Delaying Pink Bollworm Resistance

Cooperative studies and strategies protect Arizona cotton

By Susan McGinley

Tim Dennehy

Pink bollworm damage on non-Bt cotton in Parker, Arizona

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Close-up of cotton boll infected with pink bollworm

Pink bollworm (*Pectinophora gossypiella*) plagued Arizona cotton crops until 1996 when Bt cotton was introduced. Containing a natural insecticide from the bacterium *Bacillus thuringiensis*, the transgenic crop preserves yields and protects farmworkers and the environment by reducing insecticide applications. Before Bt cotton, as many as 8 to 12 sprays per season were used against cotton pests in Arizona, but now sprays are at historic lows, with the statewide average less than three per season. More than half of Arizona's cotton acreage is planted with Bt cotton. Growers adopting Bt cotton have gained an average of $15,000 per farm each season.

This success will continue only as long as pink bollworm does not evolve resistance to Bt cotton, as it has previously to conventional insecticides. Each year tens of millions of acres of Bt cotton and Bt corn are planted worldwide—mainly in the United States and China. Yet no pest resistance to Bt crops in the field has been documented so far. Many people expected rapid pest resistance to Bt crops because the diamondback moth evolved field resistance to sprays of Bt and many pests evolved Bt resistance in the lab.

"Instead, we have evidence that pink bollworm resistance to Bt cotton in Arizona remains rare, as does pest resistance to Bt crops worldwide,"says Bruce Tabashnik, head of the University of Arizona's Department of Entomology. For the past seven years a multi-agency collaboration among university scientists, commercial cotton growers and government agency personnel in Arizona has focused on research and education to delay or prevent the evolution of resistance to Bt cotton in the pink bollworm. Major collaborators in the Bt cotton program include the Arizona Cotton Growers Association, the Arizona Cotton Research and Protection Council, Cotton Incorporated, and the USDA-ARS Western Cotton Research Laboratory.

In the UA College of Agriculture and Life Sciences, Tabashnik, Yves Carrière, Tim Dennehy and other researchers are studying the interaction between Bt cotton and insects. Their research is determining the effectiveness of Bt cotton, characterizing the genetic basis for pink bollworm's potential resistance, investigating factors that affect resistance evolution, and assessing the impact of Bt cotton on non-target organisms.

The program includes yearly monitoring of resistance and Bt performance in all of Arizona's cotton growing regions, coupled with a comprehensive grower education program conducted through Cooperative Extension. Crop monitoring, planting of non-Bt cotton refuges, timing of planting and other measures are part of the scheme.

"Arizona is a model for studying insect responses to genetically engineered crops. Because transgenic crops are so controversial, the whole world is watching to see what happens here," Tabashnik says. "We're helping to provide some pieces of the puzzle."

The Arizona team conducted a 10-year analysis in 15 cotton-growing regions statewide that showed Bt cotton suppressed pink bollworm independent of weather and variation among regions. Pink bollworm populations declined significantly in regions where Bt cotton was abundant. In addition, field data collected by the Arizona Cotton Research and Protection Council showed that excellent performance of Bt cotton continued throughout Arizona in the 2002 season.

A key factor delaying pink bollworm resistance has been the systematic planting of non-Bt cotton refuges near or in Bt cotton fields. Pests that would die eating transgenic cotton can survive on the non-transgenic refuge plants. Ideally, rare resistant moths that emerge from Bt cotton mate with more common susceptible moths from non-Bt cotton refuges. Studies with lab-selected resistant strains show that the hybrid offspring produced by such matings are

THE EXTENSION ARTHROPOD RESISTANCE MANAGEMENT LABORATORY (EARML)

Now in its ninth year, this laboratory serves as a central Cooperative Extension facility devoted to long-term development and maintenance of insect resistance management programs. It was established with support from the University of Arizona, and with funding from the USDA-ARS Western Cotton Research Laboratory, Cotton Incorporated, and the Arizona Cotton Growers Association.

To prevent insects from building up resistance to both natural and chemical pesticides, the laboratory conducts extensive collaborative field research and a comprehensive insect monitoring program. EARML's mission is to collect, validate and disseminate information that will allow agricultural and urban pest managers in Arizona to combat the development of resistance to pesticides in arthropods.

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killed by Bt cotton. Thus, in theory, the refuge strategy should greatly slow resistance.

"We're using global positioning systems (GPS), geographic information systems (GIS) tools, and innovative statistics to test the refuge strategy," Carrière says. He and his team members are working with grower collaborators in every cotton producing region of the state to map all Bt and non-Bt cotton fields, and to track bollworm population density.

"We found that if you plant more than a certain amount of Bt cotton in a region, the pink bollworm population starts to decline," Carrière says. "This strongly suggests that you can transform a region that has high infestations to one that has low infestations." The information also makes it possible to track compliance with EPA regulations for growing refuges.

"This lets us know if our extension efforts are effective," Tabashnik says.

Along with field studies, Tabashnik, Dennehy and Carrière are conducting laboratory and greenhouse investigations to find out exactly how pink bollworms become resistant. They have found strains of pink bollworm that survive on artificial diets containing high doses of the Bt toxin and on Bt cotton. DNA analyses have revealed mutations in a gene encoding a cell adhesion protein (called cadherin) that confer resistance to Bt toxin. These mutations remain rare in pink bollworm in cotton fields, but identifying them assists prevention efforts.

"By screening pink bollworm DNA for mutations that confer resistance to Bt cotton, we have the potential to develop monitoring tools that are up to 5,000 times more sensitive than traditional methods," Tabashnik says. He observes that in most cases, the inheritance of resistance to Bt crops is recessive, meaning that the insect would survive after eating Bt cotton only if it received the resistant gene from both of its parents. And the resistant genes carry a cost. Compared to ordinary bollworms, the resistant individuals actually are less fit in the *absence* of Bt cotton. They have lower survival when feeding on non-Bt cotton and during the overwintering period.

The effective collaboration among Arizona scientists has attracted national and international notice. Scientists and regulators from the EPA, Africa, South America and Europe have consulted with UA scientists to help decide how to best use Bt crops.

"We're managing Bt cotton, but a lot of research we're doing is useful to other organizations," Carrière says. In fact, research data presented by UA entomologists have been used by the EPA to change its guidelines for the use of Bt cotton in Arizona.

"There has been an unprecedented integrated pest management and education effort to sustain this technology," Dennehy says. "We have cutting-edge genetics and ecology that fit hand-in-glove with the growers' needs and inputs. Half of what we do would not get done without our interaction with growers; similarly critical has been the leadership provided by the UA Cotton IPM Team leader, Peter Ellsworth."

Down the line, Tabashnik, Carrière and Dennehy would like to be able to predict the evolution of resistance, as well as regional and temporal variation in pink bollworm population densities. This has not been done before, but it would show if the refuge strategy worked on a large scale. Coupled with this, Dennehy suggests a proactive resistance management strategy that would use the DNA-based resistance detection statewide.

"Our multi-agency collaboration has the potential to deliver the world's first highly sensitive method of detecting pest resistance to a Bt crop," he says. "Our results show that Bt continues to be astoundingly effective in suppressing the most serious pest of cotton in the Southwest. This is the greatest technological change in entomology since the advent of conventional insecticides after World War II."

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Cotton field west of Phoenix is planted with Bt cotton in the foreground. Non-Bt cotton refuge in the background shows ravages of pink bollworm.

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