# *Benefits of Biotech Specialty Crops: The Need for a New Path Forward*

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As an entomologist, I work on insects affecting vegetables. This puts me in an interesting situation because every year when I see the ISAAA[1] reports—showing rapid growth in cultivation of genetically engineered soybean, maize, cotton and canola—I say, "Where are the vegetables? Where are the specialty crops?" It's ironic that the second crop to be transformed, by Monsanto, was tomato, for resistance to tomato fruitworm (*Helicoverpa zea*[2]), with a *Bt* protein. That was in 1985 or 1986, and yet we don't have any tomatoes on the market that are genetically engineered to resist insects. I keep hoping that the next ISAAA report will contain data on vegetables.

Vegetables are an important part of the human diet. Calories can be provided by cereal crops, but for nutrition—especially in the developing world, where malnutrition, or "hidden hunger," is prevalent—promotion of vegetables is needed. I'm not a vegetarian, but I eat a lot of vegetables; they're good for you, we need more of them in the human diet.

## Insecticides Applied to Vegetables

Vegetable farmers usually earn higher incomes per unit area compared to cereal producers. Vegetables are high-value commodities, but high cosmetic standards are applicable, as for papaya (described by Dennis Gonsalves[3]). Many are eaten fresh, which means that they're intensely managed with frequent use of "traditional" insecticides. The data in Figure 1 will surprise a lot of people. It shows that worldwide insecticide use on major crop groups costs $10.6 billion. Some 45% of the value of insecticides used is applied to fruits and vegetables. Furthermore, the amount applied to fruit and vegetables is 1.5 times higher than the total applied to cotton, corn and rice. So, the fresh products that we want to encourage people to use are getting blasted by insects and diseases.

[1]International Service for the Acquisition of Agri-Biotech Applications.
[2]Also known as the cotton bollworm and corn earworm.
[3]Pages 37–46.

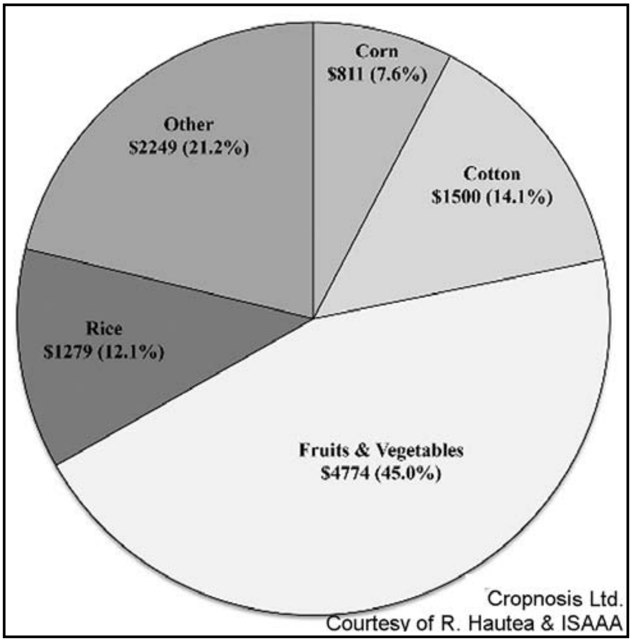


Figure 1. 2010 worldwide insecticide use on major crops (millions of US$).

After receiving an undergraduate degree in philosophy, I wanted to do something practical. Being interested in environmental issues, food security issues, and biology, like a lot of colleagues my age I read *Silent Spring*. In the last chapter, "The Road Forward," Rachel Carson says, "Why don't we use things like insect viruses, insect bacteria, insect fungi, and pheromones to control insects? Why are we using DDT and organophosphates and carbamates?" That resonated with me. So with my little philosophy degree in hand, I went to graduate school in entomology. I've always remembered *Bacillus thuringiensis*, a most interesting bacterium. Many strains exist, very safe for humans and the environment. I used it as a foliar insecticide in my graduate research. You'd spray it on and you'd have to spray it on two or three days later because it broke down so quickly in sunlight. Then someone had an idea: Why don't we engineer into plants the gene for producing the insecticidal protein? And now this second- or third-rate foliar protein is present on about 70 million hectares worldwide, in maize, soybean and cotton.

## *Bt* Potato

We haven't had a great track record with *Bt* vegetables. The first was *Bt* potato, commercialized in 1995 to control the Colorado potato beetle, a primary defoliator in North America and Europe, resistant to many insecticides, with control costs of $140 to $300 per acre. When *Bt* potato appeared—a Monsanto product—growers liked it. In the second year it doubled in sales, and in the third year it doubled again (Figure 2).

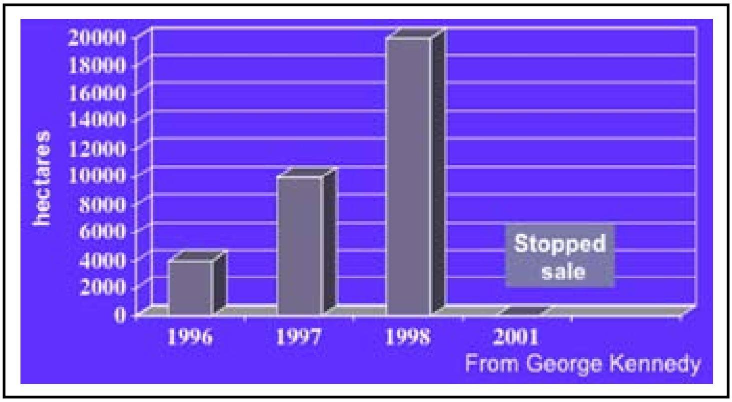

Figure 2. Rise and fall of *Bt* potato.

However, by 2001, it had fallen by the wayside. There were biological reasons, business-management reasons, and social reasons for the demise of the *Bt* potato:

- It controlled only Colorado potato beetle. It didn't affect aphids or leafhoppers.
- Only one *Bt* variety was available. Granted it was Russet Burbank, which is commonly grown.
- There were sporadic yield problems.
- The need for refuges—planting a non-*Bt* variety nearby—was new to potato growers.
- There was debate on the safety of GMOs, and
- Market consolidation.

Most ironically, a new class of insecticides, the neonicotinoids, had become available in 1995. They controlled aphids and leafhoppers as well as Colorado potato beetle. One new science technology won over another. It's noteworthy that neonicotinoid insecticides are now making the front pages of newspapers because of concern over killing bees and other organisms—and we still don't have *Bt* potatoes.

## *Bt* Eggplant

At Cornell, we are trying to bring new technologies to developing countries. The eggplant fruit and shoot borer (Figure 3) is a caterpillar that farmers "traditionally" try to control by spraying a cocktail of organophosphates, carbamates and pyrethroids, each of which has some human toxicity (Figure 4). This approach doesn't work too well. Sometimes 80 sprays are required on a crop that reaches maturity in 80 to 90 days.

Mahyco, a seed company in India, produced *Bt* eggplant. Figure 5 shows Dr. Usha Barwale Zehr from Mahyco giving seed of genetically engineered eggplant to Dr. C. Ramasamy, vice chancellor of Tamil Nadu Agicultural University, who will pass it along to his plant breeders for incorporation of the *Bt* trait into locally grown, open-pollinated varieties. The idea is for Mahyco to sell these as hybrids to make some money, but also to disseminate the technology. The superior performance of *Bt* eggplant over its non-genetically engineered, repeatedly sprayed, counterpart is clear in Figure 6.

Figure 3. Eggplant infested with fruit borer.

Figure 4. "Traditional" control of eggplant fruit and shoot borer in India. Although insecticides are toxic, farmhands are often unprotected.

Figure 5. A gift of *Bt*-eggplant seeds to the vice chancellor of Tamil Nadu Agricultural University.

Figure 6. *Bt* eggplant (right) compared with its non-GM counterpart.

The *Bt* eggplant (locally "brinjal") went through ten years of field trials, and safety trials, and then Greenpeace entered the piece. Figure 7 shows a protest in Tamil Nadu. The woman, an activist, is giving a member of the state legislative assembly what she called the "last non-GM eggplant" that will be had in Tamil Nadu if the *Bt* genotype is commercialized. Greenpeace is good at attracting publicity, whereas we try to talk science to


Figure 7. Activists present a GM-free bouquet, including eggplant, to a state assembly member to protest GM-food-crop commercialization and research in Tamil Nadu.

people and it doesn't always work. Greenpeace also held monthly anti-GM seminars by scientists, including Gilles-Eric Séralini (University of Caen, France) and Jeffrey Smith (Institute for Responsible Technology, Iowa) and disrupted a field trial at Tamil Nadu Agricultural University

It has been estimated that Greenpeace spent $100 million to derail *Bt* eggplant. Under what pretense? They have admitted that they see GM as a good fundraiser, something that garners public attention. Greenpeace can talk about global warming, over which people feel they have little control. In contrast, they do feel control over the products they consume. Consequently, Greenpeace has focused on GM, to their detriment as a credible NGO.

What's the final story? The minister for the environment, the last gatekeeper for *Bt* eggplant in India, enacted a moratorium in 2011, which is where it now sits. One lesson is that you can't outspend Greenpeace; they have deep pockets. If there is no political will, registration will not occur. On the other hand, if farmers have the will, things can happen. And if *Bt* eggplant is deregulated and commercialized in Bangladesh right next door, it will probably make its way into India, as did *Bt* cotton, which came into India before it was legal, smuggled in from somewhere. You can't control this technology if growers really want it. Of course, it would be much better if the minister for the environment had the political will to deregulate the genetically engineered, insect-resistant genotype.

## *Bt* Sweet Corn

*Bt* sweet corn in the United States is a more successful story. It's a *Bt*11 event from Syngenta that was registered for field corn and then crossed into sweet corn. Commercialized in the mid-1990s, the ride since then has been interesting (Figure 8). In 1999 it was grown on about 30,000 acres in the United States, and then, at about the same time as the controversy over the *Bt* potato, it crashed. However, since 2000, the acreage has steadily increased showing that growers like it. Despite export concerns for processors, farmer-adoption continues and in 2008 (the most recent data) it had ~9% of the total fresh market acreage.

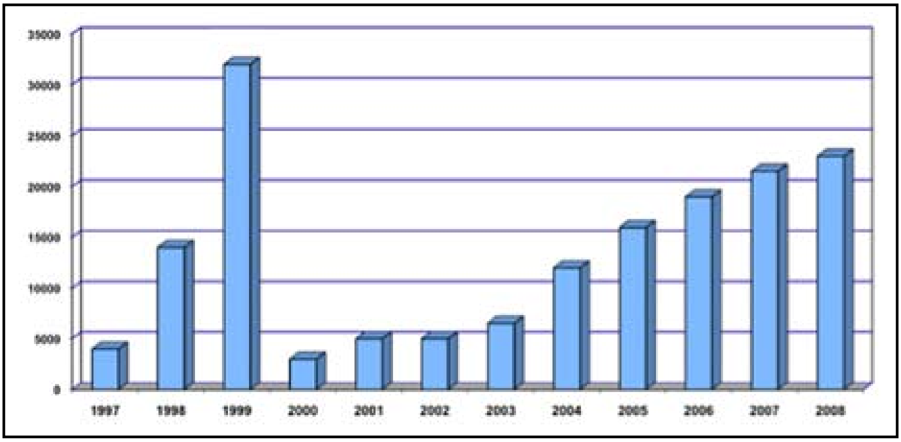


Figure 8. *Bt* sweet-corn product adoption in the United States (acres).

In 2011, Seminis Seeds came out with a two-*Bt*-gene version of their 'Obsession' sweet corn, which we field-tested in comparison with its non-*Bt* counterpart. We compared yields based on spraying either zero, four, or eight times with the insecticide "Warrior" (Figure 9). Without *Bt* and insecticide, only 6% of ears were marketable, with 94% unmarketable;

**Clean ears (%) vs frequency of Warrior II application**

| | Applications of Warrior II | | |
|---|---|---|---|
| Variety | 0 | 4 | 8 |
| Obsession Plus (Bt) | 100.0 ± 0.0a | 99.0 ± 1.0a | 100.0 ± 0.0a |
| Obsession | 6.0 ± 3.5b | 10.0 ± 2.0b | 18.0 ± 10.9b |

Means (±S.E.) followed by the same lower-case letters within a column are not significantly different (Fishers LSD means separation test, $P>0.05$)

Figure 9. Evaluation of *Bt* sweet-corn varieties combined with Warrier II applications against Lepidoptera, 2010.

it was a bad year for corn earworm. Even when we sprayed eight times, only 18% of ears were marketable. 'Obsession' with two *Bt* proteins produced 99% to 100% marketable ears, even without insecticide. That growers like the technology is understandable.

In 2012, when this was coming to market, Whole Foods stated that they would not carry it, possibly because it was associated with Monsanto, which owns Seminis Seeds. Protestors sent 460,000 "anti" signatures via email to Walmart, the biggest food market in the world. To their credit, Walmart responded, "No. We are going to sell it. We looked at the science and we looked at our customers, too, and we said, 'Yes. We will do it.'" Different customers go to Whole Foods from those who shop at Walmart, but more go to Wal-Mart rather than to Whole Foods.

## Virus-Resistant Bean

In Brazil, Embrapa[1] scientists are producing a virus-resistant common bean (*Phaseolus vulgaris*). They have worked for 10 years to achieve resistance to bean golden mosaic virus, which is transmitted by a white fly (*Bemisia tabaci*). It has been estimated that annual losses from BGMV would feed 18 million Brazilians. They expect it to be commercialized in 2014 or 2015, since the Brazilian government has the political will and they have scientists like Dennis Gonsalves[2] with the passion to carry things through.

## Event-Based Regulations

Will there be other products to come? I keep asking myself why genetically engineered, specialty crops are not more widely used. Roger Beachy[3] touched on many of the reasons. Event-based regulations—as an entomologist, this really floors me. What is the rationale for putting together a regulatory package on a Cry1Ab protein for tomato, when we know so much about it in other crops? Why do we need a new set of studies on non-target organisms? Or on allergenicity? The process should be streamlined to put this technology out where it's really, needed. The *Bt* sweet corn actually piggybacked on field corn. Groups of crops may be packaged together, such as tomato, crucifers and other vegetables that are relatively small markets in which large companies have little interest.

## Public-Acceptance Criteria

I'm also interested in public acceptance of GM products. Gonsalves pointed out that the genetically engineered papaya looked good and tasted good, which is why it has achieved broad consumer acceptance. A couple of studies suggest that consumers in North America will accept *Bt* sweet corn. One of my favorite studies was in Canada at a farm market. A farmer labeled *Bt* sweet corn and conventional sweet corn. He labeled one as a GM product and explained that it expressed a bacterial protein that would kill insects but not harm people. The other product was labeled as having been sprayed with various traditional insecticides. The GM sweet corn outsold the conventional corn 60:40. Once people became informed, they choose GM.

[1]Equivalent to USDA-ARS.
[2]Pages 37–46.
[3]Pages 19–28.

In a study in a Philadelphia supermarket, people looked at the quality of the sweet corn, the freshness, and if it was labeled "genetically engineered"; they really didn't care. Quality was more important than how it was produced.

What about public-sector production of these vegetables? Figure 10 shows a list of genetically engineered specialty food crops—produced at land-grant universities in Colorado, Illinois, Michigan, New York, Missouri and North Carolina—and where they are in the regulatory process. In most cases, the target is a horticultural characteristic. In one case, in Illinois, the target is an anticancer compound. Transgenic specialty crops can dramatically reduce the need of traditional pesticides. Dennis Gonsalves has shown this. Sweet corn evidence shows it also. But other characteristics would have even greater immediate appeal for consumers: products that will make them look better or change their health in some positive way.

Clearly, public education is essential, but it's challenging. Surveys show that 50% of people do not want genes in their food, which reveals the scope of the problem. Perhaps broad acceptance will occur first in developing countries where food security issues are

| Crop | Target | LGU | Process | Reg. Status | Constraint |
|---|---|---|---|---|---|
| Apple | Scab | CU | Intragenic | Not applied | Partner |
| Apple | Fire blight | CU | Gene express. | Not applied | Partner |
| Apple | Ornamental | CU | Knockout | Not applied | Partner |
| Apple | Flowering | IL | Transgenic | Not applied | Partner |
| Blueberry | Cold Tolerance | MSU | Transgenic | Not applied | Consumer |
| Blueberry | Herbicide Tol. | MSU | Transgenic | Not applied | Regulation |
| Blueberry | Early Flowering | MSU | Transgenic | Not applied | Regulation |
| Blueberry | Cold Tolerance | MSU | Transgenic | Not applied | Consumer |
| Blueberry | Early Flowering | MSU | Transgenic | Not applied | Consumer |
| Brassica | Salt tolerance | MSU | Transgenic | Not applied | Partner |
| Brassica | Anti-cancer | IL | Transgenic | Not applied | Consumer |
| Celery | Herbicide Tol. | MSU | Transgenic | Not applied | Regulation |
| Cherry | Virus resistance | MSU | Transgenic | Not applied | Consumer |
| Citrus | Disease/Insect | TAMU | Transgenic | Applied | Regulation |
| Citrus | Insect res. | CU | Transgenic | Not applied | Partner |
| Grape | Fruit rot | CU | Transgenic | Not applied | Consumer |
| Grape | Bacterial res | CU | Transgenic | Not applied | Consumer |
| Grape | Disease res. | MO | Knockout | Not applied | Consumer |
| Peanut | Virus res. | MSU | Transgenic | Not applied | |
| Potato | Drought tol. | MSU | Transgenic | Not applied | Consumer |
| Potato | Late blight | MSU | Intragenic | | |
| Potato | Disease/Insect | TAMU | Transgenic | Not applied | Regulation |
| Tomato | Nematode res. | NCSU | Amplification | Applied | Partner |
| Tomato | Virus res. | NDSU | Transgenic | Not applied | Licensing |
| Tomato | Disease res. | NCSU | Transgenic | Not applied | Licensing |
| Tomato | Vaccine | IL | Transgenic | Not applied | Partner |

Figure 10. Genetically engineered specialty food crops: research, regulation and constraints.

most acute. Technology may be developed in the United State, go out to developing countries, and then come back. But what really is needed is a political will. Political will and scientific evidence can be combined in an informed society to create good public policy. And that public policy can welcome products developed with modern science and biotechnology. It was very disappointing in India when the minister of the environment overrode his scientific committee. We need political will, we need scientific evidence, and we need social infrastructure with which to create policies that will foster the adoption of genetically engineered specialty crops (Figure 11) that benefit society.

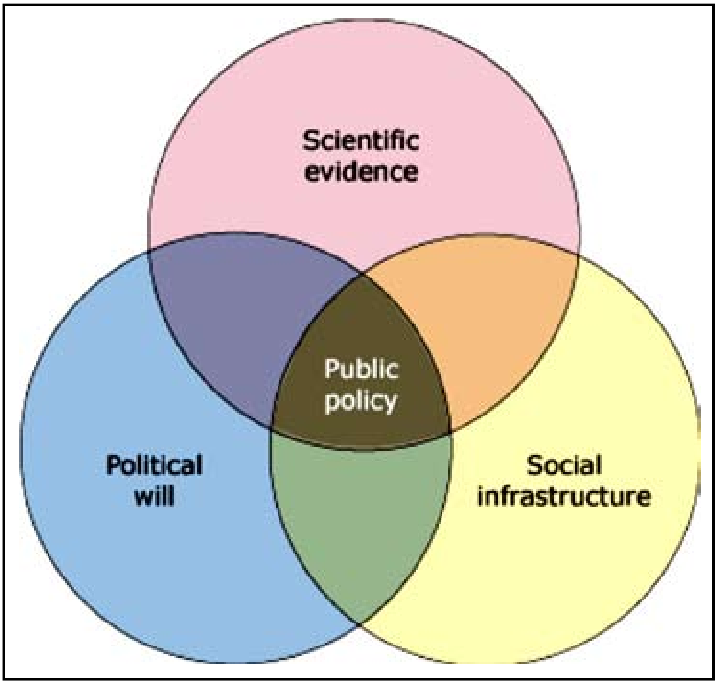


Figure 11. Factors necessary for the adoption of genetically engineered specialty crops.