Commentary

Bt corn pollen impacts on nontarget Lepidoptera: Assessment of effects in nature

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The demonstrations by Losey *et al.* (1) and Hansen and Obrycki (www.ent.iastate.edu/entsoc/nch 99/prog/abs/D81.html) that milkweed leaves dusted with heavy concentrations of Bt corn pollen are toxic to Monarch butterfly larvae (*Danaus plexippus*) feeding on them were consistent with the known toxicity of Bt endotoxin to Lepidoptera in general and the expression of Bt endotoxins in the pollen of the strains of corn they studied. Much speculation and some investigations followed, concerning the extent to which the poisoning of Monarch butterflies and other nontarget Lepidoptera might be significant contributors to the mortality of these insects in nature. For example, Shelton and Roush (2) were critical of the two earlier findings, but did not provide any data from nature, despite the fact that Losey *et al.* (1), in the original report, stated "it would be inappropriate to draw any conclusions about the risk to Monarch populations in the field based solely on these initial results."

In a recent issue of PNAS, Wraight *et al.* (3) reported their experiments with populations of black swallowtail larvae (*Papilio polyxenes*) under field conditions. The food plants were located at varying distances from plantings of Bt corn; the authors found no effects on the mortality of the larvae. These results demonstrated that Bt corn pollen from this corn strain is not toxic to this species of butterfly at levels observed in the field no matter how close the larval food plants were to the pollen-shedding corn plants. It has not been demonstrated, however, that Monarch butterflies and black swallowtails are equally susceptible to Bt endotoxins. Further, the pollen of the corn strain 176 used by Hansen and Obrycki (www.ent.iastate.edu/entsoc/nch 99/prog/abs/D81.html) in their experiments with Monarch butterflies was demonstrated by Wraight *et al.* (3) to be lethal to black swallowtail larvae in the laboratory, whereas the pollen of the strain they used in their field experiments, with 1/40 of the Bt endotoxin level of strain 176, was not. Studies of the effects of corn strain 176 pollen on both black swallowtails and Monarch butterflies in the field are underway in the summer of 2000. For their original report, Losey *et al.* (1) used still a different corn strain, N4640. At any event, the level of Bt endotoxin in the pollen of the particular corn strain, as expected, has a direct effect on the survival of black swallowtail larvae in the laboratory and presumably on the larvae of other butterfly species as well. It has not been demonstrated whether different species of butterflies have varying levels of tolerance to Bt toxin, but they probably do, as demonstrated with other toxins.

Taking the overall picture into account, the effect on the survival of butterfly populations of Bt corn pollen dusting their larval food plants appears to be relatively insignificant compared with other factors. For example, the high productivity of U.S. agriculture is made possible by the application of insecticides, herbicides, and fungicides. Despite the yearly application of about 115 million kilograms of pesticides to control insect pests, other plant pathogens, and weeds on corn, these pests continue to reduce potential corn yields by nearly one-third (4). Consequently, corn receives more pesticide treatments than any other U.S. crop. If untreated, corn rootworm can reduce corn yields by 45% and the European corn borer by as much as 20%. The corn rootworm can be controlled with insecticides by rotating corn with non-corn crops, or by newly developed genetically modified strains of corn that have not yet reached the market. The corn borer, however, is a difficult pest to control with contact insecticides, because once the larvae have burrowed into the corn stalks, they are impossible to kill by conventional spraying techniques (5), the basic reason that Bt corn has so rapidly become popular in the U.S. and to a limited extent elsewhere. Using Bt corn makes it possible for farmers to avoid the critical timing of the insecticide applications that is necessary to control corn borers (5).

In evaluating the use of Bt corn and its possible environmental damage, it is important to take into account the serious public health and environmental damage caused by the use of pesticides in U.S. agriculture generally. Human pesticide poisonings are a major health concern, with a reported 110,000 nonfatal pesticide poisonings reported each year (6), together with an estimated 10,000 cases of cancer and numerous other public health problems (7). Although 97–99% of the foods sampled in supermarkets in the U.S. have acceptable or tolerable pesticide residue levels that for the most part do not constitute health hazards, approximately 35% of such foods do have detectable pesticide residues (7), a condition that most of us would wish to avoid. In addition to the demonstrated and potential health problems associated with their use, pesticides cause widespread and serious environmental effects. An estimated 70 million birds are killed each year in the U.S. alone as a result of pesticide use (7), and billions of insects, beneficial and harmful, are also killed. These include incalculable numbers of insects that are vital to our fruit and vegetable pollination, useful biological control agents, and many others. It has been estimated that such environmental losses cost the public about $1 billion each year; they are without doubt a major factor in determining the population levels of the insects concerned.

Considering the enormous damage caused to human health and to biodiversity through the application of pesticides, it is clear that all efforts should continue to improve crop productivity while reducing the amounts of pesticides applied. In this connection, plants genetically modified to produce Bt endotoxin or other toxins clearly have an important role to play. The environmental effects of Bt endotoxin, freely sprayed or produced by genetically modified corn and other crops, have been assessed for many years, should continue to be evaluated. Many steps can be taken to ameliorate the potential prob-

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lems reported by Losey *et al.* (1) and Hansen and Obrycki (www.ent.iastate.edu/entsoc/nch 99/prog/abs/D81.html); for example, corn strains can be selected in which the Bt endotoxin is not expressed in the pollen, or that produce nonlethal concentrations of these toxins. In any case, the careful evaluation of foods produced as a result of gene splicing or any other method that alters their genetic constitution should continue; and the possibility of labeling certain food products should continue to be considered in the light of consumer preference (8).

Non-chemical alternatives for pest control have great importance, and should be pursued actively, and used in combination with environmentally relatively benign strategies. For example, if Bt corn, crop rotations, monitoring pest populations, and other known alternatives were used in corn production, insecticide use in corn production could be reduced by more than 50% (4). Such a development would be of great environmental and economic benefit to farmers while providing consumers with corn with fewer pesticide residues. Reductions in off-site environmental damage and in public health hazards would follow from reduced pesticide use (7).

Finally, additional research should be focused on the overall status of Monarch butterflies and other species of concern. From 1996–97 to 1998–99, for example, the overwintering Monarch butterfly populations in Mexico declined from 170–204 million to only 56–67 million (8). Major factors in this decrease apparently include both habitat destruction in Mexico and in the United States and the widespread application of insecticides on crops throughout both countries. Compared with the threats posed to Monarch butterflies by these factors, and considering the gains obviously achieved in the level of survival of populations of Monarch butterflies and other insects by eliminating a large proportion of the pesticides applied to the same crops, the widespread cultivation of Bt corn may have huge benefits for Monarch butterfly survival.

In conclusion, the introduction of resistance factors in corn through the application of genetic engineering technology is an effective strategy to reduce the extensive crop damage caused by corn rootworm and European corn borer populations. Yet, the diverse reactions of the different Lepidoptera to corn genotypes with varying levels of Bt endotoxin in their pollen signal that additional testing and development is required to limit or entirely prevent damage to nontarget butterfly and other beneficial insect species. Although Bt corn pollen under certain circumstances has the potential of adversely affecting the population levels of Monarch butterflies and other nontarget Lepidoptera, we consider these impacts to be minimal when compared with habitat loss and the widespread use of pesticides throughout the ecosystem. Broad agricultural investigations should focus on improving pest-management strategies in the context of sustainability and productivity to reduce the use of pesticides and make agriculture more environmentally and economically sound. In addition, broadly based research should continue to be conducted on the reasons for the decline of populations of Monarch butterflies and other species, and remedial steps should be directed to the more important of these factors as they are identified.

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