

By Steve Werblow

Battling pesticide resistance

Farmers face resistant pests with little in the pipeline



As long as man has been trying to kill pests, pests have been finding ways to survive. Some strategies are behavioral: when a prehistoric forager squashed bugs with a flat rock, survivors were the ones that hid under leaves. Others are biological, mutations that allow insects, microbes, or plants to endure an otherwise-lethal dose of even the most sophisticated pesticide.

"Resistance is a very, very natural process," says Michigan State University entomologist Ed Grafius. "It's just survival of the fittest." Pesticides don't cause resistance, he adds; they encounter it by killing susceptible targets, leaving survivors to breed.

Pesticide resistance is a worldwide problem—182 species of weeds are resistant to at least one herbicide; more than 500 insect species and 150 microbe species also have developed resistance to the pesticides that have been designed to kill them.

Resistance signals. There are plenty of reasons crop-protection products fail. Bad weather and poor coverage are often problems. Pushing product limits by trying to kill big weeds, late-stage larvae, or established diseases is another. And the challenges of early planting conditions and high-residue fields add to the odds of escapes.

But if survivors appear next to individuals that have been controlled,

or the target pest recovers from the application, it could be resistance. The key clue: if those survivors can pass the survival trait to their offspring.

The mechanism of resistance varies by pest and product. Because it exhibits several mechanisms, the Colorado potato beetle may be the poster child for resistance. By 1989, the beetle had developed resistance to 37 different insecticides, and some populations have already become resistant to neonicotinoids introduced in 1995.

It's no surprise, notes Grafius. Thick cuticles block intake, insecticides that do get in can be pushed harmlessly into fat cells or excreted, and the insect's nervous system is al-

►**Above:** The Colorado potato beetle has become resistant to dozens of insecticides by employing nearly every resistance mechanism available.

ready adapted to nerve toxins because they're a prime ingredient in potato foliage. And because they don't travel far to breed, isolation helps build up the resistant gene pool quickly.

No penalty. Colorado potato beetles also don't seem to suffer a fitness penalty—a downside caused by the mutation that helped them survive the pesticide—so resistance traits can stay in the population indefinitely, Grafius notes. That's why many populations are still resistant to DDT, which hasn't been used on them since 1968.

Fitness penalties help explain the explosion in resistance to ALS and ACCase herbicides compared to the relatively slow development of resistance to glyphosate, notes Ian Heap, an Oregon-based herbicide resistance expert who keeps a global tally of resistant weeds at www.weedscience.org.

"You can make a lot of changes on the ALS gene and the enzyme can still function," Heap explains, but "the gene encoding the EPSP synthase enzyme that glyphosate binds to is highly conserved—meaning there are few changes—between plant species. What that tells us is that almost any changes along that enzyme are either lethal or very detrimental." Instead of

►**Above:** Carol Mallory-Smith of Oregon State University studied the flow of genes between wheat and weeds, shedding light on inheritance.

alterations to the target site like those that weakened ALS and ACCase herbicides, glyphosate-resistant weeds appear to either avoid translocating much of the herbicide to the target, or to shunt it safely into storage, he says.

The result is lower incidence, and lower levels, of resistance. Instead of the one-in-a-million weeds resistant to ALS herbicides at 50 to 1,000 times the field application rate, there are probably less than one in a billion weeds that are capable of surviving two to 20 times the label rate of glyphosate. ☞



►Above: A new strain of late blight, resistant to the potato industry's staple fungicide, swept North America in the 1990s, multiplying costs.

Purdue University weed scientist Bill Johnson is watching for that one-in-a-billion mutant (and its offspring), and he has his eye firmly fixed on marestalk, which first exhibited resistance to glyphosate in 2000. "It's sort of a 'sentinel weed,' an early-warning system," he says, pointing to marestalk's adaptability, prolific seed production, comfort in no-till fields, and ability to germinate for most of the year. "It tells us we need to manage our tools much more carefully."

Chip away. Resistance doesn't spell the end of glyphosate, but it does chip away at the cheap, simple post-emergence programs that growers have enjoyed since the introduction of Roundup Ready crops, says Bryan Young at Southern Illinois University. "Glyphosate is going to be a foundation herbicide with other, more expensive herbicides around it," he predicts.

Young was part of a research team that penciled out the cost of glyphosate resistance. In Illinois, Young projected that controlling glyphosate-resistant waterhemp if and when it emerges as a problem in corn/soybean rotations will cost growers up to \$44.25 per acre per year; University of Tennessee's Tom Mueller figured that glyphosate-resistant marestalk in West Tennessee cotton/soybean/corn rotations would add \$30.46 per acre to the annual weed-control bill.

Oregon State University's Carol Mallory-Smith recalls the doomsday



predictions flying around the Pacific Northwest when ALS and ACCase resistance took hold in 1987. "There were predictions that we wouldn't be able to use these herbicides anymore," she says. "But not every single grower gets resistance on every single acre." When Glean started failing, 2,4-D and dicamba came to the rescue, despite the fact that some weed populations were resistant to them, too, she adds.

The same happened in fungicides. **W**hen sugarbeet growers faced resistance to tin by *Cercospora*, they added a triazole and a couple of strobilurins to their toolbox. Both are fungicide families whose single sites of action make them prone to resistance. But rotating among three chemistries brought tin back to almost its old levels of efficacy, says North Dakota State University plant pathologist Neil Gudmestad, and has staved off resistance in the newer products. Adds NDSU's Gary Secor, who has extensively tested fungicide sensitivity with *Cercospora* leafspot, "We need to keep all of these

fungicides balanced so we can keep them all working."

Balancing pesticides has to reach across all crops in a rotation—genes flow from generation to generation, and often from place to place.

Pigweed exposed to glyphosate in Roundup Ready beans, then again in Roundup Ready corn, is being challenged to develop resistance. *Fusarium graminearum* may appear in the same field in sugarbeets, potatoes, wheat, and weeds; if it is attacked year after year with the same fungicides, the odds of resistance increase.

Cavalry call. Similarly, flights of corn earworm in the Midwest start as cotton bollworm in the South, and may send offspring back to cotton, according to Michael Caprio at Mississippi State University. They could encounter Bt crops at every step along the way. "We don't know what proportion of the population that overwinters in the South has been exposed to Bt in the North," he admits. New double-Bt cotton may have arrived just in time to head off resistance to the single-Bt varieties, Caprio says.



►Above: Resistance doesn't spell the end for crop-protection products, but it does make cultural, biological, and mechanical tactics vital.

►Above right: New growth on a near-dead marestalk plant signals trouble to Bryan Young.

►Right: Pigweeds pose a threat to glyphosate.

As resistance blossomed from the '70s through the '90s, chemical companies were hot on its heels with hot new products. The pace of innovation has slowed, and the high cost of introducing a product—\$152 to \$184 million—isn't helping. That's especially true in the herbicide market, where Roundup Ready crops have shrunk profits in weed control. Help is on the way, but it won't be coming soon.

"There's been such a drought in discovery for the past several years," says Chuck Foresman at Syngenta. "We've already found the simple herbicides. We're embarking on new territory, but we're looking at a 10-year time window from the date of discovery."

Managing resistance, whether in weeds, insects, or diseases, requires aggressiveness and resourcefulness. All the strategies of integrated pest



management—crop rotation, planting date, application timing, nutrients, and biological and mechanical control—need to be brought to bear.

Managing weeds becomes a vital tool in denying habitat for resistant insects or pathogens. Rotating chemical families becomes vital; so does picking tank-mix partners that are each active on the target pest. And there's no room for backsliding on rates.

Resistance is tough, but it can be managed. Two of the top challenges are recognizing it and sounding the alarm. "Some growers figure they must be doing something wrong," says Grafius. "It would be a whole lot better if they let somebody know and got help. It's kind of awkward talking to the neighbors, but it would be a whole lot better for him if he'd let us know and we can help him." ■