



Trends in Pesticide Use on Transgenic versus Conventional Crops

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Characteristics and commercialization of transgenic crops

Since 1996 the large-scale cultivation of commercial transgenic (genetically engineered) crops has grown continuously, with a total of 114 million hectares cultivated in 23 countries in 2007¹. Most crops are modified with one or both of two main agronomic input traits—herbicide tolerance and insect resistance.

Crop tolerance to otherwise phytotoxic herbicides generally improves weed management, reduces the number and strength of herbicide applications, and allows topical application of herbicide to crop and weeds. Topical herbicide application can replace directed spraying between crop rows and mechanical weed removal, without damaging crops. Replacing mechanical treatment not only reduces fuel consumption but also helps conserve soil types vulnerable to erosion and compaction. Transgenic herbicide-tolerant crops also permit more flexibility in the timing of herbicide application. The new “post-emergence” herbicide treatments for herbicide-tolerant crops may actually replace both “pre-emergence” and “post-emergence” sprays with conventional herbicides.

Herbicide tolerance is achieved through application of one or both of two strategies: the introduction and expression of a gene that codes for a target enzyme that is insensitive to the herbicide; and/or an enzyme that inactivates the herbicide of interest. Herbicide-tolerant soybeans are widely adopted in both North and South American countries, including the United States of America (USA), Argentina, Brazil, and Paraguay. Other herbicide-tolerant crops include maize and cotton in the USA, and canola, which is particularly important in Canada.

In most transgenic insect-resistant crops, resistance is achieved through the introduction of genes for *Bacillus thuringiensis* (Bt) proteins. These proteins, designated Cry (crystal) proteins, occur as crystal-like inclusions in Bt bacterial cells and are insecticidal to specific target insects that ingest them, but not against humans and animals. By introducing the genes for producing very low levels of these proteins in plant tissues, the plants have internal protection against target pests. This strategy has been employed for the control of corn ear worm and stem borers in maize. The larvae of these pests reduce plant performance and harvested product quality, and require careful timing of externally-applied conventional pesticides. Another example, Bt cotton, has genes encoding Bt Cry proteins for prevention of yield and quality problems caused by the cotton bollworm.

Herbicide tolerance and insect resistance can affect pesticide use in transgenic crops carrying these traits. Moreover, these changes in pesticide use may have implications for the environment, given that each pesticide has its own characteristics, with different environmental behavior and toxicity profiles. Thus, the International Union for Pure and Applied Chemistry (IUPAC) instigated a five-year project from 2002 to 2007 to develop an inventory of pesticide use in transgenic crops in order to estimate changes in the environmental impacts of pest management. The outcome of this project is published in various media, including three scientific articles²⁻⁴ of which some details are highlighted below.

Impact of herbicide- and insect-resistant crops on pesticide use

Relevant data on pesticide use are generated by various organizations, such as the United States Department of Agriculture (USDA) and the National Center for Food and Agriculture Policy (NCFAP). These institutions collect data on the application of pesticides to transgenic and conventional crops within the USA, employing surveys of farmer crop protection practices conducted by the USDA's Economic Research Service (ERS), as well as consultation with agricultural extensionists and other experts from industry and academia.

One major trend observed by the USDA is the rapid adoption of herbicide-tolerant soybeans in the USA—89% of all soybeans planted in 2006—coupled with a shift towards the substitution of glyphosate for the other most popular herbicides. For other transgenic crops, including herbicide-tolerant canola, cotton, and maize, the NCFAP surveys show that less herbicide active ingredient is used on transgenic herbicide-resistant crops compared to the amount applied to conventional crops grown in the U.S. The reductions observed by NCFAP ranged from 25% for herbicide-tolerant soybean to 33% for herbicide-tolerant maize in 2004³. Another survey focused on the adoption of herbicide-tolerant canola in Canada². From 1995 to 2000, the adoption of herbicide-tolerant canola increased to comprise more than 90% of all canola planted, and broadcast applications of soil-active herbicides plus post-emergence herbicides were replaced with one application of either glyphosate or glufosinate. As a result, total quantities of herbicides applied decreased approximately 40%². These observations are in line with the generally observed trend towards lower pesticide use on transgenic crops³.



Other developments that occur simultaneously with the increased use of transgenic crops may affect the relative impact of transgenic crops on pesticide use. For example, in conventional crops, there is now an increasing trend towards using low-rate herbicides and insecticides. Another development that may affect the observed decrease in herbicide use on transgenic crops is the emergence of herbicide-tolerant weeds, as has been previously observed with other herbicides. Thus, increased weed tolerance to the target herbicide may require the use of other, more potent herbicides, potentially reversing the trend to increased rather than to decreased usage of herbicides.

The interest in transgenic crop technology is expanding to other crops, such as transgenic herbicide-tolerant beets, e.g., sugar beet and fodder beet. These beets are not yet commercialized within the European Union (EU); nonetheless, beets resistant to glyphosate and glufosinate are the subject of a number of investigations into their agronomic practices and/or environmental impact in Europe. Beet crops are particularly sensitive to weed infestation, requiring multiple herbicide applications in conventional beet fields to prevent yield losses. Various prospective studies indicate that the introduction of herbicide-tolerant beet crops could result in a savings in the number of and quantity of herbicide applications needed for adequate weed control⁴.

Similarly, adoption of insect-resistant crops reduces pesticide use; reductions in the number and quantity of insecticide applications are noted, particularly for Bt cotton in the USA, as well as in Australia, India, China, and South Africa. Bt cotton is also incorporated into integrated pest management practices because growers can avoid broad-spectrum insecticides that kill both target and beneficial insects³. Reduced insecticide usage in new transgenic insect-resistant cotton and maize lines also directly benefits growers.

Environmental impact assessment of altered pesticide use

The environmental behavior and toxicity profiles of most pesticides differ from each other. Therefore, merely a reduction in the amount of pesticides applied to crops, by itself, may not provide sufficient insight into their environmental impacts. Various indicators are available that predict the environmental impact of pesticide use. These indicators usually equate the quantities of an active ingredient per acre of crop to the environmental impacts, the form of which may differ, ranging from predicted levels of water contamination to the toxicity to environmental organisms.

In a previous study³, we used the Environmental Impact Quotient (EIQ) to translate the amounts of pesticides used on transgenic and conventional crops into comparable figures for predicted environmental impacts. The EIQ, originally developed by Cornell University for the extension of integrated pesticide management in horticulture, is also widely used to assess the impact of policies on pesticide use in general. The EIQ addresses three factors: the consumer; the agricultural worker; and the ecosystem (fish, birds, bees, and beneficial insects), separately or in combination. The input data include pesticide toxicity and environmental behavior (e.g., uptake by plants, persistence in soil, and leaching), and the result is an abstract number (environmental impact [EI] per surface area). EI values allow for the comparison of outcomes for different pesticide treatments, where lower values indicate less predicted environmental impact.

EIQ methodology has been applied to data obtained from the previously mentioned NCFAP study on pesticide use on transgenic and conventional crops in the USA in 2004. As mentioned above, studies by NCFAP show that less herbicide is applied to herbicide-tolerant crops. Therefore, the reduction in environmental impact for herbicide-tolerant crops is greater than the reduction in quantities of pesticides applied, corresponding to less impact per herbicide quantity applied. These environmental impact reductions are found whether consumers, agricultural workers, and the ecosystem are considered together or separately. This positive impact is most pronounced in soybean, showing a 68% reduction in the predicted adverse impact on farm workers³.

Similarly, Brimmer and co-workers² also used the EIQ model to evaluate data collected on Canadian herbicide-resistant canola. Similar to the reduced herbicide quantities used in canola fields mentioned above, the predicted EI of herbicides (EI per hectare) applied to herbicide-tolerant canola is consistently lower than that for herbicides applied to non-tolerant canola. With the increasing level of adoption of herbicide-tolerant canola, this also leads to an overall decrease in predicted environmental impact for weed management in that crop².

Concluding remarks

In addition to the currently marketed herbicide-tolerant and insect-resistant crops, transgenic crops are being developed with other traits that may also have a large impact on pesticide use. For example, planting blight-resistant potato could substantially reduce fungicide use on the considerable area of potato crop land. In addition to the further evaluation



of environmental impacts, it would be worthwhile to investigate the potential impacts of altered pesticide use on pesticide residues within transgenic crops. This issue is being explored within an IUPAC follow-up project.

References

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