Scientists Identify Mechanism for Herbicide Resistance in Waterhemp

Weed scientists in the Department of Crop Sciences at the University of Illinois have recently published the results from a study on a unique population of waterhemp that shows resistance to three classes of herbicides once effective for management of waterhemp in corn and soybean fields.

"The initial discovery of this waterhemp population in 2001 led to the first-ever report of three-way herbicide resistance in a summer-annual weed species in the United States," said Aaron Hager, assistant professor of Extension weed science at the U of I. "Our research group is now beginning to get a firm handle on the genetic basis for the resistance in this population to the protoporphyrinogen oxidase-inhibiting (PPO) class of herbicides."

The PPO herbicides are the most commonly used postemergence herbicides for waterhemp control in fields that are not planted with Roundup Ready soybeans. He noted that this waterhemp population is also resistant to the classes of herbicides that inhibit acetolactate synthase (ALS) and triazines, leaving only glyphosate as a potential means of postemergence control in soybean.

Waterhemp was not considered much of a problem weed species in agronomic crops until it began to spread across the state during the late 1980s and early 1990s. According to Hager, this once-obscure weed species now is considered the most problematic broadleaf weed species in the state.

"One adaptation of particular importance that has allowed waterhemp to flourish is its ability to thwart attempts at control with herbicides," Hager said. "In fact, various levels of resistance in this weed to the ALS class of herbicides have been widely reported across the state for several years now."

He points out that there are currently only four herbicide active ingredients for postemergence waterhemp control in soybeans, and three of these belong to one chemical family. The diphenylether herbicides (PPO-inhibitors), such as Ultra Blazer, Flexstar, and Cobra/Phoenix, were once used extensively for waterhemp control in soybeans until being largely displaced by glyphosate.

"In 2001, U of I Extension specialists began to receive reports from around Illinois indicating that waterhemp control was much less than expected following applications of diphenylether herbicides," Hager said. "We soon focused our attention on a population of waterhemp from western Illinois that was not controlled by postemergence applications of diphenylether herbicides."

The researchers conducted a series of experiments to determine how this waterhemp population responded to various soil-applied and postemergence herbicides under actual field conditions.

"It soon became obvious that this waterhemp biotype did in fact demonstrate resistance to various PPO-inhibiting herbicides," Hager said. "After several years of extensive field, greenhouse, and laboratory research, we documented in 2005 that this waterhemp biotype was resistant to not simply one herbicide family but three different herbicide families: ALS inhibitors, PPO inhibitors, and triazines."

This effort involved extensive collaboration with Pat Tranel, associate professor of molecular weed science at the U of I, and his team of researchers. Major portions of the research were conducted by graduate student William Patzoldt and by Joel McCormick, who was an undergraduate student at the time.

After extensive laboratory work, the group recently published their results in the Proceedings of the National Academy of Sciences. Their research identified a unique mechanism of resistance used by this waterhemp biotype to survive exposure to PPO herbicides. Funding support for this research was provided by the soybean checkoff through the Illinois Soybean Association.

"Plants have two different forms of the PPO enzyme, one that functions in chloroplasts and one that functions in mitochondria," Tranel said. "Typically, these two forms of the enzyme are each encoded by its own gene. What we found in waterhemp was a gene that encoded both forms of the enzyme."

He noted that this turned out to be the gene in which they identified the mutation that resulted in the herbicide resistance.

"That there are two different PPO enzymes in plants may partly explain why resistance to PPO inhibitors is so rare," Tranel said. "A mutation in a gene encoding just one or the other may not be sufficient to confer resistance. Waterhemp got around this problem by having a gene encoding both forms. Thus one mutation yielded two different resistant enzymes."

Tranel explained that the second novel aspect of the resistance mechanism is the type of mutation.

"Herbicide-resistance mutations typically involve a single change in the DNA sequence that, in turn, confers a single change in the protein, or enzyme," Tranel said. "In other words, there is a substitution of one amino acid for another in the enzyme, and this is responsible for the

Source: Aaron Hager (217) 333-4424; hager@uiuc.edu

Resisitance in Waterhemp, cont.

insensitivity of the enzyme to the herbicide."

In this case, however, there was a deletion of an amino acid, rather than a substitution.

"Prior to our research, a deletion mutation had not been reported as a naturally occurring herbicide-resistance mechanism," Tranel said. "The net result is the same — the plant is resistant due to an altered site of action. However, this unique mutation illustrates the genetic diversity that waterhemp has, and its ability to evolve in response to our attempts to control it."

Hager points out that this effort to better understand waterhemp resistance is made even more important by the recent discovery of a glyphosate-resistant waterhemp population in Missouri.

"This research marks a classic example of how Extension and basic research can work together on a problem," Hager said. "Without the involvement of each, this entire project would not have yielded the significant results that were made possible through our collaboration."

He noted that Extension weed scientists are often the first to learn of unique challenges facing farmers. In this case, they initiated field and greenhouse research to begin investigating this waterhemp population but soon realized that the scope of this particular problem would need to include researchers with expertise in the molecular sciences.

Hager pointed out that the collaboration with basic researchers who had molecular and analytic skills provided results that helped them to more fully understand what is going on and increased what they could learn from the situation and take back to help soybean growers around the state.

"This is exactly the way the system is supposed to work, combining the expertise of the basic and applied scientists to solve a real-life problem," said Bob Hoeft, head of the Department of Crop Sciences at the U of I. "I am really pleased that the collaboration between research and Extension provided such meaningful results."