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Authors: Tabashnik, Bruce E., and Carrière, Yves

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Scientific note

Bt transgenic crops do not have favorable effects on resistant insects

Bruce E. Tabashnik and Yves Carrière

Department of Entomology, University of Arizona, Tucson, AZ 85721, USA
brucet@ag.arizona.edu
ycarrier@ag.arizona.edu

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Abstract

Sayyed *et al.* (*Ecology Letters* (2003) 6: 167-169) hypothesized that insecticidal *Bacillus thuringiensis* (Bt) toxins produced by transgenic crops could have nutritionally favorable effects that increase the fitness of resistant insects eating such crops. This idea was based on increased pupal weight of resistant larvae of diamondback moth, *Plutella xylostella* (L.), fed leaf discs treated externally with a Bt toxin. We summarize evidence from diamondback moth and other pests showing that the Bt toxins in transgenic crops do not enhance performance of resistant insects. Aside from a few notable exceptions in which performance of resistant insects did not differ between Bt and non-Bt crops, Bt crops had adverse affects on resistant insects.

Keywords: adaptation, *Bacillus thuringiensis*, fitness, genetically modified crop, *Plutella xylostella*, resistance, genetic engineering

Abbreviation:
Bt *Bacillus thuringiensis*

Abstract

Sayyed *et al.* (*Ecology Letters* (2003) 6: 167-169) hypothesized that insecticidal *Bacillus thuringiensis* (Bt) toxins produced by transgenic crops could have nutritionally favorable effects that increase the fitness of resistant insects eating such crops. This idea was based on increased pupal weight of resistant larvae of diamondback moth, *Plutella xylostella* (L.), fed leaf discs treated externally with a Bt toxin. We summarize evidence from diamondback moth and other pests showing that the Bt toxins in transgenic crops do not enhance performance of resistant insects. Aside from a few notable exceptions in which performance of resistant insects did not differ between Bt and non-Bt crops, Bt crops had adverse affects on resistant insects.

Discussion

Transgenic crops producing insecticidal proteins of *Bacillus thuringiensis* (Bt) covered 14 million ha in 2002 (James 2002, Shelton *et al.* 2002), but evolution of resistance by insect pests could limit their efficacy (Gould 1998). Although field-evolved resistance to Bt crops has not been documented yet (Carrière *et al.* 2003, Tabashnik *et al.* 2003), many pests have been selected for resistance to Bt toxins in the laboratory, and diamondback moth (*Plutella xylostella*) populations have evolved resistance to Bt sprays in the field (Tabashnik 1994, Ferré & Van Rie 2002).

In a preliminary experiment in which diamondback moth larvae ate leaf discs in Petri dishes, Sayyed *et al.* (2003) found that treating the discs externally with Bt toxin Cry1Ac increased pupal weight of a laboratory-selected resistant strain from Malaysia (SERD4). They hypothesized that resistant diamondback moth larvae use Cry1Ac as a supplementary food protein. They also raised the question of whether Bt transgenic crops would therefore have unanticipated nutritionally favorable effects, increasing the fitness of resistant insects. As summarized below, the relevant published data show that Bt toxins in transgenic crops do not improve the performance of resistant insects.

The most directly relevant studies compared the performance of highly resistant strains of diamondback moth on Cry1Ac-producing transgenic crucifers and their untransformed non-Bt counterparts. Tests of a resistant strain from Hawaii revealed no differences between Bt and non-Bt canola (*Brassica napus*) in survival and head capsule width of five-day-old larvae, pupal weight, percentage pupation, and percentage adult emergence (Ramachandran *et al.* 1998). Likewise, experiments with a resistant strain from Florida detected no differences between Bt and non-Bt broccoli (*Brassica oleracea*) in larval survival or weight gain (Tang *et al.* 1999).

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In contrast to the two aforementioned studies, in which performance of resistant insects did not differ between Bt plants and their non-Bt counterparts, at least eight other reports show adverse effects of Bt plants on resistant insects. For example, tests of a Cry1C-resistant strain of diamondback moth (Cry1C-Sel), showed negative effects of Cry1C-producing broccoli (Zhao *et al.* 2000). Likewise, performance of resistant strains of pink bollworm (*Pectinophora gossypiella*) was generally impaired on Bt cotton compared with non-Bt cotton (Liu *et al.* 1999, 2001; Tabashnik *et al.* 2000a, Morin *et al.* 2003), with the exception of one case in which survival of resistant pink bollworm did not differ between Bt and non-Bt cotton (Tabashnik *et al.* 2002).

Whereas resistant insects successfully completed development on Bt plants in the cases described above, other studies found that Bt plants prevented completion of development by resistant insects. For example, Bt-resistant European corn borer (*Ostrinia nubilalis*) did not survive on transgenic Bt corn (Andow *et al.* 2000, Huang *et al.* 2002) and Bt-resistant Colorado potato beetle (*Leptinotarsa decemlineata*) did not survive on Bt potato (Wierenga *et al.* 1996).

The generally adverse effects of Bt plants on Bt-resistant insects are likely caused by high concentrations of Bt toxins in the transgenic plants. Other factors that could negatively affect performance of resistant insects on Bt plants include prolonged exposure to Bt toxins and interactions between plant chemistry and Bt toxins (Tabashnik *et al.* 2003). Insect strains are deemed resistant if bioassays show that they are significantly less susceptible to Bt toxins than are unselected conspecific strains (Tabashnik 1994). However, the reduction in susceptibility may not be sufficient to completely overcome the negative effects of Bt toxins in transgenic plants (Tabashnik *et al.* 2000b, 2003).

The disadvantage suffered by resistant insects on Bt plants relative to non-Bt plants is called "incomplete resistance" (Carrière & Tabashnik 2001). In contrast, fitness costs on non-Bt plants are caused by negative pleiotropic effects of genes that confer resistance (Groeters *et al.* 1994). If fitness costs occur, resistant individuals are less fit than susceptible individuals when toxin is not present. Refuges of non-Bt crops, recessive inheritance of resistance to Bt crops, low initial frequencies of alleles conferring resistance, fitness costs, and incomplete resistance may be key factors delaying resistance to Bt crops in the field (Carrière & Tabashnik 2001, Carrière *et al.* 2002, Tabashnik *et al.* 2003).

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