

## **ISSUES – FIGURE SET**

### **What Are the Ecological Impacts of Plant Biotechnology?**

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Green and red peppers, © B. W. Grant

#### **Figure Set 2: Bt Corn and Its Effect on Monarch Butterflies**

**Purpose:** To examine the effect of biotech crops on non-target insect species

**Teaching Approach:** pairs check

**Cognitive Skills:** (see Bloom's Taxonomy) — comprehension, analysis, synthesis

**Student Assessment:** oral presentation

#### **CITATION:**

Zycherman, D., and J. Taylor. August 2004, posting date. What Are the Ecological Impacts of Plant Biotechnology? Teaching Issues and Experiments in Ecology, Vol. 2: Issues Figure Set #1 [online]. [http://tiee.ecoed.net/vol/v2/issues/figure\\_sets/biotech/abstract.html](http://tiee.ecoed.net/vol/v2/issues/figure_sets/biotech/abstract.html)

## BACKGROUND

The focus of this Figure Set is research done at Cornell University concerning effects of Bt corn on monarch butterfly larvae. Currently, chemical insecticides are used to combat insects that damage or become lethal to crops. However, chemical insecticides often alleviate one problem while creating a new one. Potentially harmful chemicals are being released into the environment that may harm non-target species. This may occur directly through ingestion, inhalation, or absorption; or indirectly through biomagnification and subsequent ingestion or the disruption of an ecosystem which may put strain on various species. Biotechnologists have researched ways to decrease insecticide use. They found that if insecticide resistance were genetically engineered into crops, fewer insecticides would be sprayed onto crop fields. This would lessen the opportunity for some of these chemicals to harm insects, wildlife, humans, and plants.

A strain of the bacterium *Bacillus thuringiensis* (Bt) is toxic to insects through ingestion (Simmonds & Smartt 1999). This bacterium produces crystal-like proteins (Cry proteins) that selectively kill specific groups of insects. There are several strains of Bt and each have differing Cry proteins. These Cry proteins affect monarch butterfly larvae and some Cry proteins affect the varying species more than others. To create transgenic Bt plants, the specific Bt is isolated and integrated into a crop's genetic makeup. A plant genetically engineered to express the Bt toxin is resistant to specific insect devastation. For example, the European corn borer (ECB) is very destructive to corn crops. To decrease crop losses, Bt corn was developed through biotechnology and is resistant to ECB devastation. Thus, the level of insecticide treatment can be expected to decrease. Less insecticide use should result in less harm to non-target species. But what if the Bt crop is toxic to non-target species?

Researchers at Cornell University investigated the effect of Bt corn on monarch butterfly larvae. In particular, they looked at the acute toxic effects of Bt corn pollen because this corn pollen may be distributed to nearby plants and ingested by non-target species, such as the monarch butterfly (Losey, Rayor, Carter 1999). This paper was received with substantial criticism and was very controversial. Since the publication of this study, others have sought to verify or refute its implications. Additional figures are from more recent field and laboratory studies by Stanley-Horn et al. (2001) and Hellmich (2001).

### Literature Cited:

- Hellmich, R. L. 2001. Monarch larvae sensitivity to *Bacillus thuringiensis* - purified proteins and pollen. *Proceedings of the National Academy of Sciences* early edition: 1-6.
- Losey, H. E., L. S. Rayor, and M. E. Carter. 1999. Transgenic pollen harms monarch larvae. *Nature* 399: 214.
- Simmonds, N. W., and J. Smartt. 1999. *Principles of Crop Improvement*. Oxford: Blackwell Science.
- Stanley-Horn, D. E. et al. 2001. Assessing the impact of Cry1Ab-expressing corn pollen on monarch butterfly larvae in field studies. *Proceedings of the National Academy of Sciences* 98: 11931-11936.

## STUDENT INSTRUCTIONS

Work together in groups of four. Pair with one other person in the group. In each pair, one person should work on the problem while the other coaches. Choose who will have each role for the first two figures then switch roles for the two figures.

First, examine Figure 2A. In this experiment, stems of milkweed leaves were put into tubes containing water. Five three-day-old monarch larvae (instar is a stage of development) were placed on each leaf. The bar indicates variation between the five replicates.

- In Figure 2A, compare larval survival after feeding on leaves with Bt pollen with those leaves dusted with untransformed pollen or the control leaves with no pollen.
- Do you think the evidence indicates that differences in monarch larvae survival on leaves dusted with Bt pollen is due to the effects of Bt pollen?

Describe and interpret Figure 2B. Here the researchers sought to determine if there were significant differences in the numbers of larvae surviving in Bt corn fields and non-Bt corn fields in two different states, in order to analyze the toxicity of transgenic pollen on monarch larvae.

- Does this new study discredit the original study? Explain why or why not.

Figure 2C and 2D are from an experiment conducted a couple years after the first study. The vertical bars in both indicate variation between replicate larvae. Figure 2C is based on data from laboratory bioassays which investigated effects of Bt toxin on the weights of monarch butterflies. Bioassays are experiments that use living things to test the toxicity of chemicals. Figure 2D shows results of a contamination study. In this case researchers studied whether monarch larvae were affected by contaminants in the samples by comparing the varying levels of sifting of the pollen. Examine both figures.

- In Figure 2C, what were the effects of the various hybrids' pollen on the weights of monarch first instars?
- Did this vary between pollen levels tested?
- In Figure 2D, how do larvae whose diet contained beginning pollen or siftings of the contaminated pollen compare with larvae that consumed finely sifted pollen (most contaminants were removed)?
- What conclusion about the cause of the monarch larvae's reactions to the samples can you draw from this figure?
- Does this new study discredit the original study? Explain why.
- Is the overall implication of this study similar to that of Figure 2B's study?
- What investigation(s) would you propose next?

Check your answers with the other pair in your group.

## FIGURES

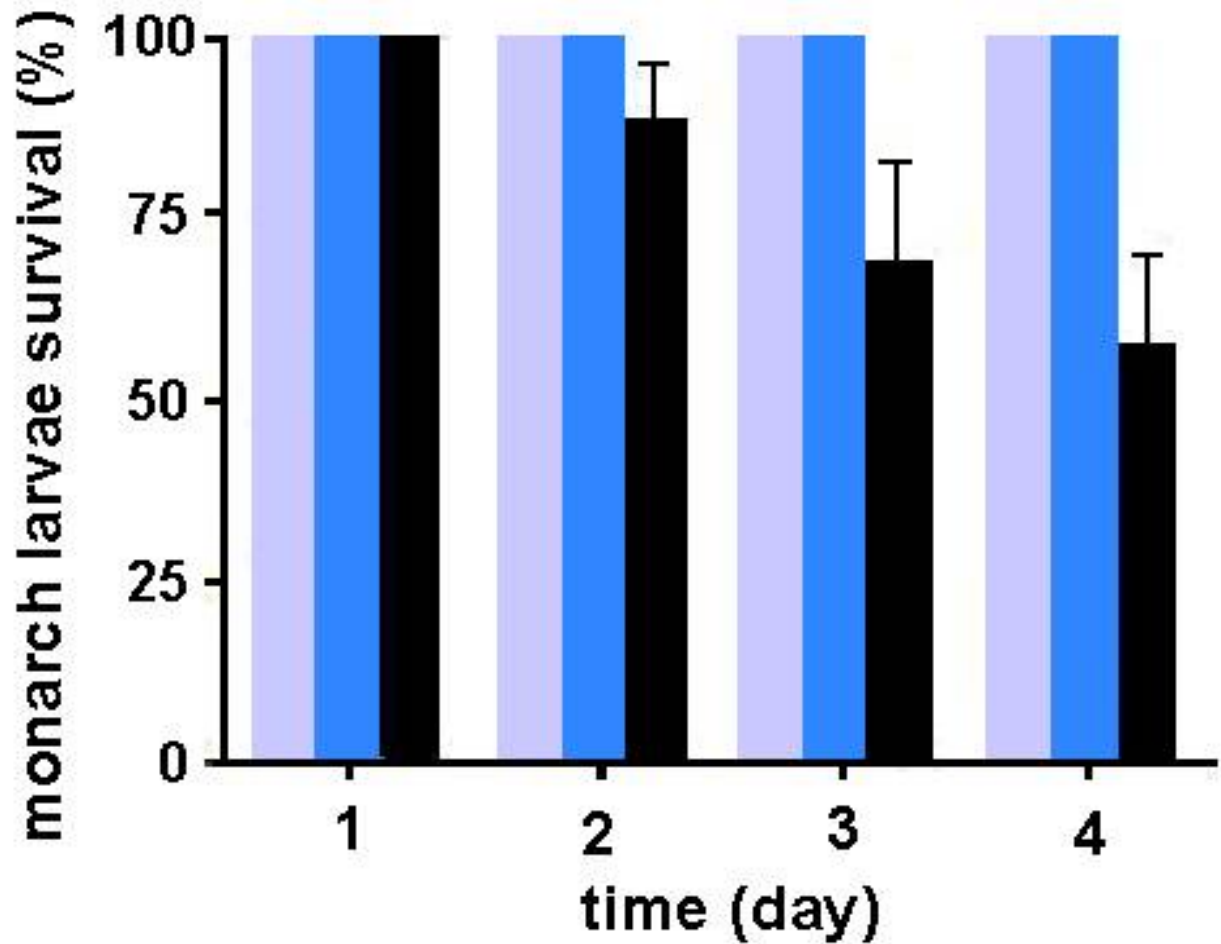


Figure 2A. The survival of second to third-instar monarch larvae was tested. Three milkweed leaf treatments were conducted: leaves with no pollen (lavender), leaves treated with untransformed corn pollen (blue), and leaves dusted with pollen from Bt corn (black). The mean survival rate is based on the proportion of larvae surviving in five replicates of each treatment (from Losey, H. E., L. S. Rayor, and M. E. Carter. 1999. Transgenic pollen harms monarch larvae. *Nature* 399: 214, © 1999 Nature Publishing Group [www.nature.com](http://www.nature.com)).

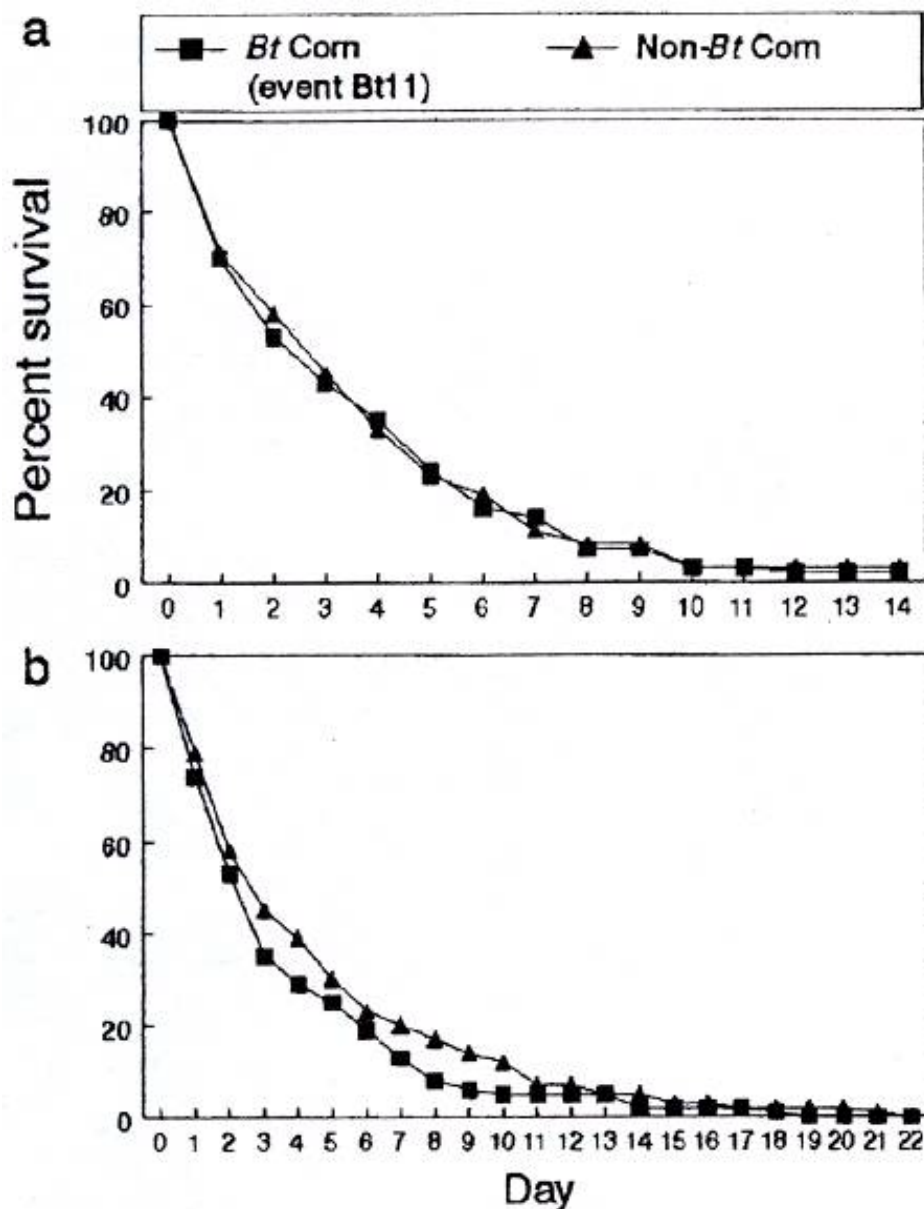


Figure 2B. Survival curves for monarch larvae placed in and near Bt and non-Bt corn fields. Survival curve (a) is based on data from Iowa and survival curve (b) is based on data from New York (from Stanley-Horn, D. E. et al. 2001. Assessing the impact of Cry1Ab-expressing corn pollen on monarch butterfly larvae in field studies. *Proceedings of the National Academy of Sciences* 98: 11931-11936, © 2001 National Academy of Sciences, U.S.A.).

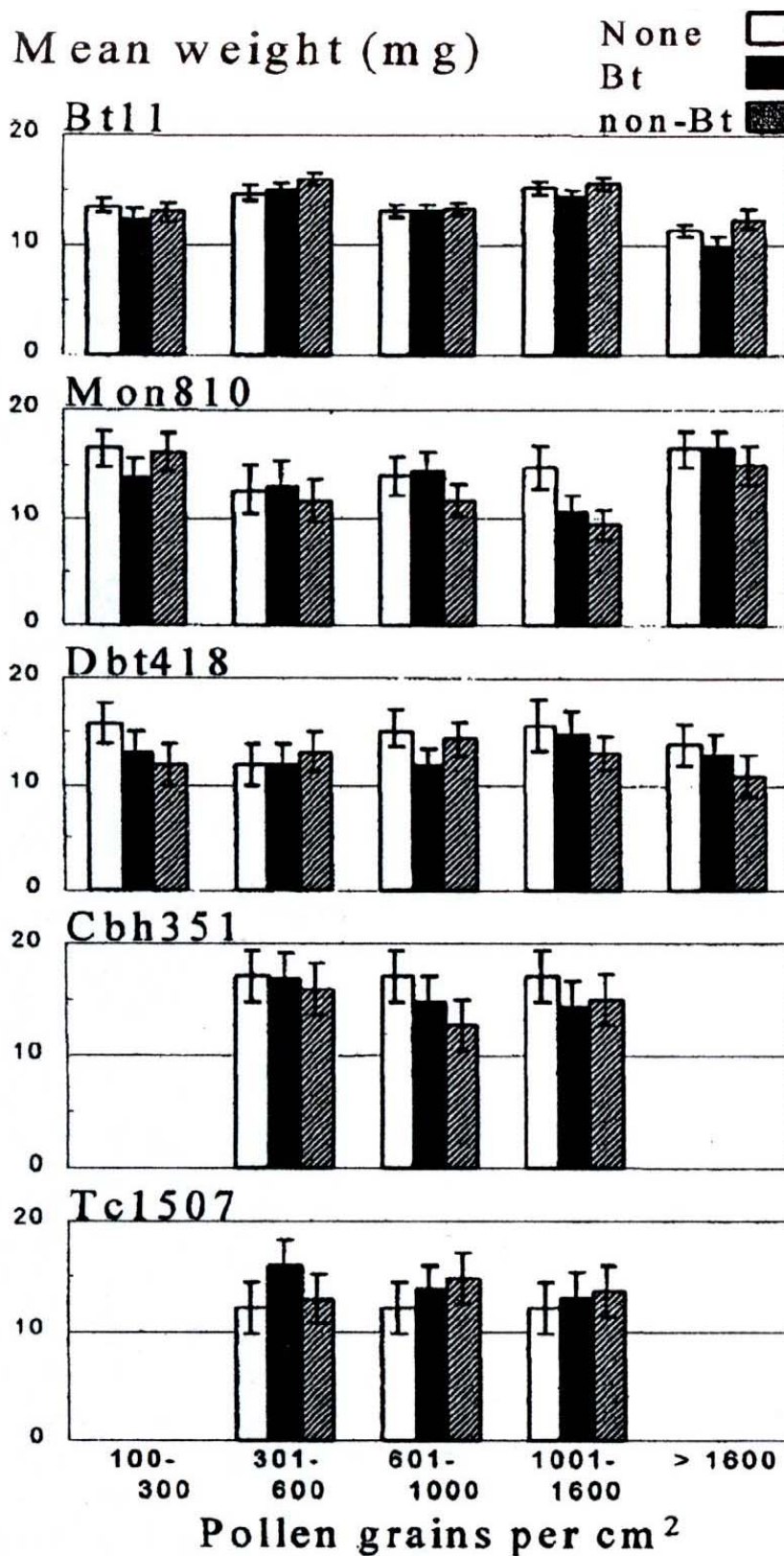


Figure 2C. Mean weight of monarch larvae after exposure to milkweed leaves with no pollen and leaves with various levels of pollen from different plant hybrids. The different hybrids tested had varying Cry proteins. The hybrids and their Cry proteins are as follows: Bt11 and Mon810 events (Cry1Ab), Dbt418 event (Cry1Ac), Cbh351 event (Cry9C), and Tc1507 event (Cry1F) hybrids, and near isolate hybrids (from Hellmich, R. L. 2001. Monarch larvae sensitivity to *Bacillus thuringiensis* - purified proteins and pollen. *Proceedings of the National Academy of Sciences* early edition: 1-6, © 2001 National Academy of Sciences, U.S.A.).

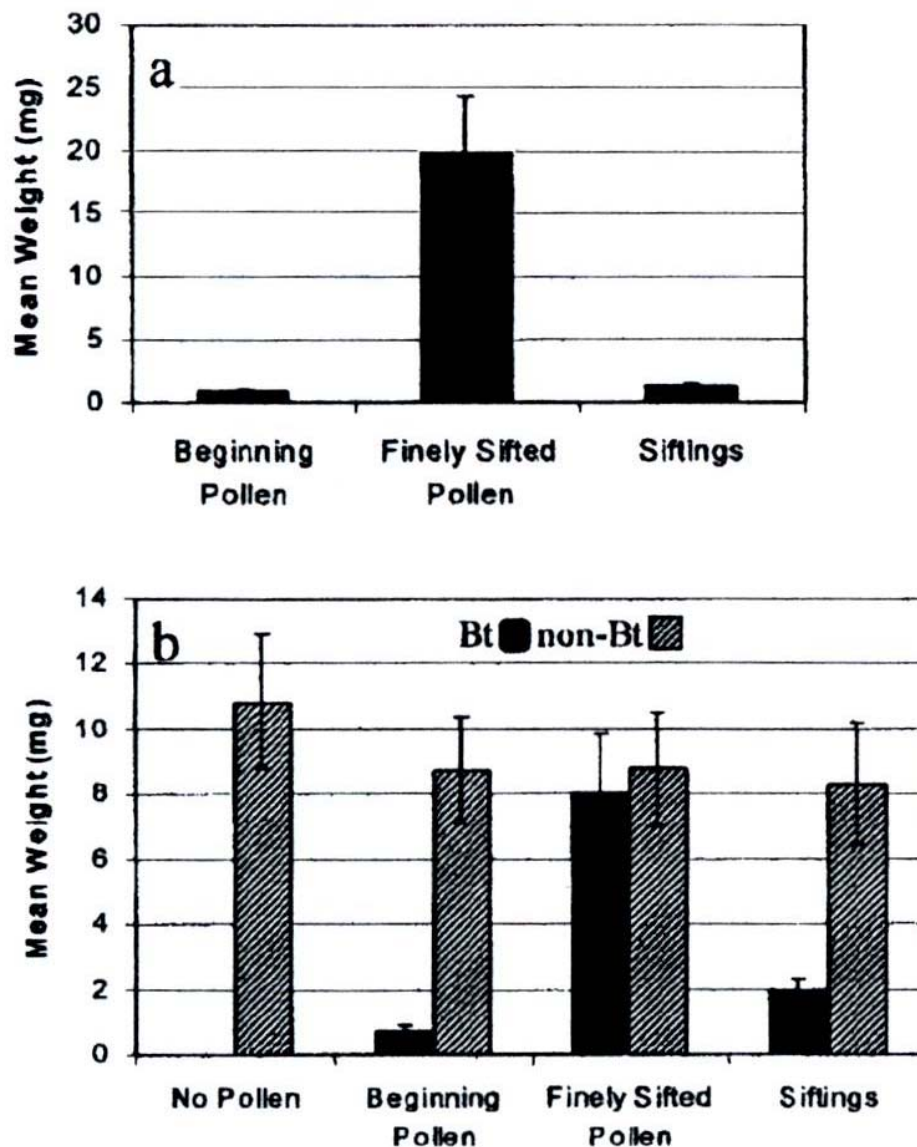


Figure 2D. These graphs depict the mean weight of monarch larvae after feeding on treated milkweed for 96 hours. Treatments included: (a) pollen from event Cbh351 (Cry9C) hybrid G8539Bt that was processed with 250- $\mu$ m sieve (beginning), pollen from same hybrid processed with 90- $\mu$ m sieve (finely sifted), and siftings remaining after the initial sample was finely sifted; and (b) no pollen, pollen from event Bt11 (Cry1Ab) hybrid N7070Bt, and pollen from hybrid N7070 (non-Bt that were processed in the same manner as pollen in a) (from Hellmich, R. L. 2001. Monarch larvae sensitivity to *Bacillus thuringiensis* - purified proteins and pollen. *Proceedings of the National Academy of Sciences* early edition: 1-6, © 2001 National Academy of Sciences, U.S.A.)

## NOTES TO FACULTY

The four figures are from experiments concerning possible impacts of Bt corn pollen on monarch butterflies. In Figure 2C, make sure students understand that Cry1Ab, Cry1Ac, Cry9C, and Cry1F are the Bt genes which produce proteins which may be toxins. Bt11, Mon810, Dbt418, Cbh351, and Tc1507 are the hybrids that contain these toxins.

Make sure to discuss the problems and benefits of laboratory experiments versus field experiments. Critics of the original 1999 study have indicated that the toxins in transgenic corn's pollen might become inactive more quickly in the field than in the laboratory. Another interesting discussion would be the bases for the various experimental designs - the specific questions the scientists were asking.

### Student Assessment:

After their pairs-check, each four-person group will prepare a short (5-10 minute oral presentation to the class. The groups will use the four figures (one, some, or all) and base their presentations on whether or not the use of the Bt corn should be banned.

An effective way to help students give more effective oral presentations is by giving them a rubric ahead of time detailing how you will judge the quality of their talks. Spend time in class discussing the rubric as well. For an explanation and an example of such a rubric see: [www.siu.edu/~deder/assess/cats/grrubi.html](http://www.siu.edu/~deder/assess/cats/grrubi.html) and [www.rickhershberger.com/bioactivesite/bio103/symposium/rubric.pdf](http://www.rickhershberger.com/bioactivesite/bio103/symposium/rubric.pdf).

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