# Pest resistance to biotech crops surging

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The caterpillar pest *Helicoverpa zea* (also known as cotton bollworm and corn earworm) has evolved resistance to four Bt proteins produced by biotech crops. Credit: Alex Yelich/University of Arizona

In 2016, farmers worldwide planted more than 240 million acres (98 million hectares) of genetically modified corn, cotton and soybeans that produce insect-killing proteins from the bacterium Bacillus thuringiensis, or Bt. These Bt proteins kill some voracious caterpillar and beetle pests, but are harmless to people and considered environmentally friendly. While organic farmers have used Bt proteins in sprays successfully for more than half a century, some scientists feared that widespread use of Bt proteins in genetically engineered crops would spur rapid evolution of resistance in pests.

Researchers at the University of Arizona in Tucson, Arizona have taken stock to address this concern and to discover why pests adapted quickly in some cases but not others. To test predictions about resistance, Bruce Tabashnik and Yves Carriere in the College of Agriculture and Life Sciences analyzed the global data on Bt crop use and pest responses. Their results are published in the current issue of the journal *Nature Biotechnology*.

"When Bt crops were first introduced in 1996, no one knew how quickly the pests would adapt," said Tabashnik, a Regents' Professor and head of the UA Department of Entomology. "Now we have a cumulative total of over 2 billion acres of these crops planted during the past two decades and extensive monitoring data, so we can build a scientific understanding of how fast the pests evolve resistance and why."

The researchers analyzed published data for 36 cases representing responses of 15 pest species in 10 countries on every continent except Antarctica. They discovered resistance that substantially reduced the efficacy of the Bt crops in the field in 16 cases as of 2016, compared with only three such cases by 2005. In these 16 cases, pests evolved resistance in an average time of just over five years.

"A silver lining is that in 17 other cases, pests have not evolved resistance to Bt crops," Tabashnik said, adding that some crops continue to remain effective after 20 years. The remaining three cases are classified as "early warning of resistance," where the resistance is statistically significant, but not severe enough to have practical consequences.

Fred Gould, Distinguished Professor of Entomology at North Carolina State University and leader of the 2016 National Academy of Sciences study on genetically engineered crops, commented, "This paper provides us with strong evidence that the high-dose/refuge strategy for delaying resistance to Bt crops is really working. This will be critically important information as more crops are engineered to produce Bt toxins."

According to the paper, both the best and worst outcomes support predictions from evolutionary principles.

"As expected from evolutionary theory, factors favoring sustained efficacy of Bt crops were recessive inheritance of resistance in pests and abundant refuges," Carriere said.

Refuges consist of standard, non-Bt plants that pests can eat without exposure to Bt toxins. Planting refuges near Bt crops reduces the chances that two resistant insects will mate with each other, making it more likely they will breed with a susceptible mate. With recessive inheritance, matings between a resistant parent and a susceptible parent yield offspring that are killed by the Bt crop.

"Computer models showed that refuges should be especially good for delaying resistance when inheritance of resistance in the pest is recessive," Carriere explained. The value of refuges has been controversial, and the Environmental Protection Agency has relaxed its requirements for planting refuges in the U.S.

The pink bollworm, a voracious caterpillar pest, quickly evolved resistance to two Bt proteins produced by biotech cotton in India, but continues to be suppressed in Arizona after more than 20 years. Credit: Alex Yelich/University of Arizona.

"Perhaps the most compelling evidence that refuges work comes from the pink bollworm, which evolved resistance rapidly to Bt cotton in India, but not in the U.S.," Tabashnik said.

In the southwestern U.S., farmers collaborated with academia, industry, EPA scientists, and the U.S. Department of Agriculture to implement an effective refuge strategy. Although India similarly required a refuge strategy, farmer compliance was low.

"Same pest, same crop, same Bt proteins, but very different outcomes," said Tabashnik.

The new study revealed that pest resistance to Bt crops is evolving faster now than before, primarily because resistance to some Bt proteins causes cross-resistance to related Bt proteins produced by subsequently introduced crops.

An encouraging development is the recent commercialization of biotech crops producing a novel type of Bt protein called a vegetative insecticidal protein, or Vip. All other Bt proteins in genetically engineered crops are in another group, called crystalline, or Cry, proteins. Because these two groups of Bt proteins are so different, cross-resistance between them is low or nil, according to the authors of the study.

Yidong Wu, Distinguished Professor in the College of Plant Protection at Nanjing Agricultural University in China, said, "This review provides a timely update on the global status of resistance to Bt crops and unique insights that will help to improve resistance management strategies for more sustainable use of Bt crops."

Although the new report is the most comprehensive evaluation of pest resistance to Bt crops so far, Tabashnik indicated it represents only the beginning of using systematic data analyses to enhance understanding and management of resistance.

"These plants have been remarkably useful, and resistance has generally evolved slower than most people expected," he said. "I see these crops as an increasingly important part of the future of agriculture. The progress made provides motivation to collect more data and to incorporate it in planning future crop deployments."

"We've also started exchanging ideas and information with scientists facing related challenges, such as resistance to herbicides in weeds and resistance to drugs in cancer cells," Tabashnik said.

But will farmers ever be able to prevent resistance altogether? Tabashnik doesn't think so.

"We always expect the pests to adapt. However, if we can delay resistance from a few years to a few decades, that's a big win."

**More information:** "Insect Resistance to Transgenic Crops: Second Decade Surge and Future Prospects," Oct. 10, 2017 *Nature Biotechnology*. DOI: 10.1038/nbt.3974

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