# Bigger refuges needed to delay pest resistance to biotech corn

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This is an adult western corn rootworm beetle, shown here searching for pollen on corn silk. Credit: Tom Hlavaty

Genetically modified crops that produce insect-killing proteins from the bacterium Bacillus thuringiensis (Bt) have reduced reliance on insecticide sprays since 1996. These proteins are lethal to some devastating crop pests, but do not harm most other creatures including humans.

Yet, just as insects become resistant to conventional insecticides, they also can evolve resistance to the Bt proteins in transgenic crops.

To delay pest resistance to Bt proteins, the U.S. Environmental Protection Agency, or EPA, has required farmers to plant "refuges" of crops that do not produce Bt proteins near Bt crops. Refuges are planted with standard, non-Bt crops that pests can eat without ingesting Bt toxins.

Planting refuges promotes survival of susceptible pests. If susceptible pests greatly outnumber resistant pests, resistant individuals are unlikely to mate with each other and produce resistant offspring.

But how much refuge acreage is enough?

In an article appearing in the June 2012 issue of the *Journal of Economic Entomology*, authors Bruce Tabashnik from the University of Arizona and Fred Gould from North Carolina State University conclude the EPA should more than double the percentage of corn acres planted to mandated refuges to delay insect resistance, encourage integrated pest management, or IPM, and promote more sustainable crop protection.

To slow resistance in the western corn rootworm (*Diabrotica virgifera virgifera*), a beetle that is one of the most economically important crop pests in the U.S., the EPA currently requires 20 percent of the total acreage being set aside as refuges for corn producing one Bt protein (Cry3Bb1), and a 5 percent refuge portion for corn that simultaneously produces two different Bt proteins.

However, the authors note that this adaptable pest has rapidly evolved resistance to Cry3Bb1 in some areas of the U.S. Corn Belt. For Bt corn to remain effective against rootworms, they recommend increasing refuge requirements to 50 percent for corn producing one Bt protein and 20 percent for corn producing two Bt proteins.

"Corn rootworms can cost U.S. farmers close to $1 billion each year. Bt corn has helped to reduce these costs and to decrease insecticide sprays, but evolution of resistance by the pests can diminish or even eliminate these benefits," said Tabashnik, who heads the department of entomology in the UA College of Agriculture and Life Sciences.

"To delay pest resistance and sustain the benefits of Bt corn, we recommend planting more corn that does not produce Bt toxins active against rootworms. This refuge strategy allows the susceptible pests to survive and has worked to slow resistance of other pests to Bt crops."

"Most of the corn seed currently produced in the U.S. is transgenic and includes genes for insect control," said Gould. "Enlarging refuges will require more seed without corn rootworm control genes. This shift in production will take time, so this process should begin immediately."

In addition to increased refuge sizes, the authors write that the best way to postpone resistance is to use IPM, in which Bt corn is combined with other control tactics such as crop rotation and judicious use of insecticide sprays.

"We advocate greater use of integrated pest management, which is a common sense approach based on the best available combination of tactics," Tabashnik said. "The goals are to limit pest damage, maximize farmer profits and preserve environmental quality. Maintaining the effectiveness of Bt toxins can help us achieve these goals."

"We're seeing the early signs of rootworm resistance to Bt corn, which fit predictions from evolutionary theory and experiments in the lab and greenhouse," he added.

The paper indicates rootworm resistance to Bt corn was first detected in 2009 in Iowa; six years after sales of rootworm-killing Bt corn began in the U.S. and only one year after this type of Bt corn was first planted on more than 25 million acres.

According to Tabashnik, Cry3Bb1 is effective enough to be economically useful, but not effective enough to meet the so-called high dose standard, the ability to kill at least 99.99 percent of susceptible pests and also nearly all of the hybrid pests that are produced when resistant pests mate with susceptible pests.

"When Bt crops meet the high dose standard, resistant individuals are extremely rare, and smaller refuges work fine, because you might have one resistant insect in a million. In this case, a 20 percent refuge provides enough susceptible individuals to dilute that rare resistance."

But plants with Cry3Bb1 allow survival of 1 to 6 percent of pests, which is expected to quickly select for resistance.

"A single farm can have millions of these beetles," Tabashnik explained. "If 1 to 6 percent survive on Bt corn, you have tens of thousands of potentially resistant insects and the refuge needs to be much bigger."

Tabashnik's research has shown that in Arizona, Bt cotton meets the high dose standard against pink bollworm and the small refuge strategy has prevented resistance for more than a decade.

On the other hand, Tabashnik pointed to a case in Puerto Rico, where adequate refuges were not planted. Within a few years, the pests evolved resistance and devoured the Bt corn plants. The biotechnology companies voluntary stopped selling Bt corn seed there, but five years later, the insects remain resistant to the toxin.

Although biotech companies recently starting selling some varieties of Bt corn that produce combinations of Bt toxins, Tabashnik said, the resistance to one toxin still raises concerns.

"You can think of the multi-Bt toxin approach as a pyramid: The base has to be stable. If one of your building blocks, which is susceptibility to

Cry3Bb1, is crumbling, you have a problem. Resistance to any one toxin jeopardizes the effectiveness of the whole system."

"We're at a tipping point where decisive action can provide long-term benefits and avoid loss of an environmentally friendly tool for pest control."

Provided by University of Arizona