Executive Summary
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Comparative Environmental Impacts of Biotechnology-derived and Traditional Soybean, Corn, and Cotton Crops

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I. Executive Summary

A comprehensive review of the scientific literature supports the conclusion that overall the currently commercialized biotechnology-derived[1] soybean, corn, and cotton crops yield environmental benefits. Furthermore, a critical analysis of the literature supports the idea that biotechnology-derived soybean, corn, and cotton pose no environmental concerns unique to or different from those historically associated with conventionally developed crop varieties.

Soybean, corn, and cotton farmers in developed and developing nations have rapidly adopted biotechnology-derived commodity crops during the six years of their commercial availability. In 2001, farmers planted biotechnology-derived seed on 46% of global soybean acres, 7% of global corn acres, and 20% of global cotton acres. To date, nearly all of the planted biotechnology-derived crops have introduced tolerance to selected herbicides for weed control or have introduced protection against pest insects. Of the 129.9 million acres (52.6 million hectares) of biotechnology-derived crops planted in 2001, seventy-seven percent were tolerant of specific herbicides (herbicide tolerant), fifteen percent were resistant to selected insect damage (insect resistant), and eight percent were both herbicide tolerant and insect resistant.

The peer-reviewed literature, regulatory assessments, nongovernmental organizations and the popular media have repeatedly raised questions about the environmental safety of biotechnology-derived crops. To answer these questions relative to soybean, corn, and cotton, the scientific literature was reviewed and analyzed to evaluate the environmental impacts of commercially available biotechnology-derived crops in relation to the current agricultural practices for crop and pest management in conventionally bred crops. Nine potential environmental impacts were identified as follows:

1. **Changes in pesticide use patterns** - Does the adoption of biotechnology-derived soybean, corn, and cotton impact the use of pesticides and, if so, do these changes alter farmer practices in ways that affect water quality or soil health?

2. **Soil management and conservation tillage** - Does adoption of biotechnology-derived soybean, corn, and cotton lead to changes in the adoption of no-till and other conservation tillage practices or otherwise impact soil erosion, moisture retention, soil nutrient content, water quality, fossil fuel use, and greenhouse gasses?

3. **Crop weediness** - Have biotechnology-derived soybean, corn, and cotton acquired weediness traits?

4. **Gene flow and outcrossing** - Do biotechnology-derived soybean, corn, and cotton hybridize with local plants or crops and impact the genetic diversity in the areas where the biotechnology-derived soybean, corn, and cotton are planted?

5. **Pest resistance** - Do biotechnology-derived soybean, corn, and cotton possess plant-protectant traits to which pests will become resistant and, if so, is the development of resistance to these traits different than development of resistance to conventional chemical and microbial pesticides? How is the development of resistance being managed?

6. **Pest population shifts** - Do biotechnology-derived soybean, corn, and cotton cause changes in weed or secondary insect pest populations that impact the agricultural system or ecology of the surrounding environment?

7. **Nontarget and beneficial organisms** - Do biotechnology-derived soybean, corn, and cotton with pest protection characteristics have an impact on natural enemies of pests (i.e., predators and parasitoids) or on other organisms in the soil and crop canopy?

[1] Biotechnology-derived refers to the use of molecular biology and/or recombinant DNA technology, or in vitro gene transfer, to develop products or impart specific capabilities in plants or other living organisms.

8. **Land use efficiency/productivity** - Does the adoption of biotechnology-derived soybean, corn, and cotton impact crop yields or impact the need for cultivating forested or marginal land?

9. **Human exposure** - Do the traits of herbicide tolerance and resistance to pest insects in biotechnology-derived soybean, corn, or cotton pose any new or different safety concerns in comparison to conventionally bred crops with similar traits?

Biotechnology-derived crops provide options and potential solutions for a number of challenges in modern agriculture, but the extent to which they may be viable or the preferred option is dependent on many economic, social, and regional factors. Nevertheless, a number of general conclusions about biotechnology-derived soybean, corn, and cotton are supported by the literature.

- Biotechnology-derived soybean, corn, and cotton provide insect, weed, and disease management options that are consistent with improved environmental stewardship in developed and developing nations.

- Biotechnology-derived crops can provide solutions to environmental and economic problems associated with conventional crops including production security (consistent yields), safety (worker, public, and wildlife), and environmental benefits (soil, water, and ecosystems).

- Although not the only solution for all farming situations, the first commercially available biotechnology-derived crops, planted on over 100 million acres (40.5 million hectares) worldwide, provide benefits through enhanced conservation of soil and water and beneficial insect populations and through improved water and air quality.

- The high adoption rates for commercially available biotechnology-derived crops can be attributed to economic benefits for farmers.

- When biotechnology-derived crops are available to small farmers in developing nations, the farmers can realize environmental benefits and reduce worker exposure to pesticides.

BIOTECHNOLOGY-DERIVED SOYBEAN

- Herbicide-tolerant soybean is the most widely adopted biotechnology-derived crop, planted on 68% of United States' soybean acreage and over 98% of Argentina's soybean acreage in 2001. The United States and Argentina together account for 99% of total herbicide-tolerant soybean production in the world, which represents 46% of the total acreage of soybean planted. Farmers in the United States are projected to plant 74% of soybean acreage to herbicide-tolerant soybean in 2002.

- The major reasons farmers have adopted the herbicide-tolerant soybean so widely are lowered production costs, reduced crop injury, and simplicity and flexibility in weed management.

- Biotechnology-derived herbicide-tolerant soybean has facilitated the adoption of conservation tillage. No-till soybean acreage in the United States has increased by 35% since the introduction of herbicide-tolerant soybean. Similar increases are observed in Argentina, which can be attributed in part to reliable and effective weed control provided by herbicide-tolerant soybean. Use of no-till farming in soybean production results in decreased soil erosion, dust, and pesticide run-off and in increased soil moisture retention and improved air and water quality.

- Biotechnology-derived soybean may lead to increased yield, through improved weed control or the ability to adopt narrow-row spacing, resulting in more efficient land use.

- Cost savings in biotechnology-derived herbicide-tolerant soybean programs have allowed adopters to decrease weed control costs, leading to price cuts of conventional herbicide programs. The result has been weed control cost savings for both adopters and non-adopters.

- Farmers using biotechnology-derived herbicide-tolerant soybean are able to use a herbicide that rapidly dissipates to inactive amounts in soil, has little potential for water contamination as a substitute for herbicides used with conventional soybean varieties, and allows greater flexibility in timing of application.

• Biodiversity is maintained in biotechnology-derived herbicide-tolerant soybean fields. Soil microbes, beneficial insects, and bird populations in conservation tillage biotechnology-derived herbicide-tolerant and conventional soybean fields were similar in number and variety.

• Both conventional and biotechnology-derived soybean production systems require effective management strategies for weed population shifts and to prevent the development of weed resistance to herbicides. Emerging reports on glyphosate-resistant weeds may be a concern in herbicide-tolerant soybean; however, herbicide resistance in weeds is not unique to biotechnology-derived crops.

• Conclusions regarding yield decreases attributed to the biotechnology-derived herbicide-tolerant trait may be inaccurate because the study design included improper comparisons between the biotechnology-derived varieties and conventional varieties.

• Soybean with insect protection properties is also in development and will be useful in climatic regions where insect pressures justify insecticide applications.

BIOTECHNOLOGY-DERIVED CORN

• *Bt* corn can enhance the biodiversity of cornfields because beneficial insects fare better than when conventional cornfields are sprayed with insecticides. Moreover, field studies of biotechnology-derived corn show that populations of beneficial insects are not adversely affected.

• Use of *Bt* corn can decrease farm worker exposure to certified organic *Bt* sprays and chemical insecticides.

• Decrease of naturally occurring mold toxins resulting from use of *Bt* corn can provide direct benefits to people and corn-fed livestock. Insect-protected corn is less vulnerable to mold infestation.

• Yields since the introduction of insect-protected and herbicide-tolerant corn have continued at historically high levels. When European corn borer pressure is high, farmers obtain significant economic benefit from the use of insect-protected corn.

• Herbicide-tolerant corn varieties allow use of herbicides that are less persistent in the environment and reduce the risks of herbicide run-off into surface water. These herbicide-tolerant corn varieties allow for greater flexibility in the timing of application and encourage the application of reduced and no-till soil and soil moisture management practices.

• Insect Resistance Management (IRM) plans have been required, developed, and implemented to prevent or to delay the development of insect resistance to *Bt*.

BIOTECHNOLOGY-DERIVED COTTON

• Herbicide-tolerant cotton enhances the use of herbicides that are less persistent in the environment.

• Herbicide-tolerant cotton is a major factor in promoting reduced and no-till farming practices, which result in improved soil and soil moisture management and reduced energy use.

• Herbicide-tolerant cotton provides greater flexibility for the timing of herbicide applications for effective weed control and less damage to the cotton plants.

• Use of biotechnology-derived cotton in developing nations does not require significant capital investment, changes in cultural practices, or significant training for adoption.

• Rapid adoption of *Bt* cotton in China serves as an example of how, in developing nations, plant-incorporated protectants greatly decrease the volume of pesticides applied and the risks of pesticide run-off while increasing safety and health of agricultural workers.

• *Bt* cotton has been documented to have a positive effect on the number and diversity of beneficial insects in cotton fields in the United States and Australia.

• The introduction of *Bt* cotton in Australia, India, and the United States demonstrates the ability of these varieties to alleviate problems with insect resistance to chemical pesticides. The future production of cotton in these regions was in jeopardy prior to the introduction of *Bt* cotton.

• The ability to add several different genes to control the same pest should delay the time it takes for pesticide resistance to develop.

• *Bt* and herbicide-tolerant cotton decreases production costs to farmers and increases the range of options available for whole-farm management systems.

AUTHORS' RECOMMENDATIONS

1. Given that biotechnology-derived crops can provide positive net environmental benefits, we recommend continued development of agricultural biotechnology to enhance environmental stewardship.

2. Biotechnology provides a tool for management of production risk in agriculture. We recommend evaluating the role of biotechnology-derived crops in the context of whole-farm management.

3. When drawing conclusions regarding the impacts of biotechnology-derived crops on productivity, we recommend that conclusions be based on comparisons involving whole-farm systems.

4. When comparing the consequences of a specific trait, we recommend the following characteristics be held constant: varieties that are genetically identical in all aspects other than the trait(s) being evaluated; the crops be grown during the same time in the same geographic location; and use of identical soil and crop management practices. For example, having observed contradictory and inconsistent data regarding yields in some crops, we recommend better measurement of yield impacts.

5. We recommend evaluating the environmental impacts of biotechnology-derived crops in agricultural regions where the crops may be adopted and in the context of viable, currently available alternatives and practices in agriculture.

6. We recommend large-scale and farm-scale field studies to provide supplemental information to document long-term environmental benefits and safety impacts of adopting biotechnology-derived crops.

7. We recommend continued development of policies for implementation of effective management strategies for insect and weed resistance in both conventional and biotechnology-derived crops. Also, we recommend continued research on management strategies to abate or slow the development of resistance to new and existing pest control tools.

8. Recognizing that gene flow is a natural process that may increase biodiversity, we recommend that research on gene flow between biotechnology-derived and other crops or native plants focus on the environmental and social impacts/consequences of that gene movement.

9. Recognizing the potential for biotechnology-derived corn varieties to help resolve current corn rootworm control problems stemming from the development of insect resistance to both chemical insecticides and crops rotation, we recommend research include consideration of resistance management strategies as well as impacts on soil and other nontarget organisms.

10. Recognizing that enhanced land use efficiency is an important environmental benefit, we recommend continued development of biotechnology-derived hybrids that improve crop yields.

Copies of Comparative Environmental Impacts of Biotechnology-derived and Traditional Soybean, Corn, and Cotton Crops are available on the web at www.cast-science.org <http://www.cast-science.org/> and www.talksoy.com <http://www.talksoy.com/> and from the United Soybean Board, 16640 Chesterfield Grove Road, Suite 130, Chesterfield, MO 63005 (800) 989-USB1 (8721).

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