Reversing pest resistance to biotech cotton: The secret is in the mix

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More than 66,000 pink bollworm caterpillars were tested for this long-term study. Credit: Peng Wan

Insect pests that are rapidly adapting to genetically engineered crops threaten agriculture worldwide. A new study published in the

Proceedings of the National Academy of Sciences reveals the success of a surprising strategy for countering this problem: Hybridizing genetically engineered cotton with conventional cotton reduced resistance in the pink bollworm, a voracious global pest.

The study is the result of a long-standing collaboration between researchers at the University of Arizona and in China. Over 11 years, they tested more than 66,000 pink bollworm caterpillars from China's Yangtze River Valley, a vast region of southeastern China that is home to millions of smallholder farmers.

According to the study's authors, this is the first reversal of substantial pest resistance to a Bt crop. "We have seen blips of resistance going up and down in a small area," said senior author Bruce Tabashnik, a Regents' Professor in the UA's College of Agriculture and Life Sciences. "But this isn't a blip. Resistance had increased significantly across an entire region, then it decreased below detection level after this novel strategy was implemented."

Cotton, corn and soybean have been genetically engineered to produce pest-killing proteins from the widespread soil bacterium Bacillus thuringiensis, or Bt. These Bt proteins are considered environmentally friendly because they are not toxic to people and wildlife. They have been used in sprays by organic growers for more than 50 years, and in engineered Bt crops planted by millions of farmers worldwide on more than 1 billion acres since 1996. Unfortunately, without adequate countermeasures, pests can quickly evolve resistance.

Seed packages containing various cotton seed mixes are for sale in China. Credit: Peng Wan

The primary strategy for delaying resistance is providing refuges of the pests' host plants that do not make Bt proteins. This allows survival of insects that are susceptible to Bt proteins and reduces the chances that two resistant insects will mate and produce resistant offspring. Before 2010, the U.S. Environmental Protection Agency required refuges in separate fields or large blocks within fields. Planting such non-Bt cotton refuges is credited with preventing evolution of resistance to Bt cotton by pink bollworm in Arizona for more than a decade. By contrast, despite a similar requirement for planting refuges in India, farmers there did not comply and pink bollworm rapidly evolved resistance.

The ingenious strategy used in China entails interbreeding Bt cotton with non-Bt cotton, then crossing the resulting first-generation hybrid offspring and planting the second-generation hybrid seeds. This generates a random mixture within fields of 75 percent Bt cotton plants side-by-side with 25 percent non-Bt cotton plants.

"Because cotton can self-pollinate, the first-generation hybrids must be created by tedious and costly hand pollination of each flower," said Tabashnik, who also is a member of the UA's BIO5 Institute. "However, hybrids of the second generation and all subsequent generations can be obtained readily via self-pollination. So, the hybrid mix and its benefits can be maintained in perpetuity."

Tabashnik calls this strategy revolutionary because it was not designed to fight resistance and arose without mandates by government agencies. Rather, it emerged from the farming community of the Yangtze River Valley. While most previous attention has focused on the drawbacks of interbreeding between genetically engineered and conventional plants, the authors point out that the new results demonstrate gains from such hybridization.

Cotton cropping systems in China, such as the patchwork of farms along the Yangtze River Valley, are quite different from the large-scale systems used for cotton in the US and Australia. "In China, there are many small-scale mixed plantings of cotton, corn, soybean, peanut and other crops that are owned and managed by individual small farmers," says Kongming Wu, who worked with Bruce Tabashnik on the project. Credit: Peng Wan

"For the growers in China, this practice provides short-term benefits," Tabashnik added. "It's not a short-term sacrifice imposed on them for potential long-term gains. The hybrid plants tend to have higher yield than the parent plants, and the second-generation hybrids cost less, so it's a market-driven choice for immediate advantages, and it promotes sustainability. Our results show 96 percent pest suppression and 69 percent fewer insecticide sprays."

Although seed mixtures of corn have been planted in the U.S. since 2010, the effects of seed mixtures on pest adaptation were not tested before on a large scale, he explained. "Our study provides the first evidence that planting mixtures of Bt and non-Bt seeds within fields has a resistance-delaying or, in this case, resistance-reversing effect," Tabashnik said.

Unlike the strategy in China, the corn seed mixtures planted in the U.S. do not involve interbreeding. Also, the corn seed mixtures have as little as 5 percent non-Bt corn, which may not be enough to battle resistance effectively.

"This study gives a new option for managing resistance that is very convenient for small-scale farmers and could be broadly helpful in developing countries like China and India," explained coauthor Kongming Wu, who led the work conducted in China and is a professor in the Institute of Plant Protection in Beijing.

"A great thing about this hybrid seed mix strategy is that we don't have to worry about growers' compliance or regulatory issues," Tabashnik said. "We know it works for millions of farmers in the Yangtze River Valley. Whether it works elsewhere remains to be determined."

More information: Peng Wan el al., "Hybridizing transgenic Bt cotton with non-Bt cotton counters resistance in pink bollworm," *PNAS* (2017). www.pnas.org/cgi/doi/10.1073/pnas.1700396114

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