Non-target risk assessment for crops engineered for insect resistance

Richard L. Hellmich
Iowa State University, richard.hellmich@ars.usda.gov

Julia Gorecka
Warsaw University of Life Sciences - SGGW

Follow this and additional works at: http://lib.dr.iastate.edu/ent_pubs

Part of the Agronomy and Crop Sciences Commons, and the Entomology Commons

The complete bibliographic information for this item can be found at http://lib.dr.iastate.edu/ent_pubs/106. For information on how to cite this item, please visit http://lib.dr.iastate.edu/howtocite.html.

This Article is brought to you for free and open access by the Entomology at Iowa State University Digital Repository. It has been accepted for inclusion in Entomology Publications by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
Non-target risk assessment for crops engineered for insect resistance

Abstract
Bacillus thuringiensis (Bt) maize genetically engineered for insect resistance has been commercially available in the United States since 1996. Bt maize has been popular with most U.S. growers because it provides economic advantages and reduces the reliance on chemical insecticides. Prior to commercialization all genetically-engineered (GE) crops go through a comprehensive and rigorous evaluation by three U.S. government agencies to demonstrate their safety to the environment and human and animal health. This paper focuses on improving methods to evaluate possible non-target effects of GE crops, which should be helpful to scientists in countries that are considering the use of GE crops.

Keywords
Bt maize, risk assessment, non-target organisms, GE crops

Disciplines
Agronomy and Crop Sciences | Entomology

Comments
This article is from Annals of Warsaw University of Life Sciences - SGGW; 29 (2008); 7-17

Rights
Works produced by employees of the U.S. Government as part of their official duties are not copyrighted within the U.S. The content of this document is not copyrighted.
Non-target risk assessment for crops engineered for insect resistance

RICHARD L. HELLMICH
Department of Entomology, Iowa State University, Ames, Iowa, USA

JULIA GÓRECKA
Department of Applied Entomology, Warsaw University of Life Sciences – SGGW

Abstract: Non-target Risk Assessment for Crops Engineered for Insect Resistance. Bacillus thuringiensis (Bt) maize genetically engineered for insect resistance has been commercially available in the United States since 1996. Bt maize has been popular with most U.S. growers because it provides economic advantages and reduces the reliance on chemical insecticides. Prior to commercialization all genetically-engineered (GE) crops go through a comprehensive and rigorous evaluation by three U.S. government agencies to demonstrate their safety to the environment and human and animal health. This paper focuses on improving methods to evaluate possible non-target effects of GE crops, which should be helpful to scientists in countries that are considering the use of GE crops.

Key words: Bt maize, risk assessment, non-target organisms, GE crops.

INTRODUCTION

Many technological advances have occurred in agriculture in the past two centuries, including the use of the steel plow, improved plant genetics, fuel-powered tractors, chemical pesticides and high-input use of manmade fertilizers. Each of these advances, though, has had impacts on the environment. Now there is a new biotechnology that has the potential to produce significant advances in agriculture and at the same time could help reduce environmental impacts of agriculture. Many of the current genetically-engineered (GE) crops produce insecticidal proteins that protect plants from lepidopteran pests. Since the insecticides are manufactured by the plant the expectation is that growers will use fewer chemical insecticides to control targeted pests. Some GE crops have been engineered for tolerance to specific herbicides. The expectation in this case is that growers will readily use no-till practices that help reduce erosion; and growers will use more environmentally-friendly herbicides to control weeds. Even though there are potential benefits to GE crops, there still is a need to ensure the safety of these crops. This paper focuses on improving methods to evaluate possible non-target effects of GE crops. Principles of risk assessment are outlined, followed by a risk-assessment case study that focuses on the monarch butterfly and Bt-maize pollen. This is followed by an outline of plans to develop, refine and harmonize laboratory tests to evaluate GE crops, which should be helpful to scientists in countries that are considering the use of GE crops.
PRINCIPLES OF RISK ASSESSMENT

People take risks everyday. Most of these risks are familiar, like driving a car, using power tools or playing a sport. But sometimes people encounter a new situation or product that requires more assessment before taking the risk. Often apprehension with novel products is allayed with education, especially when the item is well understood by scientists. Yet sometimes research is needed to answer questions. Risk analysis has two basic components: effect and exposure. What is the potential for an effect or toxicity; and what is the likelihood of exposure? One way to think about this is to consider an analogy with aspirin. Whether aspirin has a negative or positive effect on people depends on the magnitude of the exposure. Aspirin in appropriate doses is beneficial to many people, but aspirin in excessive doses is lethal. Similarly, the effect of any agricultural product on a particular organism often depends on the nature and magnitude of the exposure.

Questions on effect and exposure are answered scientifically with a set of tiered experiments that are conducted on test organisms. These tests start by exposing the selected organism for a short time to an excess of the stressor, often 10 times or more than the organism would likely encounter in nature. This worse-case approach is used to efficiently identify stressors that should be further tested. If there is any hint that there is an effect, then other tests are conducted. These tests progress from the short-term high-exposure tests to long-term normal-exposure tests, most of which are conducted in the laboratory, to large-scale semi-field or field tests. At each step scientists evaluate the potential ecological risks of the product. This approach has been used for many years to test most of the agricultural pesticides that are used today. When risks are identified restrictions are imposed. For example, some pesticides are hazardous to fish. In these cases, spraying near waterways is restricted. Also, many pesticides are harmful to bees. Applications of these products may require alerting beekeepers to close their hives during spray periods.

CASE STUDY: MONARCH BUTTERFLY

Growers in the United States first planted commercial GE maize in 1996. These plants produced a Cry protein derived from the soil bacterium Bacillus thuringiensis Berliner (Bt), which made them resistant to European corn borer, Ostrinia nubilalis Hübner, and other lepidopteran maize pests. Growers are attracted to the Bt maize hybrids for their convenience and because of yield protection, reduced need for chemical insecticides, and improved grain quality (Hellmich et al., 2008). Much is known about the safety of Bt maize because of extensive research that was conducted on the safety of Bt biological insecticides. Bt insecticides have been used safely for over 40 years to control unwanted lepidopteran pests; plus they are popular with organic farmers because they are naturally occurring organisms found worldwide in the soil. When the United States Environmental Protection Agency (USEPA) registered Bt maize they made the assumption that lepidopteran-active B. thuringiensis insecticides are likely to be hazardous to all Lepidoptera (moths and butterflies), although exposure from agricultural uses
was not expected to be high (USEPA 1995). Additional data on the effects of Bt on non-target moths come from the use of the Bt strain *kurstaki* as a microbial insecticide, where applications of Bt are the most common insecticide to control gypsy moth, *Lymantria dispar* (L), a defoliating pest of North American forests. Studies assessing mortality of non-target moths indicate increased mortality of several species following Bt applications (Miller, 1990; Johnson et al., 1995). However, species whose larvae conceal themselves in plant tissues (‘shelter-forming’ larvae) apparently avoid exposure to toxins by feeding only in areas not reached by Bt sprays (Navon, 1993; Wagner et al., 1996). This emphasizes the importance of direct exposure to Bt toxins through feeding. Because only moths feeding on maize tissues (i.e. primary or secondary pests) should be exposed to the Bt toxins produced by maize, little risk was perceived for non-target moths and butterflies. That is, their feeding habits were not expected to expose them to significant amounts of the Bt toxins inside transgenic maize. Consequently the USEPA approved the sale of Bt maize in the United States, anticipating only targeted crop pests would be harmed by Bt expressed in plant tissues.

These assumptions were questioned when a letter to *Nature* in 1999 suggested that pollen from Bt maize harmed larvae of the monarch butterfly, *Danaus plexippus* (L.) (Losey et al., 1999). Monarch butterflies are familiar to many people in North America because they are common visitors to flower gardens. Those that breed east of the Rocky Mountains in the United States and Canada migrate to oyamel fir, *Abies religiosa* (Lindl.), forests in the Transvolcanic Mountains west of Mexico City. This long-distance migration is well-known and is taught in many elementary schools. The popularity of this insect inspired one entomologist to call it the “Bambi of the insect world”. Thus it is not surprising that the public outcry and media reports that followed the *Nature* letter intensified one of the most controversial issues to face agricultural scientists in recent memory. Over the next two years a consortium of scientists addressed the monarch and Bt-maize issue by conducting effect and exposure experiments. This consortium included scientists from eight U.S. Universities, one Canadian University, and two U.S. Agricultural Research Service (ARS) Laboratories. A steering committee that included scientists from ARS, two land-grant Universities, industry, and an environmental organization oversaw activities and funding of the consortium.

**Effect Studies** – There are a number of different types of Bt-maize hybrids, each with a characteristic protein or expression profile (Tab. 1). Commercially available varieties in the U.S. include YieldGard® that produce Cry1Ab protein (events1 BT11 and MON810) and Herculex® that produce Cry1F protein (event TC1507). Laboratory experiments with pure 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-maize pollen, however, showed that when small larvae were fed high doses of pollen (more than 1,000 pollen grains/cm² of milkweed leaf surface) for 3–5 days there were no

---

1 Each event is derived from an independently transformed plant.
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 BT11 and MON810 maize 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 (Tab. 1). The Bt maize called 176 was an exception (Tab. 1). An adverse effect on monarch larvae was seen at levels of pollen commonly encountered in maize fields during pollen shed (~10 pollen grains/cm²) (Hellmich et al., 2001). This was the first type of Bt maize that was developed and it expressed high amounts of Cry1Ab protein in the pollen. This type of Bt maize is no longer sold in the U.S.

**Exposure Studies** – 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 maize pollen shed, and patterns of maize pollen deposition. Monarch butterflies lay their eggs exclusively on plants in the milkweed family, *Asclepiadaceae*. Census research conducted in the U.S. upper Midwest determined that milkweed, especially the common milkweed, *Asclepias syriaca* L., occurs extensively in disturbed habitats in and around agricultural fields (Hartzler and Buhler, 2000). Milkweed densities usually are higher in nonagricultural areas, particularly along field edges, compared with maize and soybean fields. Yet, a high percentage of monarch larvae are found in and around maize fields due to the prevalence of maize 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% agriculture, 36% maize) originate from maize fields (Sears et al., 2001).

Maize pollen shed in the upper Midwest of the U.S. occurs mainly during a one to two week period in July. In the same area monarch butterflies have two generations. Oviposition for the first generation occurs primarily in May so there is no overlap of pollen shed with this generation. Oviposition for the second generation occurs in July and August, which overlaps to some degree with maize pollination, depending on latitude. Phenology studies of monarch larvae and maize pollination indicate that there is a greater temporal overlap between monarch larvae and maize pollen shed in the northern than the southern part of the monarch summer breeding range.

### Table 1. Summary of *Bacillus thuringiensis* (BT) maize events 176, BT11, MON810 and TC1507 with protein and expression profile

<table>
<thead>
<tr>
<th>Event</th>
<th>Company</th>
<th>U.S. Trademark</th>
<th>Protein</th>
<th>Tissues</th>
<th>Pollen Bt</th>
</tr>
</thead>
<tbody>
<tr>
<td>176</td>
<td>Mycogen Seeds</td>
<td>NatureGard</td>
<td>Cry1Ab</td>
<td>green/pollen</td>
<td>high</td>
</tr>
<tr>
<td></td>
<td>Novartis Seeds</td>
<td>Maximizer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BT11</td>
<td>Syngenta Seeds</td>
<td>YieldGard</td>
<td>Cry1Ab</td>
<td>all</td>
<td>very low</td>
</tr>
<tr>
<td>MON810</td>
<td>Monsanto</td>
<td>YieldGard</td>
<td>Cry1Ab</td>
<td>all</td>
<td>very low</td>
</tr>
<tr>
<td>TC1507</td>
<td>Dow Agrosciences</td>
<td>Herculex</td>
<td>Cry1F</td>
<td>all</td>
<td>low</td>
</tr>
</tbody>
</table>
because of earlier pollen shed in the south. Percent overlap ranges from about 5–10 percent in southern Iowa to about 50–60% in southern Minnesota (Oberhauser et al., 2001; Dively et al., 2004).

The third set of studies related to exposure involved determining the density of maize pollen on milkweed plants inside and outside of maize fields during pollination. Results from several studies showed that pollen density was highest (avg. 171 grains/cm²) inside the maize field 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 would not encounter high pollen densities outside of maize fields and rarely would encounter densities above 1000 pollen grains/cm² inside the field.

Risk Assessment – In the formal risk assessment of Bt maize 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 maize 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 maize fields during their entire development. In these cases there were small effects found, but a more detailed analysis of exposure determined that the risks were still small (Dively et al., 2004). To return to the aspirin analogy, the exposure was never sufficient to be harmful to monarch populations.

PREPARING LABORATORY TESTS TO EVALUATE CROPS

Regulatory agencies require extensive testing of GE crops before they are released in the environment. In the United States three government agencies share the responsibilities of regulating products developed from modern biotechnology. These agencies include U.S. Department of Agriculture’s Animal and Plant Health Inspection Service (USDA–APHIS), the U.S. Environmental Protection Agency, and the Department of Health and Human Services Food and Drug Administration (USFDA). This coordinated framework was established in 1986 to ensure biotechnology products are safe for the environment and human and animal health. A risk-based system is used and depending on characteristics of the product one or more of these agencies will review the product. There are a number of publications that provide more extensive information regarding regulation of GE crops and the responsibilities of the three U.S. agencies (e.g., USNAS 2002, Nestmann et al., 2002).

In the case of Bt maize the USEPA is the lead agency. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) mandates that the USEPA regulate the use and sale of pesticides to protect human health and preserve the environment while at the same time taking into account the benefits provided by those pesticides. Under this Act the USEPA regulates plants that are genetically engineered to express insecticidal proteins. Before a GE plant is registered, an ecological risk assessment is conducted to determine whether there are potentially any unreasonable adverse effects from
the use of these plants. Maize plants that express proteins derived from the bacterium *B. thuringiensis* have been evaluated with tests adapted from guidelines for microbial pesticides. USEPA used these guidelines to minimize variations among tests that were being conducted. They are readily available from the USEPA Office of Prevention, Pesticides and Toxic Substances (OPPTS) (e.g., USEPA 1996a). Many tests involve feeding the GE crop or the expressed protein to test organisms in laboratories. Organisms that have been tested include rats, dairy cattle, catfish, bobwhite quail, chickens, earthworms, daphnia, honey bees, lady beetles, parasitic wasps, lacewings, and collembola (or springtails). These organisms are easily maintained in the laboratory and have been used for many years to test agricultural pesticides.

The current USEPA guidelines provide a starting point for developing protocols for testing GE plants; but critics have suggested that they could be improved. A USEPA Scientific Advisory Panel that assessed non-target organism data requirements for GE plants recommended that the USEPA should provide applicants with detailed recommendations regarding experimental design and data analysis (USEPA 2000). At present there are several different efforts among entomologists and risk assessment scientists to standardize laboratory tests so that protocols are unambiguous, results are easily interpreted, and there is consistent logic in the approaches to testing and their relationship to monitoring.

The tests that are more easily standardized are lab-based Tier I and Tier II tests. Tier I tests simulate worst-case scenarios and often have exposure levels that exceed (> 10×) the expected environmental concentration (EEC). Diets are usually artificial with incorporated proteins administered in maximum limit dose, short duration studies. If warranted on the basis of Tier I results or the nature of concern, Tier II tests and higher level tests may be conducted. Tier II tests are a step closer to reality because plant tissues are used, usually at the expected environmental concentration (i.e., 1× EEC) and with exposure routes and duration that better represent the field environment. If Tier II tests indicate hazard (or toxicity) is sufficient to have an effect then Tier III testing is required. The advantage of Tier I and Tier II tests are that they allow for increased replication and control over testing conditions. Tier III tests are long-term laboratory or semi-field tests, which sometimes are followed by Tier IV simulated or actual field testing.

The USEPA has numerous test guidelines for tiered tests in categories including Spray Drift, Residue Chemistry, Ecological Effects, Microbial Pesticides, Biochemicals, among others. Microbial Pesticide test guidelines, which are most relevant to GE crops, are divided into the following groups: A, Product Analysis; B, Residues; C, Toxicology; D, Non-target Organism; and E, Environmental Expression. The following tests are within the Non-target Organism group:

<table>
<thead>
<tr>
<th>USEPA #</th>
<th>Test Guidelines Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>885.4050</td>
<td>Avian oral, Tier I</td>
</tr>
<tr>
<td>885.4100</td>
<td>Avian inhalation test, Tier I</td>
</tr>
<tr>
<td>885.4150</td>
<td>Wild mammal testing, Tier I</td>
</tr>
<tr>
<td>885.4200</td>
<td>Freshwater fish testing, Tier I</td>
</tr>
<tr>
<td>885.4240</td>
<td>Freshwater aquatic invertebrate testing, Tier I</td>
</tr>
</tbody>
</table>
The other set of test guidelines that might prove useful for developing standardized tests for arthropods are in the category Ecological Effects. These include two honey bee tests (850.3020 and 850.3030), pollinator test (850.3040), earthworm test (850.6200) and two daphnia tests (850.1010 and 850.1300).

Many of these guidelines provide generalized protocols that sometimes lack detail. For example, the Microbial Pesticide Test Guidelines for Tier 1 testing of honey bees entails only a few paragraphs (USEPA, 1996b). These harmonized protocols provide scientists flexibility for adapting tests to new products. One challenge in developing tests is establishing the level of detail. There are tradeoffs between too little detail, which may preclude repeatability of studies among laboratories, and too much detail, which might stifle experimental flexibility.

During the registration process, the development of testing protocols involves consultation among USEPA and applicant representatives. The applicant starts with the tests guidelines and associated publications and develops detailed protocols suitable for testing their product. The modified protocols in some case are then reviewed by the USEPA and recommended changes are made. This process may be repeated until the USEPA determines the tests are appropriate. This iterative approach has some advantages because it allows the applicant and the USEPA to make necessary adjustments to the tests. For example, in the case of honey bee tests, the appropriate food source (pollen or honey) or age of bees (larvae or adults) may depend on the route of exposure or type of stressor. These types of adjustments are logical and can be made after consultation. This approach, however, also has disadvantages. There is the possibility that each applicant or associated testing laboratories could develop unique protocols. Under these conditions, tests from different laboratories and sometimes tests within the same laboratory are fundamentally different and cannot be compared. These limitations open the door for outside scrutiny and call into question whether some of these tests should be standardized.

Any effort to standardize tests should involve a series of inter-laboratory tests or ring tests that could include laboratories from different countries. Initially, these tests probably should focus on one or two traditionally tested taxa, such as honey bees, earthworms, daphnia, collembola, lady beetles, parasitic wasps, and green lacewings. Representatives from the laboratories would need to develop harmonize protocols based on existing protocols from taxon-specific tests derived from various publications (e.g., Candolfi et al. 2000) and testing laboratories. In many cases protocols would be modified for testing GE plant products. The harmonization process would be followed by the ring tests for validation. Protocols will vary depending on the
taxon, but a general outline could include the following:

Organism – common and scientific names
Rearing methodology (deliver stage specific organisms)
Bioassay
  Life stage(s) tested (egg, larvae, adult, multiple, etc.)
  Length of test
  Endpoint(s) (LC50, size/weight, etc.)
  Test system and conditions
  Test material (origin, form)
  Dose calculation (based on 10X highest expressing tissue, dry weight)
  Treatment application (protein in artificial diet, plant material, etc.)
  Replicate number
  Positive control (compound used)
  Negative control
  Validity criteria (e.g., control mortality limits)
  Statistical methods (power tests, t-test, ANOVA, etc.)

As mentioned previously, one challenge will be to develop tests with appropriate amount of detail to avoid problems with test repeatability and at the same time allow for experimental flexibility. For some tests, variances could be incorporated into the standardized tests to allow for at least some flexibility. These tests could be made available to the public through peer-reviewed journal articles, handbooks, websites or a combination of these outlets. A core group of harmonized tests to assess non-target effects of GM plants would foster communication among scientists and regulators and ultimately would contribute to science-based decisions related to the regulation of GE crops.

ENVIRONMENTAL IMPACTS AND FUTURE OF GE CROPS

Genetically-engineered crops only have been available for about a decade, so studies to evaluate their effect on ecosystems are fairly new or still ongoing. Yet the data to date suggest GE crops developed for insect tolerance are more environmentally friendly than broad-spectrum chemical insecticides. This is particularly true for cotton and with the development of rootworm-tolerant maize this is likely to be true for maize too. These reductions in the use of insecticides have benefited biodiversity and have reduced risks of human poisoning.

A recent paper by Brookes and Barfoot (2005) suggests the global reduction in pesticides due to GE crops has been about 172 million kg. They calculate the decrease in the environmental impact associated with pesticides is about 14%. Plus, if herbicide-tolerant GE crops are included, they estimate agro biotechnology has reduced greenhouse gas emissions equivalent to removing five million cars from the road. These developments represent steps in the right direction. Yet, there are several needs that must be addressed to assure biotechnology continues in this direction.

Insects have a long history of evolving resistance to insecticides. Loss or reduction in the use of biotech crops would impact agroecosystems if growers returned to controlling pest insects with broad spectrum insecticides. Insect resistance management (IRM) strategies have been developed to prevent the development of insects that are resistant to GE plants (Gould, 1998). The IRM strategy currently used for Bt maize and Bt cotton in the U.S. focuses on the use
of high levels of protein expression in plants (a high-dose) and the planting of a refuge (a percentage of non-Bt plants; Tabashnik and Croft, 1982; Gould, 1986). Specific refuge placement and size recommendations for each GE crop in any given area of the world will need to be developed depending on the biology of the pest insects and the realities of the farming systems.

Bt cotton has been so effective in Arizona that it appears pink bollworm populations have been suppressed area-wide (Carrière et al., 2003). Removing a major insect from an ecosystem undoubtedly will influence the other plants and insects in that system. On one hand, the reduced use of insecticides could allow natural enemies to reach population levels that control secondary pests. Yet, on the other hand, there will be circumstances where secondary pests are not controlled and they could become economically important pests, such as the sweetpotato whiteflies and Lygus species in Arizona cotton. Also, area-wide suppression of a pest such as the cotton bollworm (also maize earworm), beet armyworm or fall armyworm could reduce the damage on another crop. Preservation of beneficial insects in Bt crops also may result in an increase of these species on a landscape scale. There are a myriad of possible interactions that could be investigated that will influence pest control positively and negatively. Entomologists should rest assured there will be many opportunities for research with GE crops.

New types of GE crops will be developed and each will need to be evaluated to determine if there are possible environmental risks. Value added traits related to nutrition and fiber undoubtedly are in development. In the insect control arena, new insecticidal proteins will be discovered and developed either to pyramid with existing proteins to control Lepidoptera or Coleoptera (beetles) or use as replacements should insect resistance occur. Furthermore, there still is a need to control piercing-sucking insects, since many homopterans (especially whiteflies and aphids) and hemipterans (true bugs) are important crop pests. GE crops that could control these insects certainly would help reduce the ecological impacts related to the application of broad spectrum insecticides used in pest control.

There always will be uncertainties with new technology. Yet, if decisions regarding these products are science based the risks will be better understood and society can make decisions on accepting the risks that are based on facts. The monarch and Bt-pollen issue demonstrated that sound science can prevail even when the subject is well-known and highly controversial.

Acknowledgements
Mention of a proprietary product does not constitute an endorsement or a recommendation for its use by United States Department of Agriculture or Iowa State University. The authors would like to thank Michael J. Weiss and Jarrad R. Prasifka for valuable discussions.

REFERENCES
BROOKES G., BARFOOT P., 2005: GM crops: The global economic and environmental


Non-target risk assessment for crops engineered...


Streszczenie: Ocena ryzyka upraw genetycznie zmodyfikowanych odpornych na szkodniki dla organizmów niedocelowych. Genetycznie zmodyfikowana kukurydza Bt (Bacillus thuringiensis), odporna na szkodniki w Stanach Zjednoczonych, stała się popularna wśród amerykańskich farmerów ze względu na korzyści ekonomiczne i redukcję zależności od chemicznych insektycydów. Przed komercjalizacją wszystkie genetycznie zmodyfikowane (GM) rośliny uprawne są poddawane rygorystycznej i wszechstronnej ocenie przez trzy agencje rządu Stanów Zjednoczonych w celu udowodnienia ich bezpieczeństwa dla środowiska oraz dla zdrowia ludzi i zwierząt. W tym artykule skupiono się nad ulepszaniem metod oceny możliwego niezamierzonego wpływu upraw genetycznie zmodyfikowanych na organizmy niedocelowe.

MS. received July 22, 2008

Authors’ addresses:
Richard L. Hellmich
USDA-ARS, Corn Insects and Crop Genetics Research Unit
and Department of Entomology
Iowa State University
Genetics Laboratory c/o Insectary
Ames, Iowa 50011-3140
Richard.Hellmich@ars.usda.gov

Julia Górecka
Katedra Entomologii Stosowanej
Wydział Ogrodnictwa i Architektury Krajobrazu
SGGW
ul. Nowoursynowska 166, 02-787 Warsaw
juliag2@wp.pl

Poland