Bt Corn Not a Threat to Monarchs

Last summer, when entomologist Mark K. Sears was researching whether *Bt* corn posed a risk to monarch butterflies, he noticed that two monarchs had hit his car's windshield as he drove to test fields around Ontario, Canada.

"That's probably more monarchs than were lost that day because of *Bt* corn, according to findings in our studies," says Sears, with the Department of Environmental Biology at the University of Guelph.

Sears is part of a group of scientists coordinated and partially funded by the Agricultural Research Service who have spent 2 years investigating whether *Bt* corn is a threat to monarch butterflies.

Bt corn contains genes from the bacterium *Bacillus thuringiensis* so that the plant will produce proteins to protect itself against insect pests such as the European corn borer. This reduces the amount of insecticide farmers need to apply. Since *Bt* corn was introduced to the marketplace, use of the insecticides recommended for European corn borer control has decreased from 6 million acre treatments to slightly over 4 million in 1999, a drop of about one-third, according to the Environmental Protection Agency.

Although *Bt* corn was approved in 1995, new concern about possible risk was raised when a note published in a May 1999 issue of *Nature* suggested that *Bt* corn could harm monarch butterflies when the caterpillars were given no choice but to feed on milkweed leaves heavily coated with *Bt* corn pollen.

Monarch caterpillars feed exclusively on leaves of milkweed plants, which grow in and around cornfields. But during the 1 to 2 weeks a year that corn pollen is shed, it can be blown onto the milkweed leaves.

In response, ARS organized a series of workshops that encouraged butterfly biologists, corn researchers, ecologists, entomologists, and other experts to work together to determine whether a risk actually existed. During a February 2000 workshop, a group of scientists from government, universities, industry, and environmental groups prioritized specific research needs. The idea was to ensure that all the most important questions were covered. In addition to funds already assigned, ARS contributed $100,000 to a grant pool, which was then matched by industry, to fund the research.

The Real Risk to Monarchs

Monarch butterflies are popular insects. Children and adults all over the country help track this butterfly's annual migration across North America. They are not currently an endangered or threatened species. Habitat destruction; mowing of highway right-of-ways, ditches, and pastures, which destroys milkweed; collisions with vehicles; and insecticides all play a part in reducing monarch populations. But the most common fate for monarch caterpillars is being eaten by another insect. Fewer than 10 percent of monarch caterpillars make it to adulthood each year.

The collaborations established at the workshops continued throughout the research process. For example, the group agreed early on to use similar experimental designs and methods, such as how to handle the pollen. This ensured that data collected by different scientists would be compatible.

"Being able to pool data gave us much larger, more reliable sample sizes, so we could develop the best scientific answers to the question of risk," says ARS entomologist Richard L. Hellmich, with the Corn Insects and Crop Genetics Research Unit, Ames, Iowa. Hellmich was the lead ARS scientist on the project.

Cooperation even extended to how the research was published. All the researchers funded from the special grant pool got together and divided the data into logical sections and agreed to submit all manuscripts together to a single scientific journal. Publishing the exposure, toxicity, and risk-analysis studies at one time in one journal provided the most complete picture possible of whether any risk actually existed.

Two Big Questions

To determine whether the concern about *Bt* corn was valid, two major questions needed to be scientifically answered: "Exactly how much *Bt* pollen does it take to cause toxic effects in monarch caterpillars, and what are the chances caterpillars will encounter that dose under natural conditions?" Hellmich says.

PEGGY GREB (K9649-1)

Entomologist Rich Hellmich (right) and technician Randy Ritland collect milkweed leaves near pollinating corn.

PEGGY GREB (K9645-1)

Student aid Stacy Van Loon releases a monarch butterfly into a breeding cage. The butterflies consume artificial nectar from the flower-shaped feeder.

PEGGY GREB (K9644-1)

A newly emerged monarch butterfly feeds on an artificial feeder.

Toxic Anthers

When Hellmich and his colleagues began their *Bt* corn/monarch butterfly laboratory studies, they encountered a much higher level of *Bt* protein in the pollen than expected. They checked several possible explanations, including inspecting their methods for pollen collecting and preparation.

"We found that some of the pollen we were using in our tests was contaminated by ground-up or fractured anthers," Hellmich says. Anthers—the organs at the end of plant stamens that produce pollen—have a much higher level of *Bt* protein than does pollen itself. "But simply passing the pollen through a fine screen before using it removed the anthers," he adds.

The problem of anther contamination may explain the toxic results in some earlier studies, Hellmich points out. But that left the question of whether caterpillars might eat the high-*Bt*-containing anthers under natural conditions.

"Anthers have commonly been found on milkweed leaves within cornfields, but none of them were fractured. Fractured anthers appear to be an artifact of pollen processing in the laboratory," Hellmich says.

Then they looked at caterpillar-anther interaction. "Our preliminary results show that small larvae avoid anthers. With the size difference, it would be like a person trying to eat a city bus," Hellmich points out. "Wind and rain also readily dislodge anthers from milkweed leaves, making it less likely that caterpillars will encounter anthers."

First, the scientists assessed the feeding behavior of monarch larvae—caterpillars—to see whether *Bt's* presence on milkweed leaves influenced their weight and survival. Pollen from six *Bt* corn types—BT11, MON810, CBH351, DBT418, TC1507, and BT176—was tested along with no-pollen and non-*Bt*-corn-pollen controls.

"We looked at larval weight and larval survival and found it took large amounts of pollen to get any statistically significant effect," Hellmich says.

Eating leaves with pollen coating densities below 1,000 grains/cm^2 had no effect on caterpillars' weight or survival rate. Above 1,000 grains/cm^2, caterpillars were smaller than those from the control treatments, but their survival rate was no different from that of controls.

One type of *Bt* corn—BT176—did show some harm to larvae at pollen levels of 10 grains/cm^2. BT176 was the earliest *Bt* corn developed and was quickly supplanted by other types. It has never been planted on more than 2 percent of all corn acres and is likely to be completely phased out by 2003.

Once the scientists knew how much *Bt* corn pollen it took before monarch caterpillars showed any ill effect, the second question was how often are they exposed to pollen levels above 1,000 grains/cm^2 under natural conditions?

To find out, the researchers established corn pollen density and distribution patterns on milkweed leaves near cornfields. Hellmich's team set up lines of collecting devices at seven different fields, from the edge of the field to 600 feet away, in all four compass directions.

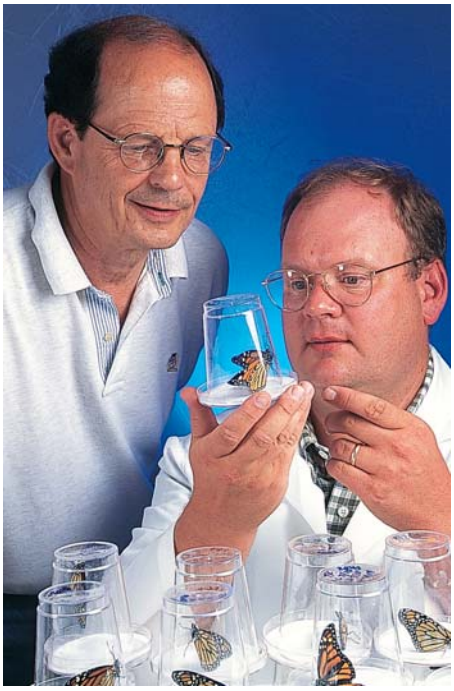
The researchers measured pollen deposition three ways. They put out tubes holding cuttings of milkweed stems with two leaves, whole potted milkweed plants, and microscope slides coated with glycerin. Sampling lasted about 10 days—covering peak pollen production periods.

"We found that, on average, less than 30 percent of the pollen that corn produces ends up on milkweed leaves, even when conditions are perfect, and most of that gets deposited on milkweed within the cornfield," Hellmich says of his field studies in Iowa.

PEGGY GREB (K9642-1)

A large monarch caterpillar feeds on a common milkweed plant.

PEGGY GREB (K9647-1)



Entomologist Les Lewis (left) and technician Keith Bidne observe a group of newly emerged monarch butterflies.

In Ontario, Sears conducted similar field studies of pollen deposition and found the same pattern. Other pollen studies by University of Maryland and University of Nebraska researchers also confirmed the pattern and extent of pollen distribution.

Data pooled from Iowa, Nebraska, Maryland, and Ontario showed that the average *Bt* corn pollen density on milkweed leaves inside cornfields was about 170 grains/cm^2, and it rarely went above 600 grains/cm^2.

"These pollen densities mean monarch caterpillars inside cornfields will encounter pollen levels exceeding 1,000 grains/cm^2—the lowest observable effect dose—less than 1 percent of the time," Hellmich points out.

Many factors contribute to keeping pollen density low. Corn pollen is relatively heavy, so it doesn't blow far; higher milkweed leaves tend to shelter lower leaves; and rain washes pollen off of milkweed leaves easily, Hellmich says.

Given the low toxicity of *Bt* corn pollen and the low rates of exposure, the effect of *Bt* corn pollen from common commercial hybrids on monarch butterfly populations is negligible. "Furthermore, you need to compare the potential for risk to monarchs from *Bt* corn with the alternative, which is chemical insecticide use," Hellmich says.—By **J. Kim Kaplan,** ARS.

This research is part of Crop Protection and Quarantine, an ARS National Program (#304) described on the World Wide Web at http://www.nps.ars.usda.gov.

Richard L. Hellmich is in the USDA-ARS Corn Insects and Crop Genetics Research Unit, Iowa State University, Ames, IA; phone (515) 294-4509, fax (515) 294-2265, e-mail rlhellmi@iastate.edu. ◆