How a cutting edge gene tracker can help map the rise of pesticide resistance in caterpillars

Farmers rely on pesticides to control agricultural pests. But insects often develop resistance to the toxins in pesticides. University of Maryland researchers have developed and successfully tested a strategy for using genomics to monitor for and identify emerging resistance to specific toxins early, well before it becomes a widespread problem. The work will enable farmers to mitigate resistance and prolong the effectiveness of pest management tools.

The research was published on March 18, 2024, in the *Proceedings of the National Academies of Science*.

“Global food security and protection of public health rely on the availability of effective strategies to manage pests, but as it currently stands, the evolution of resistance across many pests of agricultural and public health importance is outpacing the rate at which we can discover new technologies to manage them,” said Megan Fritz, an associate professor of entomology at UMD and senior author of the study. “I’m really excited about this study, because we’re developing the framework for use of genomic approaches to monitor and manage resistance in any system.”

For many years, farmers have been planting corn that has been bred to contain natural chemicals that are harmless to humans but toxic to many pests, including the voracious, crop-damaging caterpillar known as corn earworm. But corn earworm has developed widespread resistance to some of these toxins, and it is unclear how farmers can prolong effectiveness of the remaining toxins, largely because it is difficult to monitor and identify emerging resistance before it’s too late.

In a previous paper in 2021, Fritz and her team showed that genomic tools could be used to detect signs that resistance was evolving in corn earworms four years prior to the insect being able to cause widespread failure in managed crops. But the approaches the team used were more suited for research than widespread use in agriculture, because they required two separate experiments to distinguish the genomic changes linked to toxin resistance from those associated with other factors such as environmental changes.

For this study, the researchers modified their strategy and identified the specific genomic changes responsible for resistance to multiple types of toxins called Bt toxins. Corn earworm have largely developed resistance to two of the three Bt toxins, Cry1Ab and Cry1F. The third toxin, known as Vip3A, is the only Bt toxin that remains effective against corn earworm.

To test their new strategy, the researchers first sequenced the genomes of corn earworm collected from corn that expressed only individual Cry toxins and compared it to those collected from non-toxin-expressing corn.

They found that genomic signatures of resistance to toxins could be detected after only a single generation of exposure.The team also identified specific genes with mutations that could explain toxin resistance. These genes encode digestive enzymes that chop Cry toxins into smaller pieces, perhaps preventing them from killing the caterpillars.

Fritz and her team then used the same genome sequencing approach to identify changes in corn earworm collected from corn expressing the Vip3A toxin. Not only did they identify early warning signs of emerging resistance to Vip3A, but they also described how common strategies for preventing resistance could actually be facilitating Vip3A resistance.

Non-Bt expressing corn is often planted near Bt corn, so that corn earworm have a refuge from Bt toxins. It was believed that corn earworm feeding on non-Bt corn would not be exposed to Vip3A and thus maintain their susceptibility to it. That would allow susceptible corn earworm to persist and multiply in greater abundance than resistant corn earworm. The thinking is that this strategy prevents or slows the buildup of resistance in a corn earworm population.

However, Fritz's team found that non-Bt corn planted within four rows of Bt corn expresses some level of Bt toxins, including Vip3A. This is likely due to wind pollination that causes Bt pollen to land on non-Bt corn. As they grow, some non-Bt kernels are "contaminated" and express Vip3A toxin. The team's results suggest that inter-planting non-Bt corn with Bt corn to prevent resistance, sometimes called "seed-blended refuge" may in fact expose caterpillars to low levels of Vip3A and hasten the emergence of Vip3A resistance.

Fritz's work indicates that true resistance prevention might require changing strategies, both for how Bt corn is planted, as well as how resistance is monitored. This study offers a genomic testing framework for monitoring the success of resistance prevention in the future.

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