to pair the experiential knowledge of growers with the scientific data/experience of the university colleagues. Requirement is the time and talent to drive/facilitate community programs – it takes a lot of his time and resources to facilitate this work.

Nick – his biggest ‘a-hah’ moment was that it is as challenging to get researchers on the same page, beyond need to have all the answers, and to have an open mind to new approaches.

Amy and David S. – both are on the EPA-PPDC advisory board and working with the resistance workgroups. There are opportunities but many obstacles to this effort. Bill provided insight and a challenge to WSSA to **help make PPDC recommendations actionable by EPA so they have a framework to more easily implement the workgroup recommendations.**

Parking Lot thoughts to be addressed later in the day or.....

1. Lack of expertise in USDA on the issues of agricultural economics after the relocation of ERS in 2018.
2. Lack of rural sociology expertise interested in this issue. Universities are cutting rural sociology programs as well. There is hope for addressing issues through interdisciplinary programs but, without trained rural sociologists or teaching of rural sociology, these programs are threatened as well.
3. Consider impact of social media on rural communities – how does it enhance/cause reduction in personal communication and community.
4. How do we work with/inform federal agencies? This needs a targeted approach; a sales and marketing plan to inform about the need for structural changes to assist growers with HRM.
 - a. Consider approaching NIFA to develop a program of workforce development/enhancement.
 - b. Consider if a state by state approach to dealing with structural change is more effective.
5. What is our capacity as a discipline to broaden this discussion? We need to address succession planning. How do we work within WSSA to broaden the voice/impact of this committee?
6. Dave E. – We need to focus on consistent messaging and we could make a big impact if we can move the needle on this issue. A prime example is better education on what constitutes an effective rotation of MOAs, a principal recommendation to slow resistance evolution. George Frisvold and Dave inserted a MOA question in their national survey of turf managers and only about one third answered it correctly. That low percentage is consistent with previous ag chem industry survey data and poses a significant obstacle to making progress on HRM.
7. How do we diversify our scope/community to help move us forward?

NEXT STEPS discussion:

1. The discussion about progress and challenges led to a need to diversify our group to address next steps.
 - a. Criticism is made that we are too herbicide focused and there is a need for RM across disciplines which EPA/PPDC workgroups are working to address.
2. What is the problem we are trying to solve?
3. What does success look like?
 - a. A sustainable system that is resilient and adaptable.
 - i. Work toward prevention and adaptable reaction to a more sustainable management system...

- ii. How do we leverage resources to adapt the system?
 - b. Remember whatever we move forward with we will have success and failure, but the keys will be a connection of resources to action, facilitation of networking and enhancing transdisciplinary work in HR. Transdisciplinary work is the key to today's issues.
 - c. This committee could be the nexus to help network all the stakeholder groups who are working on resistance issues – who are they and what are their goals and activities?
 - d. This committee could work on enhancing transdisciplinary work – and by respecting farmer led knowledge [community, education, communication, mapping/detection].
 - i. We think we need to change grower behavior, but how do we move beyond this mentality to change into a need to empower growers to succeed?
 - ii. In Douglas County, the GROWERS want to CHANGE researcher behavior. How do we get communities to the point they are not led by extension or researchers and grow on their own?
 - e. Empowering growers should be a goal – the blame game by all parties (?) needs to be changed.
 - i. Community engagement training
 - ii. NRCS framework developed in Iowa – how to pilot?
 - iii. Enhance capability of extension
4. What are our leverage points?
 - a. There is evidence of declining enrollment by farmers in conservation programs which is an environmental concern, a soil health concern, and endangered species concern...
 - b. Trade barriers are being erected because of the presence of weed seed, including with herbicide resistance, -- these are nontariff barriers.
 5. We need to go back and re-evaluate the BMPs discussed in the Norsworthy paper, e.g., effective MOA rotations – prevention and resilience need to be part of the BMPS
 - a. Who would evaluate?
 - b. Should we include farmers on the project?
 6. Need to recognize that education and technical assistance has great value
 7. Some growers feel that we need to change research mindset/behavior to provide new value to their objectives.

Action Items (with updates):

1. **2024 symposium proposal** – revise based on discussion and submit. Bill is lead.
 - a. **Title: The Changing Landscape of Rural Communication, Submitted 6/23**
2. **Transdisciplinary workshop proposal** – Katie did one with ESA, will share information and we will develop a proposal for WSSA. This could serve as a roadmap to take to other agencies/work training opportunities. Dave has submitted a transdisciplinary workshop proposal for the 2024 AAAS meetings in Denver titled “Equipping scientists with transdisciplinary skills to tackle wicked problems.” If accepted. Nick Jordan of the U. Minnesota will give a presentation “ **Note: This proposal was not accepted for presentation at the AAAS meetings.**
3. ***Organizing transdisciplinary action and learning to support agricultural diversification.*** “
4. **Revisit/revise and update Norsworthy paper on BMPs** – Ian will lead (?) effort and recruit a writing team and lead author.
5. **Work through PPDC workgroups to enhance facilitation with relevant federal agencies.** Amy and David with Jill support as needed.
6. **Talk to Jim Kells about how to bring workforce training initiatives into NIFA programs** – facilitating community engagement. David and Jill to discuss with Jim.

Parking lot of ideas that were addressed: What is our capacity as a discipline to broaden this discussion? See diagram below for a suggestion on how we might structure this next discussion going forward.

Potential Disciplines to Include in discussions going forward

- **Communication**

- **Crop Life or Retired Registrant**
- **Economist**
- **Graduate Student**
- **Grower or Consultant**
- **IPM Center**
- **New Technologies**
- **Retailer**
- **Sociologist**
- **Weed Scientist**
- **Behavioral Psychologist?**

disciplinary ties in
the group?



II. Newsletter article: **Recommendations to Manage Herbicide-Resistant Weeds: It's Not as Easy as Some Believe** – Aaron Hager

One of the most daunting challenges facing agronomic crop production is the continuing evolution of weeds resistant to herbicides. The magnitude of herbicide resistance is best measured on a global scale. The most recent summary indicates 520 unique cases of herbicide resistance—encompassing 268 species—occur globally. Approximately 11–12 cases of unique resistance are discovered each year. In contrast, our understanding of how and why weeds are evolving various resistance mechanisms is evolving much slower. This introduces a somewhat precarious situation: if we do not fully understand how/why these resistance mechanisms evolve, how do we develop sound herbicide recommendations to better manage this? Despite these scientific uncertainties, a few “themes” (i.e., recommendations) about how to manage herbicide resistance by using more herbicides or different herbicide use patterns continue to perpetuate among some weed management practitioners.

Recommendations to slow the evolution of herbicide-resistant weeds have been promoted by university and industry scientists for many years. A common element of these recommendations has been to diversify the herbicide modes of action (MOA) to which weed populations are exposed. Herbicide rotations (within and between years) and tank-mixtures are two strategies recommended to achieve this diversification, but few quantitative data described the effectiveness of these approaches at a landscape level. In April 2015, USDA/ARS and University of Illinois weed scientists published the results from a project that studied the evolution of target site-based glyphosate-resistant waterhemp (Evans et al. 2015). The research examined factors related to landscape, weed, and management from 105 Illinois grain fields, including over 500 site-years of herbicide application records. This research discovered that simply rotating herbicide modes of action actually increased the frequency of resistance. In contrast, exposing populations to multiple MOA through tank-mixtures greatly reduced the selection for glyphosate-resistant waterhemp. A field in which 2.5 MOA per application were used was 83 times less likely to select glyphosate-resistant waterhemp within 4–6 years than a field in which only 1.5 MOA per application were used.

What became of this (at that time) new information? By in large, the crop protection industry “signed on” and began campaigns to encourage growers to use multiple herbicides/multiple, effective herbicides/herbicide mixtures (add whichever other cliché is your favorite) more than promoting rotating from Herbicide X this season to Herbicide Y next season. But has this message now become overused? It does seem somewhat simplistic, that all you need to do to solve the challenges of weed resistance to herbicides is to continue using herbicides but in a slightly different way than we have historically. A recent industry podcast highlighted a prominent concern of many weed scientists; that all some want to do is use herbicides to solve a problem created by using herbicides.

Is it more likely weeds will evolve resistance to soil- or foliar-applied herbicides? Many will assert it's easier to evolve resistance to foliar-applied herbicides than to soil-applied herbicides, but are there data to support this? A recent statement that “...there is much less potential to develop resistance [to soil-residual herbicides] begs the following question: does anyone actually know how common resistance is to soil-residual herbicides? The simplest answer to this question is no. Remember, most of the research done at the University of Illinois is with waterhemp and not with other weed species. But what we do know about waterhemp is that if a plant is resistant to a foliar-applied herbicide from herbicide Groups 2 (ALS inhibitors), 14 (PPO inhibitors) or 27 (HPPD inhibitors), the plant also is resistant to soil-applied herbicides from these herbicide groups. Add in Group 15 (VLCFA inhibitors) resistance in waterhemp and the frequency of resistance to soil-applied herbicides becomes even more concerning.

It is critically important to note the work we did demonstrating herbicide mixing was a more effective strategy to mitigate the evolution of resistance compared with herbicide rotation was based on a target site resistance mechanism. Much of the research our group has undertaken the past five to eight years has not involved target site-based resistance mechanisms, but rather nontarget site-based resistance mechanisms, most notably the

ability of resistant waterhemp to rapidly metabolize a herbicide before it causes a lethal effect. To our knowledge, there are no similar data that describe if herbicide mixtures are the most effective way to mitigate the evolution of nontarget site-based resistance mechanisms. In fact, research published from Europe a couple years ago suggested herbicide mixtures might actually favor the evolution of “generalist resistance mechanisms” (i.e., enhanced herbicide metabolism) instead of the “specialized resistance mechanisms” (i.e., target site resistance) often selected when single herbicide active ingredients are used repeatedly (Comont et al. 2020).

We have identified waterhemp populations resistant to herbicides to which the population had not been previously exposed. How is that possible? In every instance to date, the resistance mechanism has not been a change in the herbicide target site, but rather a nontarget site mechanism (usually enhanced herbicide metabolism). So then, how does one know which herbicides remain effective against any waterhemp population? The simple answer is there is no simple way to know. Simply adding soil-residual herbicides to your weed management program, or “layering” residuals with your postemergence application, or tankmixing two or more herbicides may seem to be the solution, but we must admit we do not fully understand how these tactics will impact the future evolution of resistance mechanisms. At this time, the only certainty we have is that if there are no weed seeds produced at the end of the growing season, there is no change in the frequency of any resistance mechanism. Anything short of that is not much more than speculation. Those few, scattered waterhemp remaining in the field when the combine arrives probably won’t do much to slow the harvest operation, but seeds from those few females just might contain the next and newest herbicide-resistance mechanism. We have no doubt that herbicides will continue to be valuable tools to help preclude crop yield loss, but we also must consider additional tactics to ensure no weed seed production during every growing season. This point is worth repeating: consider additional tactics to ensure no weed seed production.

Dr. Patrick Tranel recently discussed aspects/challenges of metabolic herbicide resistance for a recent “War Against Weeds” podcast. You can listen to this informative conversation from April 19, 2023 at: <https://waragainstweeds.libsyn.com/>

Literature Cited

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Notes from January 3 full committee meeting: