THE GOOD, THE BAD AND THE UGLY: IMPACTS OF GE CROPS IN THE UNITED STATES

Scientific achievements in molecular genetics, biotechnology, and plant breeding

Remarkably rapid adoption

A picture is worth a thousand words...

Remarkable commercial success

Stephen Duke and Michael Owen on glyphosate, herbicide-tolerant technology

"...the most rapid adoption of a crop technology in the history of agriculture."

"...the most important change in technology in the history of agriculture."

Roundup Ready (RR) technology largely solved difficult soybean and cotton weed management challenges in the mid-1990s associated with the need to apply multiple, low-dose, often persistent and phytotoxic herbicides

<table>
<thead>
<tr>
<th>1995</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.7 herbicides/acre [hay]</td>
<td>1.7 herbicides/acre</td>
</tr>
<tr>
<td>Tricky timing for optimal control</td>
<td>Wide application window, very forgiving technology</td>
</tr>
<tr>
<td>Damage from carryover and/or phytotoxicity</td>
<td>Few if any problems with carryover or phytotoxicity</td>
</tr>
</tbody>
</table>

Huge commercial success. Profits financed the creation of a new, hybrid, multi-billion $ industry combining assets previously in the separate seed and pesticide industries.

• Changes in patent and intellectual property law and policy created unprecedented opportunities to expand profit margins
• The pesticide industry, for all intents and purposes, took over the seed industry, in the late 1980s – early 1990s
• DuPont purchased the remaining shares of Pioneer Hi-Bred International for $7.7 billion in March 1999, at an 80% premium over the stock’s trading value
Short-term reduction in herbicide use over the first four years of commercial use

- Herbicide-tolerant (HT) corn, soybeans and cotton reduced herbicide use by 14.5 million pounds in 1996-1998, or by about 2%
- Rates have risen steadily since, driven by 10%+ annual increases in glyphosate rates per crop year
- The 90 million pound increase in herbicide use on HT crops, just from 2010-2011, is six-times larger than the short-lived reduction in 1996-1998

Sustained reductions in insecticide use in both corn and cotton, and generally successful mandatory resistance management plans recommended and monitored by mostly independent university scientists

<table>
<thead>
<tr>
<th>GE Insect Pest Management Trait</th>
<th>Reduction in Insecticides (pounds a.i./acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bt corn for ECB &amp; other Lepidoptera insect control</td>
<td>0.06 – 0.23</td>
</tr>
<tr>
<td>Bt corn for corn rootworm and other Coleoptera insect control</td>
<td>0.1 – 0.28</td>
</tr>
</tbody>
</table>

The BAD

Regional, national and global environmental effects from the dramatic increase in reliance on glyphosate and other herbicides

- Glyphosate is found in 60 – 100% of rain and air samples tested in Iowa and Mississippi by the U.S. Geological Survey
- Nearly every stream, river and reservoir in heavily farmed regions contain glyphosate and its degradation products


Rapid and unprecedented increases in farmer’s seed costs, made possible by changes in intellectual property law and policy, and GE trait technology fees

<table>
<thead>
<tr>
<th>Commodity</th>
<th>1980s</th>
<th>1996</th>
<th>Today</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn seed</td>
<td>$60 - $70 / bag</td>
<td>$12.00 / bag</td>
<td>$250 / bag</td>
</tr>
<tr>
<td>Soybean seed</td>
<td>$12.00 / bag</td>
<td>$14.80 / bag</td>
<td>~$45.00 - $60.00 / bag</td>
</tr>
</tbody>
</table>

GE cotton seed costs have risen about six-fold since 1995. GE seed cost over 30% of expected gross cotton income per acre in 2010, compared to less than 5% of gross income in the pre-GE era.

Shift in approximately 30% of historic net corn, soybean, and cotton income per acre from farmers to the seed-bio tech-pesticide industry

Historically high crop prices since 2007 have softened the blow of rising costs of GE crop technology

What will happen when crop prices return closer to historic norms?

Herbicide-tolerant technology has dramatically accelerated the emergence and spread of resistant weeds

- Over 14 million acres in the U.S. are now infested with herbicide-resistant weeds
- 22 weeds now resistant to glyphosate, and more than a dozen now pose an economic threat to U.S. farmers
- Some weeds have evolved resistance via two or more mechanisms of resistance!!!

Herbicide-tolerant technology has triggered the emergence and spread of a boatload of multiple-herbicide-resistant weeds...farmers are not "feeling lucky"

- 108 biotypes of 38 weed species are simultaneously resistant to herbicides in 2 or more families of chemistry
- 44% of multiple resistant weeds have appeared since 2005
- Common waterhemp in the U.S. is resistant to more than 20 currently marketed active ingredients, including glyphosate, ALS, and PPD herbicides

“...it is very unlikely that new herbicides with new modes of action will be available within ten to 15 years.”


No quick herbicide-based fixes on the horizon

Major BAD:

No major new herbicide mode of action has been commercialized in about 20 years**

** “Giereck, "Thirty years of herbicide discovery: surveying the past and contemplating the future.” Agrow (Gray-Allen Edition)

Impacts of Bt corn and cotton on Cry protein endotoxin production

Bt Corn Expression Levels per Plant Tissue: Major Events and Products

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Event</th>
<th>Cry Protein</th>
<th>Plant Stage</th>
<th>Shoot Conc.</th>
<th>Root Conc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dow AgroSciences Pioneer Hi-Bred Herculex® RW</td>
<td>AT 11</td>
<td>Cry1F</td>
<td>R4-5</td>
<td>32,000</td>
<td>0.36</td>
</tr>
<tr>
<td>Monsanto YieldGard® Rootworm</td>
<td>MON 88017</td>
<td>Cry1Ab</td>
<td>R2</td>
<td>32,000</td>
<td>0.412</td>
</tr>
<tr>
<td>Syngenta Agrisure® CB</td>
<td>MON 89034</td>
<td>Cry2Ab2</td>
<td>R4-5</td>
<td>32,000</td>
<td>1.65</td>
</tr>
</tbody>
</table>

Bt Corn Cry Protein Quantities per Land Area: Major Events and Products

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Event</th>
<th>Cry Protein</th>
<th>Plant Stage</th>
<th>Plants/acre</th>
<th>Cry/acre (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dow AgroSciences Pioneer Hi-Bred Herculex® RW</td>
<td>AT 11</td>
<td>Cry1F</td>
<td>R4-5</td>
<td>32,000</td>
<td>0.252</td>
</tr>
<tr>
<td>Monsanto YieldGard® Rootworm</td>
<td>MON 88017</td>
<td>Cry1Ab</td>
<td>R2</td>
<td>32,000</td>
<td>0.288</td>
</tr>
</tbody>
</table>

Corn Expression Levels per Plant Tissue: Major Events and Products

Genetically engineered crops have increased pesticide use in the U.S. by about 400 million pounds over the first 16 years of commercial use

- HT corn, soybean, and cotton have increased herbicide use an estimated 525 million pounds, compared to what use would likely have been in the absence of HT technology
- Bt corn and cotton have reduced insecticide applications by about 125 million pounds since 1996
- First-generation GE crops and traits have increased overall pesticide use by about 400 million pounds (~7%) since 1996

*C. Benbrook et al., 2010. "Estimating the impact of GE Crops on herbicide use: little evidence of reduced use available today"
Dramatic increase in Bt Cry protein endotoxins in corn-cotton production systems...and nearby soil and aquatic ecosystems

Every acre planted to Bt corn for European corn borer control —
• Reduces Lepidoptera-targeted insecticide use by about 0.13 pounds active ingredient per acre, but also...
  • Introduces 0.18 to 0.6 pounds of Bt Cry proteins per acre

Each acre planted to Bt corn for corn rootworm and other soil-borne insects —
• Reduces Coleoptera-targeted insecticide use by about 0.21 pounds per acre, but also...
  • Introduces between 0.5 and 2.5 pounds of Bt Cry proteins per acre

On fields planted to Monsanto-Dow AgroSciences SmartStax corn

• Each plant expresses six different Bt Cry proteins, three for ECB/Lepidoptera, and three for corn rootworm/Coleoptera control
  • Total expression of Bt proteins is 3.73 pounds per acre – 10-times more than the insecticides displaced (0.34 pounds active ingredient [0.13+0.21 pounds])

What about Bt crop endotoxin production compared to natural levels of Bt in soil

<table>
<thead>
<tr>
<th>Natural Bt Soil Microorganisms</th>
<th>Bt Cotton</th>
<th>Bt Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 g/ha*</td>
<td>400 – 1000 g/ha</td>
<td>2,800 – 4,200 g/ha</td>
</tr>
</tbody>
</table>

Bt cotton produces up to 4,000 times more Bt than soil microorganisms, while Bt corn produces up to 16,800 times more.


Clear evidence that Bt resistance is emerging in multiple Cornbelt corn rootworm populations

Why? Bt corn for rootworm control produces only a moderate dose... and over 41% of corn farmers did not comply with mandatory Bt corn resistance-management provisions in 2010.


“Insufficient planting of refuges and non-recessive inheritance of resistance may have contributed to resistance. These results suggest that improvements in resistance management and a more integrated approach to the use of Bt crops may be necessary.”


Growing economic costs associated with GE “adventitious presence” (AP) in non-GE, organic, and identity-preserved corn, soybean, and alfalfa crops, grain and seeds

• Testing costs
• BMPs to prevent pollen flow and seed contamination
• Market disruption and loss of premiums in high-value, GE-sensitive markets

Concern along the corn value chain over Syngenta’s high-amylose GE corn

Developed to facilitate conversion of corn to ethanol, but also alters corn functional traits in food manufacturing at a reported 1 in 10,000 contamination level

High amylose corn is ...“an accident waiting to happen”

Lynn Clarkson, member, AC 21 Agricultural Biotechnology Advisory Committee
First-generation GE corn has undermined 30 years of progress in Integrated Pest Management (IPM), increasing the cost of pest management and enhancing the risk of serious crop losses.

"Within the past 14 years, producers have transitioned from a traditional IPM paradigm (scouting, use of thresholds, and rescue treatments) to that of a less integrated and more insurance-based approach to insect management…" — Michael E. Gray, 2011. "Relevance of Traditional Integrated Pest Management (IPM) Strategies for Commercial Corn Producers in a Transgenic Agroecosystem: A Bygone Era?" J. Agricultural and Food Chemistry, Vol. 59, pages 5852-5858.

Nine reasons contemporary Bt corn technology is incompatible with the principles of IPM

1. Prophylactic treatment not reliant on scouting and thresholds.
2. Inability to target treatments to parts of fields with populations exceeding economic thresholds.
3. Toxin expressed throughout the production season and not just when insects are most vulnerable or actively feeding.
4. Toxin expressed throughout plant, including tissues that are not fed upon by a target insect.
5. The technology is dependent on single, or closely related toxins, increasing risk of resistance and/or cross-resistance.

Factors strengthening the case that Bt corn and cotton are compatible with IPM

1. Fall scouting to determine likely pest pressure in the subsequent season, coupled with adherence to economic thresholds prior to planting of a Bt or other transgenic variety.
2. Insect-feeding damage is required to trigger production of the defensive response, i.e. Bt toxins in the case of Bt corn or cotton. (So, in the event of no or very low pressure, the plant expends no energy on the biosynthesis of Bt proteins, nor would any transgenic proteins enter the environment).
3. Bt toxin expression is limited to the tissues under attack, and subsides once insect feeding ends.

The resistance clock is ticking, fast

Waterhemp resistant to five herbicide modes of action are expected in 2012

Few, if any, viable chemical options will remain

Non-chemical options are costly and require significant system changes -
- Return to rotations
- Use of heavy tillage to bury weed seeds
- Planting of cover crops.
- Mechanical cultivation and/or hand weeding

...and in response to claims that there are “very few” weed species currently resistant to synthetic auxin herbicides...

“Globally, there are 28 species (resistant to 2,4-D and dicamba) with 14 to 2,4-D, and at least 2 resistant to both active ingredients.”

“...the potential for synthetic auxin-resistant or combined synthetic auxin- and glyphosate-resistant weeds in transgenic cropping systems is actually quite high.”

73-fold increase in the pounds of 2,4-D applied to corn could occur by 2019, compared to the low-point in 2,4-D corn use in 2002 (4% of acres treated)

Key parameters in projecting the increase of 2,4-D use on 2,4-D HT corn

- Dicamba-tolerant corn is not approved or marketed
- Adoption peaks at 55% in 2019 (not!)
- Average rate of application increase from 0.35 pound in 2010 to 0.6 pounds
- Average number of applications increase from 1.1 in 2010 to 2.3 in 2019
- All acres planted to HT 2,4-D corn varieties WILL be sprayed with 2,4-D

Industry push to market next-generation 2,4-D, dicamba, and paraquat herbicide-tolerant crops

High risk gamble, like pouring gasoline on a fire to put it out

Five weed scientists on second-generation HT crops –

“...we expect that synthetic auxin-resistant (2,4-D, dicamba) cultivars will be embraced by growers and planted on rapidly increasing areas in the United States and worldwide over the next 5-10 years.”

Economic damage and neighbor-to-neighbor problems caused by the off-target movement of 2,4-D and dicamba applied on second-generation HT crops

2,4-D drift and volatilization has already become a huge problem on my farm. It has now become an annual occurrence causing significant damage to my farm. Not even the state chemist can determine where this volatilization comes from.”

Dave Simmons, Indiana farmer and member of the Save Our Crops Coalition (SOC)
Drift and volatilization of 2,4-D and dicamba

Even without 2,4-D HT crops, 2,4-D is the #1 cause of crop damage episodes investigated by state departments of agriculture.

2,4-D HT crops will vastly worsen problems because of higher rates and applications later in the crop season.

“Our company was decimated by an instance of 2,4-D exposure. We continue to try to regain the confidence of our customer base, but it may never be the same. I have joined this coalition to see that no other specialty crop producer has to endure the devastation that our farm has experienced.”

Gary Phillips, a Kentucky tree farm and SOCC member

Dealing with the collateral damage from 2,4-D and dicamba applications on second-generation HT crops

“The acrimony in rural areas will be a major concern as this drift damage occurs. To solve the glyphosate resistant weed problem, we will have to pay a big price and that price will be primarily borne by those who receive little or no benefit from the herbicide application.”

Doug Doohan, Associate Professor at Ohio State University

Courts will have a very hard time dealing with 2,4-D and dicamba drift and damage cases

“Our courts and communities are already struggling with the divisive effects of spray drift from genetically altered crops. Right now, this issue is pitting neighbor against neighbor.

“The volatilization issues associated with 2,4-D and dicamba make tracing the source of applications more difficult, and proving liability even for those with devastated crops is costly and uncertain.”

Jean Ann Sieler, an attorney representing growers involved in herbicide drift damage litigation in Michigan and Ohio.

Environmental and public health problems in the wake of massive increases in synthetic auxin herbicide use

Multiple studies link 2,4-D applications in the spring to reproductive problems, spontaneous abortions and birth defects 6-9 months later.

Farm workers in California employed by operations spraying 2,4-D had dramatically elevated risk of non-Hodgkin’s lymphoma (NHL) (odds ratio = 3.8), with female workers facing higher risks.


Economic damage and neighbor-to-neighbor problems from 2,4-D and dicamba movement

Quotes from Save Our Crops Coalition, Press Release, April 2, 2012, and website, access at www.saveourcrops.org

Near-complete failure by government, industry, and farm groups to forestall or prevent herbicide resistance in the face of its virtual certainty

“Farmers are ‘working on the advice largely of industry anymore…Public research is dead; it’s decimated.’”

Troy Roush, Indiana farmer and VP of the American Corn Grower’s Association.
“...the problems associated with GE [genetically engineered] HT [herbicide-tolerant] crops and HR [herbicide-resistant] weeds seem to be largely without resolution attributable, in part, to the general unwillingness of growers to recognize the implications of their management tactics, the unrealistic marketing by the herbicide and seed industries, and the erroneous belief that new technologies and tactics will be available in the short-term future.”


Industry’s near-total success in blocking independent research on GE, pest-management related traits and systems

GE seed “technology agreements” must be signed when purchasing seed, and all provisions are binding. Most agreements contain language to the effect that –

“This seed is for commercial use by farmers growing crops, and may not be used for any research purpose. Use in any trial or study comparing performance to other corn/soybean/cotton varieties is prohibited.”

The loss of an independent seed industry dedicated to solving production problems through varietal development

From the 1950s – 1990s, the major goal of plant breeding research was solving problems confronting farmers, while increasing yield and crop quality.

Beginning in late 1990s, the focus has been on commercializing patentable pest-management-related traits.

Most universities have essentially ended plant breeding work; except 1-3 crops per state, and only in a handful of states.

Unprecedented escalation in the breadth and toxicity of seed treatments

Nicotinyl seed treatments critical in protecting farmers investment in Bt corn for rootworm (CRW) control.

- Lack of a lethal dose of Bt toxin in root tissues early in the growing season.

Virtually 100% of conventional corn seed treated with a systemic, nicotinyl insecticide, plus one to three fungicides.

- Nicotinyl seed treatments are likely important missing piece of the honeybee Colony Collapse Disorder (CCD) puzzle.

Growing evidence of heightened vulnerability of corn and soybeans to a range of plant pathogens, insect, weed, and plant nutrition problems

Declining plant health triggered by changes in genetics, planting densities, and crop management during the GE crop era.

2010 – 11% corn was treated with fungicides (NASS-USDA data).

Less than 1% of corn acres were treated with fungicides in all previous NASS surveys.

Reliance on systemic seed treatments lead to novel exposure pathways for a wide range of non-target organisms (bees, livestock, aquatic invertebrates, people).

Mixing multiple active ingredients in seed treatments increases the risk of resistance emerging in a variety of soil borne insects.
Next-generation transformation technologies likely to be safer and more predictable.

Some next-generation traits likely to deliver meaningful benefits for the environment and consumers, but...

The seed-biotech-pesticide industry has failed to win public trust and skepticism is growing over unfulfilled promises, exaggerated claims (e.g., average doubling of corn yields by 2030), and the adequacy of safety testing.

The public debate over second-generation 2,4-D and dicamba HT crops will likely have a significant, lasting impact on farming systems, regulatory policy, and the PR landscape here and abroad.