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Herbicide resistance: Experiences east of the Mississippi River

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The continual evolution of weed species and populations resistant to herbicides from one or more mechanism-of-action families represents one of the most daunting challenges faced by weed management practitioners. Waterhemp has evolved resistance to more herbicide mechanisms of action than any other Illinois weed species, including resistance to inhibitors of acetolactate synthase (ALS), photosystem II (PSII), protoporphyrinogen oxidase (PPO), enolpyruvyl shikimate-3-phosphate synthase (EPSPS) and hydroxyphenyl pyruvate dioxygenase (HPPD). Not every individual waterhemp plant is resistant to one or more herbicides, but the majority of field-level waterhemp populations contain one or more types of herbicide resistance. Perhaps even more daunting is the occurrence of multiple herbicide resistances within individual plants and/or fields. Waterhemp plants and populations demonstrating multiple herbicide resistance are becoming increasingly common and greatly reduce the number of herbicide options that remain effective for their control.

Beginning in 2010, the Illinois Soybean Association provided funding to screen waterhemp samples for herbicide resistance. During the first three years of screening, approximately 1000 samples were submitted; however, in 2013 alone over 1200 samples were submitted. These samples have allowed us to monitor the spread of herbicide resistance (and in particular glyphosate resistance) across Illinois (Figure 1). One point of particular interest as early as 2013 was that the vast majority of samples were submitted from counties north of Champaign County.

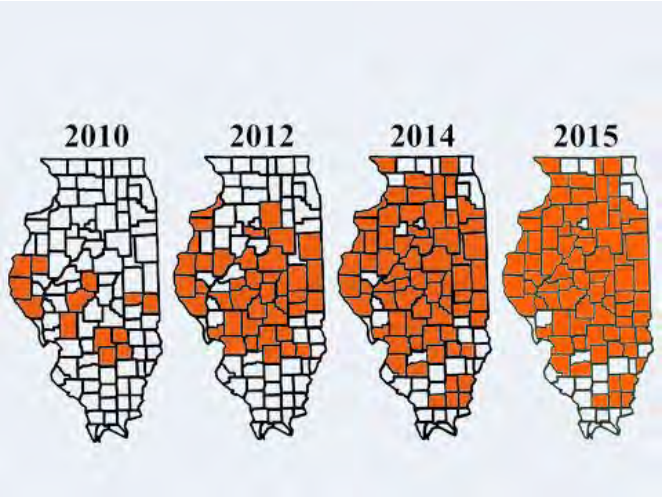

Figure 1. Range expansion of glyphosate-resistant waterhemp (based on grower submissions)

The screening results also indicate another disturbing trend; an increase in the frequency of PPO resistance in waterhemp. Waterhemp samples from 295 fields were submitted for screening in 2014 (the last season this free service was offered). Figure 2 shows that, of the 295 fields from which waterhemp samples were submitted for resistance screening in 2014, resistance to PPO-inhibiting herbicides was present in two-thirds of the fields. An increase in the frequency of PPO resistance in Illinois waterhemp populations can be explained by the increased use of soil- and foliar-applied PPO-inhibiting herbicide in corn and soybean. Some incorrectly believe this type of resistance exists only to foliar-applied PPO inhibitors. Biotypes of

waterhemp resistant to PPO-inhibiting herbicides are resistant to those herbicides regardless of whether the herbicide is applied to the soil or foliage. Selection for herbicide resistance occurs each time a herbicide is applied, regardless of the herbicide or whether it is applied to the soil or plant foliage.

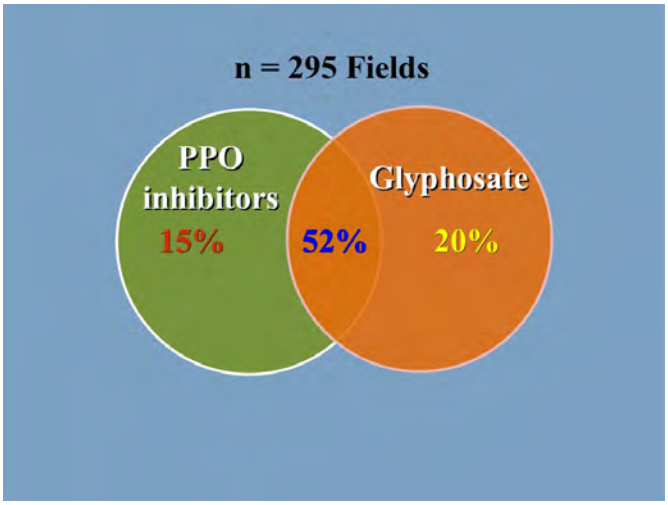

Figure 2. Multiple-resistant waterhemp summary (2014).

Many individuals involved in production agriculture have first-hand experience with the numerous challenges caused by herbicide-resistant weeds. The magnitude of herbicide resistance is best measured on a worldwide scale. The most recent summary indicates 471 unique cases of herbicide resistance – encompassing 250 species – occur globally. Approximately 11-12 cases of unique resistance are discovered each year. Methods employed to detect and study the evolution of herbicide resistance have improved greatly over time, but our understanding of the epidemiology of herbicide resistance has lagged.

Recommendations to slow the evolution of herbicide-resistant weeds have been promoted by university and industry personnel for many years. A common element of these recommendations has been to diversify the herbicide mechanisms 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 exist that describe the effectiveness of these approaches at a landscape level. So the question that largely remains unanswered is: does rotating herbicide MOA annually, or exposing weeds to multiple MOA simultaneously (i.e., tank-mixtures), do more to slow the evolution of herbicide resistance?

A recently completed research project sought to answer this critically important question. In April 2015, USDA/ARS and University of Illinois weed scientists published the results from a project that studied the evolution of glyphosate-resistant waterhemp. The research examined factors related to landscape, weed, and management from 105 Illinois grain fields, including over 500 site-years of herbicide application records. The researchers employed a statistical analysis known as CART (classification and regression tree) to identify relationships between the presence of glyphosate-resistant waterhemp and 66 variables related to environment, soil, landscape, weed community, and weed management.

Results of this landscape-level analysis indicated that management practices were the best predictors of glyphosate-resistant waterhemp among all 66 variables included in the analysis. The occurrence of glyphosate-resistant waterhemp was greatest in fields where glyphosate had been used in over 75% of the seasons included in the analysis, where fewer MOA were used each year, and where herbicide rotation occurred annually. Simply rotating herbicide MOA actually increased the frequency of resistance.

On the other hand, 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. But the researchers stressed that this strategy will work only if each component of the tank-mixture is effective against the target species. They also emphasized that effective, long-term weed management will require even more diverse management practices.

What are some possible implications of these results as farmers continue to struggle with herbicide-resistant weeds? The data indicate lack of effective tank-mixtures, not lack of residual herbicides, was the best predictor of glyphosate-resistant waterhemp. In other words, each application made to a population, whether that be before emergence or after, should expose the population to more than one effective MOA. A soil-residual herbicide applied before or after planting followed by single postemergence herbicide is unlikely to be a sustainable resistance management approach.

What about other and future herbicide-resistant traits? Simply switching from a Roundup Ready system to Liberty Link, Enlist, or Extend is unlikely to provide a long-term solution. If glyphosate-resistant weeds are already present in fields planted with varieties containing these other traits, we will begin selection for resistance to glufosinate, 2,4-D, and dicamba, respectively, if we don't carefully consider how to best steward these traits. These alternative herbicide-resistance traits are often touted as a "solution" to existing herbicide-resistant populations, but these types of marketing slogans unfortunately might serve to shorten the effective lifespan of these traits. Long-term, sustainable solutions to herbicide resistance are unlikely to be "simple" or "convenient."

One of the encouraging findings of the study was that, as previously stated, management practices were the most important predictors of glyphosate-resistant waterhemp. Proximity to infected fields, or weed population densities within a given field, were not important predictors of resistance. In other words, even if you have large populations of waterhemp in your field, or a neighbor with glyphosate-resistant waterhemp in their field, you can keep glyphosate-resistant waterhemp at bay if you implement appropriate weed management strategies.