Monarch Butterflies and Bt Corn

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A correspondence in the scientific journal *Nature* was published in May 1999 that suggested pollen from genetically engineered corn (Bt corn) could be hazardous to the larvae of the monarch butterfly, *Danaus plexippus* (Losey et al. 1999). During a small laboratory feeding trial young monarch larvae that fed on milkweed, *Asclepias curassavica*, leaves coated with pollen from a Bt corn hybrid grew slower and had a higher mortality rate than larvae feeding on leaves coated with pollen free of Bt. These preliminary findings were criticized by the scientific community because of the way they were conducted and largely misrepresented by mainstream media before the potential impact of Bt corn pollen on monarch populations could be adequately assessed. Such reports heightened public awareness, increased scrutiny of the potential environmental impact of transgenic plants, and intensified one of the most controversial and polarizing issues to face agricultural scientists in recent memory. In response, several scientists conducted detailed studies to evaluate whether Bt corn pollen posed a risk to monarch butterflies.

Question: How are monarch butterflies associated with corn fields?

Answer: Plants in the milkweed family (Asclepiadaceae) are the only food source of monarch butterfly larvae. Common milkweed, *A. syriaca*, occurs throughout the U.S. Corn Belt, particularly in disturbed habitats like fields and roadsides, and usually is considered a noxious weed by growers. During corn pollen shed, which generally occurs 7–10 days in July, corn pollen can fall on the leaves of milkweed plants when they occur in or near cornfields. Any monarch larvae that feed on these plants are potentially exposed to corn pollen.

Q: What is Bt corn and why was it developed?

A: Bt corn has been enhanced through biotechnology to defend itself against insect pests. These plants produce an insecticidal protein derived from the bacterium *Bacillus thuringiensis* that is used to control the larvae of a small moth called the European corn borer. These larvae bore into the stalks of corn, which reduces yield and grain quality. Corn borers are difficult to control because after the larvae bore into stalks they cannot be controlled with traditional insecticides. Losses in the U.S. resulting from corn borer damage and control costs are more than a billion dollars a year. Thus corn growers were excited when a genetically engineered corn plant was developed that produced its own insecticide and was resistant to European corn borers and other lepidopteran (caterpillar) pests. Commercially available Bt corn hybrids produce one of two types of lepidopteran-active crystal (cry) proteins called Cry1Ab and Cry1F. Much is known about the safety of Bt corn because *Bacillus thuringienis* insecticides have been used safely for over 40 years. Plus Bt insecticides are popular with organic farmers because they are naturally occurring organisms found worldwide in the soil.

Q: How was this issue investigated?

A: After the *Nature* correspondence a large, informal group of interested parties came together in workshops sponsored by the Agricultural Research Service (ARS) of the United States Department of Agriculture to discuss questions about monarch butterflies and Bt corn pollen. This group included scientists from U.S. and Canadian Universities, ARS, industry and environmental organizations. Two major questions emerged from these workshops related to effect and exposure:

- How much Bt protein is produced in Bt corn pollen and how much does it take to affect monarch larvae?
- What is the probability that monarch larvae are exposed to hazardous amounts of Bt protein?

In December 1999, ARS and the Agricultural Biotechnology Stewardship Technical Committee (ABSTC) each contributed $100,000 to a grant pool to fund research. ABSTC is a consortium of agricultural biotechnology companies and associations that at the time included Aventis CropScience, American Crop Protection Association, Biotechnology Industry Organization, Dow AgroSciences, Monsanto, Novartis Seeds, and Pioneer Hi-Bred International.

In April 2000, there was a call for proposals based on questions outlined in the workshops, and then the following month funds were allocated to scientists with successful proposals. Most of the research was conducted over the summers of 2000 and 2001. Overseeing these studies was a steering committee consisting of Adrianna Hewings, Midwest Area Director, ARS–USDA; Eldon Ortman, Purdue University; Eric Sachs, Monsanto; Mark Scriber, Michigan State University; and Margaret Mellon, Union of Concerned Scientists.

Q: Is Bt toxic to monarch larvae?

A: There are a number of different types of Bt corn varieties, each with a characteristic protein and level of protein expression. Commercially available varieties in the U.S. that are active against lepidopteran species include YieldGard hybrids, which produce Cry1Ab protein, and Herculex hybrids, which produce Cry1F protein.

Laboratory experiments with pure Cry toxins mixed with artificial diets determined that Cry1Ab toxin was harmful to monarch larvae, but Cry1F toxin was not (Hellmich et al. 2001). Other laboratory experiments with Bt corn pollen, however, showed that when small larvae were fed high doses of pollen (more than 1,000 pollen grains/cm^2 of milkweed leaf surface) for 4 or 5 days there were no observed effects in terms of weight gain or mortality (Hellmich et al. 2001). Field studies corroborated the laboratory findings, as no acute effects were observed when monarch larvae fed on milkweed leaves dusted with natural levels of pollen from YieldGard or Herculex corn hybrids (Stanley-Horn et al. 2001).

The reason pollen from these Bt hybrids did not affect the monarch caterpillars was because Bt protein expression in the pollen is low. A Bt corn called 176 was an exception. An adverse effect on monarch larvae was seen at levels of pollen commonly encountered in corn fields during pollen shed (Stanley-Horn et al. 2001, Zangerl et al. 2001). This was the first type of Bt corn that

was developed and it expressed high amounts of Cry1Ab protein in the pollen. This type of Bt corn is no longer sold in the U.S.

Q: Are monarch larvae exposed to Bt toxins?

A: Studies were conducted to address the exposure question that included looking at monarch use of milkweed in agricultural and nonagricultural habitats, monarch larvae overlap with corn pollen shed, and patterns of corn pollen deposition. Milkweed densities usually are higher in nonagricultural areas, particularly along field edges, compared with corn and soybean fields. Yet, a high percentage of monarch larvae are found in and around corn fields due to the prevalence of corn in some areas (Oberhauser et al. 2001). For example, estimates based on field and nonagricultural surveys suggest more than half of the monarchs in Iowa (land area: 89 percent agriculture, 36 percent corn) originate from corn fields (Sears et al. 2001).

The first generation of monarch butterflies lay eggs primarily in May so there is no overlap of pollen shed with this generation. Second generation monarch butterflies, however, lay eggs in July and August, which overlaps to some degree with corn pollination, depending on latitude. Phenology studies of monarch larvae and corn pollination indicate that there is a greater temporal overlap between monarch larvae and corn pollen shed in the northern than the southern part of the monarch summer breeding range, because of earlier pollen shed in the south. Percentage overlap ranges from about 5–10 in southern Iowa to about 50-60 in southern Minnesota (Oberhauser et al. 2001; Dively et al. 2004).

A third set of studies related to exposure involved determining the density of corn pollen on milkweed plants inside and outside of corn fields during pollination. Results from several studies showed that pollen density was highest (avg. 171 grains/cm2) inside the cornfield and was progressively lower from the edge of the field outward, falling to 14 grains/cm2 at 2 m (Pleasants et al. 2001). Monarch larvae do not encounter high pollen densities outside of cornfields and rarely do they encounter densities above 1000 pollen grains/cm2 inside the field.

Q: Is Bt corn safer than traditional insecticides?

A: Field corn is treated occasionally for European corn with chemical or microbial insecticides, especially in the Western Corn Belt where another corn pest called the Southwestern corn borer occurs. But sweet corn is commonly treated 10–15 times per season. A field test conducted by scientists from the University of Maryland showed that when sweet corn fields were sprayed with λ-cyhalothrin, a common broad-spectrum insecticide, that nearly all monarch larvae on milkweed plants inside the field were killed. Also, survival of larvae on plants 3 meters outside of the field greatly decreased due to drift of the insecticide spray. Thus Bt corn is safer than traditional insecticides.

Q: What is the final assessment of risk; are monarch populations threatened by Bt corn?

A: In the formal risk assessment of Bt corn on monarch populations, scientists carefully considered results from the effect and exposure studies. They concluded the risks were negligible because exposure of monarch caterpillars to Bt pollen is low and, at least for the commercially available Bt corn hybrids, the toxicity of Bt pollen also is low (Sears et al., 2001). To leave no stone unturned, follow-up experiments were conducted to assess the risks of long-term exposure

to Bt pollen. Monarch larvae were exposed to Bt pollen on milkweed plants in corn fields during their entire development, a worse-case scenario that would affect a small percentage of larvae. In these cases larvae feeding on milkweed leaves with Bt corn pollen compared to those that fed on milkweed leaves with non-Bt pollen had increased mortality and delayed development, but a more detailed analysis of exposure determined that the risks were still small (Dively et al. 2004). The bottom line from these studies is that all commercial Bt corn hybrids have negligible effects on populations of monarch butterflies, especially when compared with traditional insecticides.

References and further reading

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