

## AGRICULTURE

# What Happens When Weed Killers Stop Killing?

**INDIANAPOLIS**—“U.S. farmers are heading for a crisis,” says Stephen Powles of the University of Western Australia, Crawley. Powles is an expert on herbicide resistance, a worsening problem in U.S. fields. Weeds resistant to glyphosate—the world’s most popular herbicide—are now present in the vast majority of soybean, cotton, and corn farms in some U.S. states. Perhaps even worse, weeds that can shrug off multiple other herbicides are on the rise. Although the problem was highlighted here last week at an American Chemical Society (ACS) meeting symposium, chemists have little to offer: Few new weed killers are near commercialization, and none with a novel molecular mode of action for which there is no resistance.

Herbicide resistance has ebbed and flowed for decades. But because most herbicides could not kill all weeds, farmers had to continually rotate their crops and rotate herbicides to prevent resistant weeds from taking over their fields. That picture changed in the 1990s with the commercialization of transgenic crops resistant to glyphosate, marketed as Roundup by Monsanto. Glyphosate disrupts the ability of growing plants to construct new proteins. Because the transgenic crops didn’t suffer this fate, their use—and glyphosate’s—soared.

“Glyphosate used to control everything easily,” says Bryan Young, a plant biologist at Southern Illinois University, Carbondale. Some experts referred to it as agricultural heroin because it was so effective and easy to use that farmers quickly became hooked. “We trained a generation of farmers that weed control was very easy,” says Thomas Mueller, a weed management scientist at the University of Tennessee, Knoxville. But the overuse had a cost, selecting for resistant weeds.

Among the biggest concerns is a family of weeds that includes waterhemp (*Amaranthus rudis*). At the ACS meeting, Kevin Bradley, a weed management scientist with the University of Missouri, Columbia, reported that a 2008 to 2009 survey of 144 populations of waterhemp in 41 Missouri counties revealed glyphosate resistance in 69%. “It’s way higher than that now,” Bradley says. “It just blew up dramatically.” The problem extends far beyond Missouri. Micheal Owen of Iowa State University in Ames reported that surveys of weeds from some 500 sites throughout Iowa in 2011 and 2012 revealed glyphosate resistance in approximately 64% of waterhemp samples.

In response to the rise in glyphosate resistance, farmers have turned to other herbicides—often applying several in a single growing season—to protect their crops. In the United States, most midwestern and southern farmers continue to use glyphosate because it still kills most weed species. But they’ve had to add additional herbicides, known as residuals, to deal with resistant weeds. “We’ve seen the use of more residuals in the last couple of years than the previous 10 years combined,” says Bob Scott, an agricultural extension scientist with the University of Arkansas in Lonoke.



**Survivors.** Glyphosate-resistant horseweed plants stand bright green amid dead stalks of their vulnerable kin in a soybean field in Illinois.

Perhaps because of the use of multiple herbicides, the spread of glyphosate resistance appears to have slowed. According to data at WeedScience.org, an international database of herbicide resistance in weeds, from 2005 through 2010 researchers discovered 13 different weed species that had developed resistance to glyphosate. But since then only two more have been discovered.

The alternatives could meet the same fate as glyphosate, however. A survey that Bradley and colleagues conducted last year in Missouri shows that weeds resistant to multiple herbicides with completely different biological modes of action are also on the rise. Of weed populations they sampled in Missouri, 43% are now resistant to two different herbicides; 6% are resistant to three herbicides; and 0.5% are resistant to four separate herbicides. In Iowa, Owen also found a rise in multiherbicide resistance, with 89% of waterhemp populations he sampled now resistant to two or more herbicides, 25% resistant to three, and 10% resistant to five separate herbicide classes. “We are looking at control that is not working,” Owen says.

The need to apply more herbicides, more often, is affecting farmers’ bottom line. For cotton grown in the South, the cost of using herbicides has climbed from between \$50 and \$75 per hectare a few years ago to about \$370 per hectare today, Scott says. For soybeans in Illinois, Young says the jump has been from about \$25 to \$160 per hectare. “It changes how profitable it is to grow the crops,” Scott says. And in the South it is contributing to a massive shift away from growing cotton; over the past few years, the area planted with cotton has declined by 70% in Arkansas and by 60% in Tennessee, says Larry Steckel, a

weed management scientist at the University of Tennessee’s West Tennessee Research and Education Center in Jackson.

Dow, Bayer CropScience, Syngenta, and Monsanto are all developing new seed varieties resistant to herbicides other than glyphosate, which will make it easier for farmers to use alternative weed killers. Even though weeds have already evolved some resistance to those herbicides, Powles says the new seed-and-herbicide combos should work well if used with proper crop and herbicide rotation. However, he adds, “if there is an over-reliance on them, they will fail and fail rapidly.”

If that happens, farmers may have little to fall back on. Although herbicide companies say research is going full tilt, no new herbicide with a novel mode of action has hit the market in 20 years. And researchers at the meeting say they know of no new herbicides on the way that have proven to be effective, short-lived, and nontoxic to other life forms. “Growers think there will be something over the horizon that will bail them out,” Steckel says. “But there isn’t.”

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