Biosafety Considerations for Transgenic Insecticidal Plants: Non-Target Predators and Parasitoids

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INTRODUCTION

The range of transgenic insecticidal crops grown in the United States and the potential benefits associated with those crops have been outlined in Losey et al. (this volume). As noted by Losey et al., the negative impact on non-target species can be separated into direct effects on insects that feed on living or dead corn tissue (e.g., herbivores, pollenivores, detritivores) and indirect effects on organisms that are primarily predaceous or parasitic on those direct consumers. Losey et al. focus on direct consumers, and in this entry we focus on predators and parasitoids.

BACKGROUND

Transgenic insecticidal plants produce proteins that are toxic to particular groups of insects. In addition to their toxicity to herbivorous insects feeding directly on plant tissues, the engineered plants may affect predator and parasitoid species. The proteins may be directly toxic to predators and parasitoids that supplement their diet with pollen, nectar, or tissues such as roots. Simply feeding upon prey or hosts that have consumed insecticidal plant tissue also may be detrimental to both predators and parasitoids. Finally, reductions in predator and parasitoid populations may be linked to reductions in prey and host populations associated with insecticidal plants. The few empirical studies to date bearing on these issues have reported mixed results.

Previous research showing some negative effects of microbial insecticide formulations of *Bacillus thuringiensis* on natural enemy species[1] indicates a need to assess the impact of Bt corn on populations of insect predators and parasitoids in the corn ecosystem.[2] Numerous species of insect natural enemies attack both the European corn borer, *Ostrinia nubilalis*, and the corn rootworm, *Diabrotica* spp., in North America. *O. nubilalis* natural enemies include several predatory species that tend to have relatively broad host ranges and several specific insect parasitoids.[3] Although there are no significant parasitoids of corn rootworms, there are several important soil- and litter-dwelling predators that may be affected by transgenic Bt corn including carabid and staphylinid beetles, ants, spiders, and mites.[3] In addition to preying upon corn rootworm, carabid and staphylinid beetles are also known to consume the lepidopteran corn pests: black cutworm, armyworm, fall armyworm, common stalk borer, and European corn borer.[3] Transgenic corn may affect natural enemies via three modes: 1) direct feeding on corn tissues, e.g., pollen, roots; 2) feeding on hosts that have fed on corn; and 3) through reductions in host populations.[4] Data submitted for governmental registration of transgenic crops appear to focus primarily on the first mode.[5]

INSECT PREDATORS

Several species of insect predators that attack the corn borer also feed on corn pollen (Table 1). Direct consumption of transgenic corn pollen by immature stages of three predatory species commonly found in cornfields did not affect development or survival.[6] However, increased mortality of lacewing (*Chrysoperlacarnea*) larvae, which may consume pollen, was observed when *C. carnea* larvae fed on artificial diet containing Bt toxin.[7] Predator species may consume other corn tissues as well. Many carabid species which are primarily predators, such as *Stenolophus comma* and *Clivinia impressefrons*, also feed directly on plant roots and tissues.[a] However, there

[a]Schmaedick, M., Cornell University, personal communication.

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Table 1 Interactions between natural enemies and transgenic insecticidal Bt Corn

Species	Location of Study: L = Lab; F = Field	Effect: – = negative; + = positive; 0 = no effect	Results of comparison between transgenic and non-transgenic corn	Reference
	Insect Predators			
Neuroptera: Chrysopidae				
Chrysoperla carnea	F	0	Number of adults in transgenic fields	10
	L	0	Larval development and survival on transgenic pollen	6
	L	–	Decreased larval survival on transgenic pollen or prey exposed to Bt toxins	7
	L	0	Larval development and survival on aphid prey reared on Bt corn	15
Coleoptera: Coccinellidae				
Coleomegilla maculata	F	0	Number of adults and larvae	9
	F	0, +	Increased number of adults	10
	L	0	Larval survival and development on pollen	6
Cycloneda munda	F	0	Number of adults	10
Hippodamia convergens	F	0	Number of adults	10
Hemiptera: Anthocoridae				
Orius insidiosus	F	0	Number of adults and nymphs	9
	F	–,+	Number of adults	10
	L	0	Nymphal survival and development on pollen	6
Orius majusculus	L	0	Nymphal survival and development on thrips prey reared on Bt corn	8
	Insect Parasitoids			
Hymenoptera: Braconidae				
Macrocentris cingulum (formerly *M. grandii*)	F	–	30 to 60% reduction in adults in transgenic fields	10
	F	0	Parasitism of larval hosts on non-transgenic plants within transgenic plots	9
Hymenoptera: Ichneumonidae				
Erioborus terebrans	F	0	Parasitism of larval hosts on non-transgenic plants within transgenic plots	10

(Adapted from Ref. 2)

are no data bearing on the effects of Bt corn tissues on these organisms.

There is also little data on indirect consumption of Bt toxins through prey or hosts that have fed on Bt corn. Lacewing larvae that preyed upon corn borers or other lepidopteran larvae that had fed on transgenic corn show increased mortality,[7] but similar developmental times and survival rates were observed when the predator *Orius majusculus* was fed a thrips species that had been reared on either Bt or non-Bt corn.[8]

Negative effects on invertebrate predators have not been documented in the field (Table 1); sampling from transgenic and non-transgenic cornfields has detected no differences in predator abundance.[9,10] In one field study, higher numbers of predators were observed in Bt cornfields (Table 1). However, in a two-year field study, abundance of the parasitoid species *Macrocentriscingulum* (previously *Macrocentrisgrandii*), specific to corn borer larvae, was lower in Bt cornfields in Iowa[10] (Table 1). This reduction is expected because of significant reductions of larval hosts in Bt corn. The abundance of a second parasitoid species, *Erioborusterrebrans*, may also decline in transgenic fields due to the lack of corn borer hosts, although a field study reported no effects of transgenic corn on *E. terebrans* parasitism.[9] In Orr & Landis,[9] relatively small non-transgenic plots, were planted within larger transgenic plots, and *O. nubilalis* larval hosts were parasitized in these non-transgenic plants. Effects of Bt corn on *E. terebrans* parasitism may only be detectable in field studies conducted on a larger scale.

The potential trophic-level effects of Bt corn on vertebrate predators also should be considered in an ecological assessment of this biotechnology because bats and birds are known to prey on larvae and adults of several lepidopteran corn pests. Feeding Bt toxin directly to bobwhite quail for 14 days showed no effect on the quail.[5] We are not aware of any studies that have considered the indirect effects on bird populations resulting from declines in *O. nubilalis* densities following use of transgenic corn. However, if lepidoptera and their predators and parasitoids are significantly reduced in Bt cornfields and adjacent margins, we might expect the insect prey available for birds, rodents, and amphibians to decrease (see Ref. 11 for a simulation of the potential effects of herbicide-tolerant crops on seed-eating birds).

Long-term field studies are needed to determine if the widespread planting of transgenic corn creates an ''ecological desert'' with relatively few hosts for natural enemies. This type of ecological pattern has been observed following the overuse of insecticides or regional planting of highly resistant crop varieties.[12] The interactions among natural enemy and pest populations will likely occur within a mosaic of transgenic and non-transgenic cornfields, due to the current requirement for non-transgenic corn refugia to maintain susceptible corn borer populations. If corn borer densities are significantly suppressed by the use of transgenic corn, it might follow that significant reductions in natural enemy densities will occur, which may influence the rate of development of resistant pest populations.[13] Natural enemies currently cause substantial levels of mortality of the corn borer.[14] If this level of mortality were reduced and corn borer populations developed resistance, the result could be higher densities of the corn borer. Thus, negative impacts on natural enemies raise the possibility that overuse of transgenic corn could lead to the types of resurgence and secondary pest outbreaks that are associated with misuse of synthetic broad-spectrum insecticides.

CONCLUSIONS AND RECOMMENDATIONS—CONSIDERATIONS OF THE RISKS AND BENEFITS OF Bt CORN

Clearly more data are needed on the potential impact of Bt*k* and Bt*t* corn on predators and parasitoids. Studies on direct consumption of corn tissues are the simplest to carry out, but impacts mediated through the consumption of toxic prey or reductions in prey densities may have equal or greater importance in the field. Predicting the impact of future transgenic crops is difficult based on current studies because virtually all available data regarding impacts on predators come from Bt*k* corn, which targets butterflies and moths (lepidoptera), essentially none of which are predaceous. Impacts seem more likely in Bt*t* corn since the toxin affects beetles, the largest and most important group of predators. The greater risk to predators associated with Bt*t* corn highlights the need for a functional approach to assessment of non-target impacts. Important aspects of a functional assessment of predator impact would include field-level measures of predation rate and pest population suppression. Understanding the interaction between biological control and biotechnology will greatly facilitate the integration of these two important pest management strategies and increase the probability of avoiding the problems associated with the rapid adoption of pesticides.

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