

# *A Perspective on Actual Versus Potential Environmental Benefits of Agricultural Biotechnology*

Remarks By:

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Case Statement for the Pew Initiative on Food and Biotechnology Meeting:

## **Environmental Savior or Saboteur? Debating the Impacts of Genetic Engineering**

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No doubt about it – biotechnology offers a powerful set of tools to advance the science and art of food production. I am sure that agricultural biotechnology will eventually deliver significant environmental and consumer benefits, and maybe even economic benefits to farmers. But so far, it surely has not done so.

Discussing the generic environmental or public health risks and benefits of “ag biotechnology” is about as nebulous as a similar assessment of the pros and cons of “energy production technology.” Obviously, a hydroelectric dam entails very different technologies, impacts, risks and costs compared to a nuclear or coal fired power plant. The same is true of agricultural biotechnologies. To have a meaningful discussion of ag biotechnology’s impacts on the environment, we have to get grounded and be specific.

We must ask how an ag biotechnology has actually changed farming systems. Then, we must weigh all the positive and negative consequences of those impacts, to the extent possible, given that there are also substantial uncertainties about longer-run impacts.

In the real world, contemporary GMO crops encompass herbicide tolerant (HT) varieties genetically engineered to resist certain weed killers and crops engineered to be resistant to certain insects, by expressing a natural bacteria toxin in plant cell tissues.

Herbicide tolerant crops account for about three-quarters of all acres planted to GMO crops, both in the U.S. and worldwide. For this reason HT crops must be a major focus when assessing the environmental impacts of ag biotech.

Herbicide tolerant soybeans account for over two-thirds of the total acres planted to HT varieties. HT corn and canola account for nearly all other HT acres planted. Roundup Ready (RR) soybeans, engineered to tolerate applications of Monsanto’s

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glyphosate herbicide, have been by far the most widely planted GMO crop, accounting for about half the total GMO acreage in the U.S. and worldwide.

About 12 to 15 percent of the acres planted to GMO crops have been varieties engineered to express in their tissues a natural insecticidal toxin from the bacterium *Bacillus Thuringiensis* (*Bt*). *Bt* cotton and corn dominate this category. The rest of the acres planted to GMO crops have been so-called “stacked” varieties engineered to be both herbicide tolerant and produce *Bt* toxins in plant tissues.

The major environmental benefit of HT crops is supposedly reduction in the use of herbicides. This claim does not square with official USDA data on soybean herbicide use, nor does it really make any sense when you think about it for a minute. The purpose of engineering a plant to be HT is to make it possible for a farmer to rely more heavily on a particular herbicide. Farmers pay \$7.00 to \$9.00 more per acre for HT seed and are thus likely to take advantage of the HT trait triggering premium prices. They do this by applying a particular herbicide, usually more than once, over the top of a growing crop – applications that would be deadly to an unengineered plant variety.

Plus, the herbicide that dominates the world of HT plants, Monsanto’s Roundup, is applied at a relative high rate per acre – about 0.75 pounds per acre. Many soybean farmers apply Roundup twice or three times per crop year, and also treat their land with another kind of herbicide designed to control grasses over a long period of time. These residual grass control products usually are applied at a rate falling between 0.75 and 1.25 pounds per acre. So, the average acre planted to Roundup Ready soybeans are sprayed with 1.75 to 2.75 pounds of herbicides per acre. By any measure this is heavy herbicide use, especially compared to popular “low-dose” weed killers on the market today.

There are over a dozen herbicides widely used by soybean farmers that are applied at rates of one-tenth of a pound per acre or less; a few are so potent it takes only one-one hundredth of a pound to keep target weeds in check. Another half-dozen major products are applied at moderate rates – 0.1 to 0.5 pounds per acre. How can switching from a weed management system that requires one to two applications of low- and/or moderate-dose herbicides to a RR system dependent on nearly 3 pounds of herbicides reduce the pounds of herbicides applied? The answer is it doesn’t and never will.

On the positive side, Roundup herbicide is one of the safest to mammals and hence poses few risks to the average person, farm animals or wildlife. RR soybeans also have increased the adoption of no-tillage planting systems, which help reduce soil erosion rates – an unmistakable environmental benefit. But regrettably, these benefits of RR plant technology are not the full story. There is a dark side to RR technology that scientists are now unraveling and that farmers are just learning about.

Everyone on this panel will agree that the major environmental benefit of producing soybeans stems from this plant’s natural ability to affix nitrogen from the atmosphere through the good work of symbiotic Rhizobium bacteria that colonize the roots of soybeans. Not only does soybean nitrogen (N) fixation meet the needs of the

soybean crop, it also produces an excess that allows farmers to cut N fertilizer rates the next crop season, when corn would typically be grown in rotation with soybeans.

But in 2000 field work, a team of University of Arkansas scientists found that Roundup sprayed over the top of RR soybeans, just as farmers would do, delays and decreases nitrogen fixation and retards soybean root development. The adverse impacts on yields – up to 25 percent -- were greatest in dry fields where the plants are also dealing with drought stress. The environmental damage stemming from lessened N fixation and root development on fields planted to RR soybeans more than off-sets any other benefits.

Equally worrisome, U.S. and Canadian researchers have recently documented in both RR soybeans and RR canola that the genetic modification needed to make crops tolerant of Roundup herbicide sets the stage for other plant health problems, especially when plants are battling other sources of stress caused by, for example, excessive cold or high pest pressure, or a mineral or microbial imbalance in the soil.

These indirect plant health problems arise because the genetic material moved into RR crops to make them tolerant of Roundup modifies the normal functioning of a key biochemical pathway that also happens to trigger and regulate a plant's immune response. Unfortunately, it now appears that RR crops are more vulnerable to certain diseases and insect pests under some relatively common circumstances, which will in the long run either increase the use of other pesticides or decrease yields. Either outcome is bad news for farmers and the environment.

Herbicide tolerant crops have been hugely popular with farmers because they simplify a complicated job – managing weeds. Economically, HT technology is about a wash; the premium paid for seed is saved in lower herbicide costs. (Demand for Roundup Ready crops has triggered a herbicide price war lowering average product prices by 40 percent since 1996; herbicide expenditures per acre have declined despite an increase in pounds applied). Unlike insects and plant diseases, which are not a big problem on tens of millions of acres of cropland each year, weeds must be dealt with on every acre, every year by every type and scale of farmer, as well as by back-yard gardeners. This never-ending need to deal with weeds leads to another suite of environmental problems, given today's level of reliance on RR soybeans.

Excessive reliance on any single weed management tool (like Roundup herbicide) triggers shifts in weed species toward those less vulnerable to a given control tactic. In some cases, excessive reliance leads to the emergence of genetically resistance weeds. For example, some once-sensitive weeds can now survive even heavy applications of Roundup.

Pesticide use reduction is also the major environmental benefit claimed for crop varieties engineered to express natural *Bt* toxins in plant tissues. In the case of *Bt* cotton, USDA pesticide use data do show a correlation between the planting of *Bt* cotton and reductions in cotton insecticide use in several states, but not all.

In the case of *Bt* corn, the data are equally clear but this time show that *Bt* corn has not appreciably changed corn insecticide use. This is true for a simple reason – few farmers spray corn to manage the European corn borer (ECB), the insect that today's *Bt* corn varieties are engineered to kill. By far the majority of corn insecticide use is applied to manage soil insects such as rootworms and cutworms. These insects are, by the way, the targets of the next generation of *Bt*-corn technologies now under development by Monsanto, Dow AgroSciences-Pioneer, and Syngenta.

While it is true that natural *Bt* toxins are a much safer way to poison insects than today's conventional insecticides, from the perspective of mammals, *Bt* crops have multiple other impacts on farming systems that may in the end undermine their effectiveness and/or lead to secondary pest, agronomic, or environmental problems.

One set of problems stems from the fact that *Bt* crops express toxin throughout the tissues of a plant and throughout the growing season. This increases the chance for harm to non-target species including Monarch butterflies and a variety of insect predators, the so-called “good bugs” that help keep dozens of insect pests in check through natural biological control processes. It also increases what scientists call the “selection pressure” imposed on target insects. The greater the selection pressure, the higher the chance that genetic resistance will emerge in the target pest population.

The emergence of resistance to pesticides and *Bt* toxins is a fact of farming life and happens through similar mechanisms. Yet no one knows what the full range of adverse impacts will be as various insects develop resistance to *Bt*. Judging from past history, resistance is never a positive development. In the case of such an important, ubiquitous natural insect toxin, the implications could be serious if once innocuous insects rise to major pest status because their populations are no longer capped by exposure to natural *Bt* toxins emitted by soil bacteria.

Let me close by highlighting what many scientists fear will be the most significant, long-lasting negative environmental impact of today's ag biotechnologies. To get the *Bt* gene or RR gene into a corn, soybean, or canola plant, biotechnologists have to use plant virus-based vectors to overcome the plant's natural defenses against the introduction of foreign DNA. Once the new genetic material is ferried inside plant cells by a viral vector, or shot inside a cell by what is called a gene-gun, powerful promoters must also be used to get the genes to function (i.e., express themselves, thereby creating in the plant a new genetic trait or capability).

Plants have evolved elaborate mechanisms to keep foreign DNA out, to detect it when it does find its way into a plant's cells, and to, in effect, either get rid of it or silence its expression. The job of a plant biotechnologist is to turn off, sneak around, or just overpower these natural mechanisms used by plants to guard against deleterious genetic mutations.

The problem is that some of the impacts that follow applications of the tools of biotech – viral vectors and gene promoters – are indiscriminate, uncontrollable, and

changeable over time. It is now accepted that these tools can speed up, or otherwise change the evolution of other organisms that come into contact with GMO plants. Such changes have been documented in soil microbial communities, as well as in the digestive tracks of mammals that have consumed food or animal feed from GMO plants. Of greatest concern are the impacts on bacteria, organisms known as the most promiscuous of all life forms because of their ability to freely exchange genetic traits among themselves in what amounts to an endless quest to be the “perfect” bug.

It is possible that the prominence of genetic engineering techniques and tools, and the widespread availability of GMO drugs, animals and plants, is actually tipping the evolutionary scale in favor of bacteria, the cause of most infections in people. With us humans, evolution gets at most one shot per year and over a woman’s lifetime, just a few chances to come up with advantageous new combinations of genetic traits to better ward off bacterial infections and other diseases.

Bacteria and most disease organisms, on the other hand, go through dozens to hundreds if not thousands of generations in the time it takes for a life-cycle (generation) of a human, a rose bush, or an apple tree. Any technology that enhances the natural ability of bacteria and other microorganisms to adapt, evolve and survive through gene exchange could make it that much harder for humans, and scientists to keep up with the evolution of new bacteria. The human health impacts of speeding up the pace of evolutionary change in bacteria compared to people could be of monumental consequence.

What about tomorrow’s ag biotechnologies? Will they be more likely than HT crops and *Bt* varieties to deliver durable environmental and consumer benefits?

Again, the tools and technology clearly have that potential, but the signs are not encouraging. First, people need to know that the tools of biotechnology, and increasingly the world’s stock of germplasm, are largely under the control of a half-dozen large corporation’s. These so-called “Gene Giants” have invested billions in gaining strong patent positions and intellectual property rights (IPRs) in order to limit the use of the core tools of ag biotechnology and plant germplasm, except of course under a license and generally for a fee.

Just a handful of companies – Monsanto, Dupont/Pioneer, Syngenta, Bayer-Aventis, Dow AgroSciences, and BASF -- control when and how, and for what purpose ag biotechnology will be deployed. Given that these corporations must earn a respectable return on stockholder equity, they have an obligation to use these tools only when there is a good chance that a saleable product – a new variety – can be produced that will deliver solid profits sufficient to compete with other investments and business opportunities.

Also remember that these same companies offer a wide range of synthetic pesticides designed to manage the same pest problems that GMO plants strive to address. Circumstances have and will arise when a biotech-seed-pesticide company has to choose between investing in a new genetics-based or chemical technology to help farmers deal with a given pest problem. The typical example will entail use of conventional plant

breeding techniques, perhaps bolstered by “soft” applications of ag biotechnology like marker-assisted breeding, to produce a new plant variety that should negate the need to apply a given pesticide.

Historically the seed industry has earned profits on the order of 10 percent to 20 percent on each dollar of sales, while the pesticide industry has delivered a much greater return, typically on the order of 25 percent to 30 percent (albeit still shy of returns earned by pharmaceutical companies!). Does it make sense for a company to invest R+D funds to produce a plant variety that will cut sales of a more profitable solution to the same problem, sold by the same company? Sure, from the perspective of the farmer and society. This outcome though is likely to be the exception rather than rule as long as private companies retain such strong IPR controls over plant germplasm, the tools of ag biotechnology, not to mention seed and pesticide industry R+D and marketing strategies.

In summary, agricultural biotechnology is a powerful and evolving set of tools. These tools can be used to produce ever-stronger animal drugs and vaccines, plants producing novel kinds of proteins and toxins drawn from any organism on the face of the earth, or ever-more potent strains of anthrax and foot and mouth disease.

On the farm, they can be used to great advantage in understanding and possibly circumventing the genetic and management-based factors that make some plants and farm animals highly productive, where others fair poorly and succumb to disease or pest attacks. Applications designed to understand how organisms interact on the farm will benefit organic and conventional farmers alike, but are now languishing because public funding for such applied problem-solving research has all but dried up and corporations lack a way to capture a return on investment when the primary output from R+D is knowledge leading to ways to avoid or largely mitigate problems, and without having to buy some product.

In humans, the tools of biotechnology are likewise leading to profound new insight into the ways that genetics and lifestyles influence health and well-being. But we must remember, both on the farm and in our own lives, that better understanding of the genetic foundation of good health, and even heightened ability to move genes around, will rarely assure quick or easy cures to the common ailments of the day. Just ask my 15 year-old stepson who had a rendezvous with a tree on News Years day while snowboarding. He has a titanium plate and five screws on his left ankle to remind him of what bones – and good health – are made of.

In announcing this meeting, Pew asks whether ag biotech will be an “Environmental Savior or Saboteur?” So far, it is neither but if current trends and policies continue, the odds are the environment will suffer as today’s high-yield, high-chemical, and homogenous pest management strategies are recycled and perpetuated with the “benefit” of the new tools of biotechnology.

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## For More Information –

Herbicide tolerant soybeans and related environmental issues, see the Ag BioTech InfoNet “Herbicide Tolerance” section accessible at:

<http://www.biotech-info.net/herbicide-tolerance.html#soy>

For an in-depth discussion of problems with Roundup Ready soybeans, see the May 2001 report “Troubled Times Amid Commercial Success for Roundup Ready Soybeans: Glyphosate Efficacy is Slipping and Unstable Transgene Expression Erodes Plant Defenses and Yields”:

- To access the full report: <http://www.biotech-info.net/troubledtimes.html>
- Herbicides applied to Conventional and RR soybeans: Part I
- <http://www.biotech-info.net/troubledtimesfinal-1.pdf>
- Nitrogen fixation and plant health problems with RR soybeans: Part III  
<http://www.biotech-info.net/troubledtimesfinal-3.pdf>

“Plant Growth and Nitrogenase Activity of Glyphosate-Tolerant Soybean in Response to Foliar Glyphosate” – ABSTRACT, by C. Andy King, Larry C. Purcell, and Earl D. Vories, University of Arkansas:

<http://www.uark.edu/depts/agronomy/purcell/pubs/aj01gly.html>

"Herbicide Impact on *Fusarium spp.* and Soybean Cyst Nematode in Glyphosate-Tolerant Soybean" – ABSTRACT, by R.J. Kremer, USDA-ARS, P.A. Donald, A.J. Keaster, H.C. Minor, Univ. of Missouri, American Society of Agronomy Annual Meeting, Title Summary Number: S03-104-P: [http://www.biotech-info.net/fungi\\_buildup\\_abstract.html](http://www.biotech-info.net/fungi_buildup_abstract.html)

“Factors Shaping Trends in Corn Herbicide Use”, Ag BioTech InfoNet Technical Paper Number 5, July 23, 2001: [http://www.biotech-info.net/corn\\_reduct.html](http://www.biotech-info.net/corn_reduct.html)

“Glyphosate Weed Killer Benefits Soil Fungus”, Editors, *Progressive Farmer*, January 03, 2001: [http://www.biotech-info.net/soil\\_fungus.html](http://www.biotech-info.net/soil_fungus.html)

Overview of GMO crop impacts on pesticide use, see “Do GM Crops Mean Less Pesticide Use?” VIEWPOINT in *Pesticide Outlook*, published by the U.K. Royal Society of Chemistry, October 2001,” accessible at:

[http://www.biotech-info.net/benbrook\\_outlook.pdf](http://www.biotech-info.net/benbrook_outlook.pdf)

Insect resistance issues relating to the use of genetically engineered *Bt* crops, see Ag BioTech InfoNet Insect Resistance section accessible at:

<http://www.biotech-info.net/bt-transgenics.html>

Transgene flow technical papers: [http://www.biotech-info.net/gene\\_flow.html](http://www.biotech-info.net/gene_flow.html)

Gene silencing: [http://www.biotech-info.net/gene\\_silencing.html](http://www.biotech-info.net/gene_silencing.html)

Foreign and naked DNA: [http://www.biotech-info.net/FN\\_DNA.html](http://www.biotech-info.net/FN_DNA.html)