Genetically Engineered Crops: Myths and Realities.

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Presented to the Yale School of Forestry and Environmental Studies, February 2003

The Central Premises of GM

The foundational premises of GM agriculture are that:

1) crop genetics is the primary limit to everything from increasing crop yields to lowering pesticide use, enhancing farm profitability, keeping down the price of food, alleviating world hunger and environmental degradation, and even eliminating childhood blindness in the Third World¹. It probably sounds odd to impute simplistic linear causality to such complex issues, but that is pretty much how it has been sold to farmers, consumers, and policymakers.

2) genetic improvement - and specifically GM - can redress these genetic weaknesses and resolve these problems (e.g. yield, pesticides etc), and

3) GM can do this better, faster, cheaper, or more effectively than conventional plant breeding

I will argue instead, that

1) genetic solutions to agricultural problems are of interest primarily because they are proprietary,

2) many of the problems being ‘solved’ by GM are in fact caused not by inferior genetics, but rather, by ecologically dysfunctional production systems.

3) GM interventions prolong and exacerbate system dysfunction (e.g. enviro-pig) because they focus on symptoms - such as pestiferous weeds or insects - rather than causes (dysfunctional systems), this ensuring continued dependence on proprietary solutions

4) the easiest way to ‘solve’ these various problems is just not to create them in the first place, by using production system designs which are problem-avoiding, ecologically sound, and cost-internalizing.

5) The primary reason more holistic, system-based approaches are not being pursued with rigor is specifically because they are not proprietary.

¹Ingo Potrykus, the father of golden rice, stated “If some people decide that they want blind children and white rice, it’s their decision. I’m offering the possibility of yellow rice and no blind children” (cited in GRAIN, 2001).
Supporting Evidence?

How compelling is the evidence to support the premises of GM agriculture?

Premise 1. Genetics is the Primary Limit?

Jared Diamond, in *Guns, Germs, and Steel*, noted that while we typically consider 'necessity to be the mother of invention', in point of fact, 'invention is the mother of necessity' is much closer to the truth - and nowhere more clearly than with GM crops. Why do we 'need' herbicide-tolerant (HT) crops? Or Bt crops? Was 'need' even an issue? Actually, there is precious little evidence that anyone asked farmers what they wanted, any more than Ingo Potrykus asked the Third World how they would choose to address the problem of Vitamin A-deficiency-induced childhood blindness.

It was perhaps predictable the first crops to be fitted with HT genes were corn and soybeans, and the place where HT - and especially HT soybeans - really took off was in the midwest. Why? Because the most common crop rotation in the upper midwest is com-beans-com-beans..... This is an ecologically dysfunctional rotation, in that it opens up a wide niche for spring-vigorous weeds. Both corn and soybeans are warm-season species which are planted a month later than spring cereals, and they grow slowly in cold soils, reaching full cover only well into June or even July. Corn and sometimes soybean are also wide-row crops. This combination presents strong selection pressure - and a large window of opportunity in time and space - for spring-vigorous weeds - hence, the attractiveness of HT.

But the fault is not in the genetics of the corn or the soybean. Rather, it is the design of the production system - management - which is at fault. The HT trait dumbs down the complicated process of herbicide application, but does nothing about the reason why weeds have become so problematic in the first place (Table 1). Roughly 80% of American soybean acreage, much of it in RR soybean, is treated with Roundup at least once a year, often more than once. Thus, HT trait exacerbates the problem by promoting weed resistance - which is evolving rapidly in response to the severe selection pressure imposed by over-reliance on a single approach (herbicides) and to a great extent, a single herbicide (Roundup). Each of the several affected species, and many would add waterhemp to this list, is already resistant to 1 or more other herbicide families.

Genetic solutions to management problems are unhelpful, particularly when compared to approaches which seek to identify the cause and close the niche - for example, by growing a more complex rotation. The same reasoning could be applied to Bt corn, where high N, leaving surface residue which serves as habitat for overwintering European cornborer (ECB) (*Ostrinia nubilalis*), and frequent return to corn have all been identified as factors causal to ECB outbreak. Dealing with causes would seek to close the niches which have been opened through management, rather than treating the symptoms, which simply ensures sustained dependence on proprietary synthetic or plant-produced biocides.
Table 1. Trends in evolution of biotypes resistant to Roundup (glyphosate) (adapted from www.weedscience.com)

<table>
<thead>
<tr>
<th>Species</th>
<th>Where (when?)</th>
<th>Year First Identified</th>
<th>Affected Acreage (affected sites)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horseweed (<em>Conyza canadensis</em>)</td>
<td>Delaware (2000)</td>
<td>2000</td>
<td>10,001-100,000 ac (101-500)</td>
</tr>
<tr>
<td></td>
<td>Tennessee (2001)</td>
<td></td>
<td>100,001-1,000,000 ac (501-1000)</td>
</tr>
<tr>
<td></td>
<td>Indiana (2002)</td>
<td></td>
<td>101-500 ac (2-5)</td>
</tr>
<tr>
<td></td>
<td>Maryland (2002)</td>
<td></td>
<td>501-1000 ac (6-10)</td>
</tr>
<tr>
<td></td>
<td>New Jersey (2002)</td>
<td></td>
<td>101-500 ac (6-10)</td>
</tr>
<tr>
<td></td>
<td>Ohio (2002)</td>
<td></td>
<td>101-500 ac (2-5)</td>
</tr>
<tr>
<td>Goosegrass (<em>Eleusine indica</em>)</td>
<td>Malaysia (1997)</td>
<td>1997</td>
<td>101-500 ac (2-5)</td>
</tr>
<tr>
<td>Italian Ryegrass (<em>Lolium multiflorum</em>)</td>
<td>Chile (2001)</td>
<td>2001</td>
<td>101-500 ac (2-5)</td>
</tr>
<tr>
<td>Rigid ryegrass (<em>Lolium rigidum</em>)</td>
<td>Australia (Victoria) (1996)</td>
<td>1996</td>
<td>11-50 ac (2-5)</td>
</tr>
<tr>
<td></td>
<td>Australia (NSW) (1997)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>California (1998)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>South Africa (2001)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Premise 2. Genetics - and GM - is ‘the way’ to resolve problems?

The promises made for GM range from increasing yield to reducing pesticide use, feeding the world, protecting the environment etc. Independent (not industry-sponsored) evidence is lacking to support virtually all claims, as will be demonstrated below for yield and pesticide use.

**Yield.** Increasing yield is still promoted in the farm press as a rationale for growing GM crops. Many farmers still believe that productivity means profitability, although this ceased to be a valid argument decades ago. Nonetheless, it is attractive, particularly when combined with illusions to ‘feeding the world’ and ‘population increase’ - of which both verge on outright deceit. Millions of people are starving for reasons that have remarkably little to do with crop genetics.

How well does GM actually increase yield? Under what circumstances might an HT or a Bt crop yield more than a non-GM crop? First, recognize that a GM crop is nothing more than a regular crop cultivar or hybrid into which a gene packet carrying typically a single active transgene is inserted. Roughly 99% of all GM crops in commerce to date are either HT (75% worldwide) or Bt (12-15%), or both (stacked). Neither HT nor Bt is intended to increase yield. Both are single gene traits. Yield is the result of a complex array of multi-genic traits. So, how could these simple genes actually ‘increase’ yield?

They don’t. The only way that these GM crops can ‘increase’ yield is by decreasing losses to yield that would otherwise occur due to weeds (HT crops) or to the targets of Bt crops [e.g.
European corn borer for corn; the pink bollworm (*Helioconverpa zea*)/tobacco budworm (*Heliothis virescens*) (BBW) complex for cotton. The degree to which this occurs due to the GM trait has to be compared to what could be achieved through other means.

So, if a RR soybean sprayed with Roundup actually produces a higher yield than a non-GM soybean with other herbicides, which it does on some farms, then it may be inferred that weed pressure was particularly high or the weeds present were resistant to other herbicides. Either circumstance reflects an ecologically dysfunctional production system - in other words, a system which is designed in such a way as to open niches for pests to proliferate.

In general, however, GM traits do *not* increase yield. In fact, RR soybeans yield less, not more than conventional soybeans. The most comprehensive analyses have been published by Benbrook (1999 and 2001a), revealing a typical yield drag of 5-10% for RR soybeans. Benbrook (2001a; Table 2.25) reproduced a survey of 17 company-run comparisons of RR and conventional soybean varieties published in the *Farm Journal*, of Council Bluffs, Iowa (Horstmeier, 2001). Mean yield reduction in RR soybeans was **18.9%**, with each trial consisting of a single variety of each of RR and non-GM.

Benbrook (2001a) also reported on results from 3 state-run variety trials where only the 5 top-yielding varieties were compared for each of RR and non-GM soybeans (Table 2). Mean yield reduction, by state, ranged from -2.3 to -6.1%.

**Table 2.** Yield comparisons (bu/ac) of **top 5** conventional (non-GM) and **top 5** RR soybean varieties in variety trials (adapted from Benbrook, 2001a)

<table>
<thead>
<tr>
<th>Trial</th>
<th>non-GM</th>
<th>RR</th>
<th>% diff</th>
<th>Trial</th>
<th>non-GM</th>
<th>RR</th>
<th>% diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois, 2000</td>
<td></td>
<td></td>
<td></td>
<td>Nebraska, 2000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perry</td>
<td>55.5</td>
<td>53.96</td>
<td>-2.7</td>
<td>East Central (early maturing)</td>
<td>51.5</td>
<td>47.5</td>
<td>-7.8</td>
</tr>
<tr>
<td>Dwight</td>
<td>68.18</td>
<td>67.16</td>
<td>-1.5</td>
<td>East Central, (late maturing)</td>
<td>50.9</td>
<td>50.8</td>
<td>-0.3</td>
</tr>
<tr>
<td>New Berlin</td>
<td>68.7</td>
<td>66.66</td>
<td>-3.0</td>
<td>South East (late maturing)</td>
<td>55.3</td>
<td>57.1</td>
<td>+3.3</td>
</tr>
<tr>
<td>Monmouth</td>
<td>59.2</td>
<td>61.16</td>
<td>+3.3</td>
<td>North East (Group 2)</td>
<td>56.1</td>
<td>62.3</td>
<td>-6.8</td>
</tr>
<tr>
<td>Erie</td>
<td>69.00</td>
<td>68.64</td>
<td>-0.5</td>
<td>Mean</td>
<td></td>
<td></td>
<td>-2.9</td>
</tr>
</tbody>
</table>

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2 The global total to date is 272 Resistant Biotypes of 162 Species (98 dicots and 64 monocots) and over 210,000 fields, caused by overreliance on herbicide technology for weed control (weedsience.com)

3 Companies included AgriPro, Asgrow, DeKalb, Garst, Golden Harvest, Mycogen, Novartis, and Pioneer, among others.
<table>
<thead>
<tr>
<th>Goodfield</th>
<th>64.06</th>
<th>60.62</th>
<th>-5.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>DeKalb</td>
<td>62.52</td>
<td>71.02</td>
<td>-2.1</td>
</tr>
<tr>
<td>Dixon Spring</td>
<td>65.4</td>
<td>58.08</td>
<td>-11.1</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>-2.3</td>
</tr>
</tbody>
</table>

**Minnesota, 1999**

<table>
<thead>
<tr>
<th>Southern, Group 4</th>
<th>55</th>
<th>54.6</th>
<th>-0.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southern, Group 5</td>
<td>55.4</td>
<td>53.4</td>
<td>-3.6</td>
</tr>
<tr>
<td>Central, Group 3</td>
<td>60.2</td>
<td>64.4</td>
<td>-9.6</td>
</tr>
<tr>
<td>Central, Group 4</td>
<td>67.6</td>
<td>62.4</td>
<td>-7.7</td>
</tr>
<tr>
<td>Northern, Group 3</td>
<td>47.6</td>
<td>43.4</td>
<td>-8.8</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>-6.1</td>
</tr>
</tbody>
</table>

Among the clearest comparisons was that reported by Elmore et al. (2001a and b). After a 2 year trial which demonstrated that glyphosate, per se, did not affect yield of RR soybeans, they then conducted a trial at 4 locations over 2 years allowing comparison of 5 backcross-derived pairs of sister-lines (RR vs. non-RR). The RR sister lines averaged 5% less than the non-GM lines, leading them to conclude that the yield drag associated with the RR trait resulted from the RR gene or gene insertion process itself - not the applied glyphosate or any other genetic difference.

Likewise, a Bt crop can only ‘increase’ yield if the target of the Bt is then pestiferous, e.g. at pestiferous levels. For Bt-corn, European cornborer (ECB) occurs so infrequently and unpredictably as to make this costly technology ‘targetless’ - and pointless - in most years, at most places. For this reason, Bt-corn acreage has stalled at 20%, compared to astronomical acreage takeover by RR soy (68%; 2002), HT-cotton (56%; 2001) and Bt-cotton (37%; 2001).

Thus, evidence does not support the premise that GM crops increase yields. Indeed, more clearly supported is the conclusion that GM crops, and specifically RR soybean, actually decrease yield.

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**What about pesticides?** Absence of a yield benefit could be accepted or even welcomed if pesticide dependence declined. However, this is quite unlikely simply because plant-produced pesticides impose selection pressure even more severe than synthetic biocides, and will engender exactly the same kinds of problems with resistance and non-target side effects as synthetic pesticides. As stated by Lewis et al. (1997),

“The use of therapeutic tools, whether biological, chemical, or physical, as the primary means of controlling pests rather than as occasional supplements to natural regulators, to
bring them into acceptable bounds violates fundamental unifying principles and cannot be sustainable”.

To date, the effect of GM on pesticide use has been variable, depending on the crop and specific GM application.

**RR soybean**: It is widely acknowledged, even by Fernandez-Cornejo and McBride (2002), that RR soy requires more, not less, active ingredient (a.i.) per acre than competing herbicides, many of which act at perishingly small concentrations. Using typical tank mixes, herbicide rates on farms range from 0.84 to 2.63 kg a.i./ha for RR soybeans vs. 0.09 to 1.68 kg a.i./ha for conventional varieties (Table 1.10; Benbrook, 2001a). Alternative herbicides such as FirstRate, Classic, Assure II, and Pursuit, typically require very much lower dosages than Roundup to be effective.

Compounding this trend, weed control in RR soybeans after several years in commerce requires either additional herbicides or multiple applications of Roundup to compensate for the growing problem of tolerant or resistant weeds. As a result, RR soybean growers are now applying about 0.56 kg/ha MORE herbicide than non-RR soybean growers - which amounts to 9 million kg more herbicide a year in the U.S. (Benbrook, 2001a).

**Bt-corn**: Benbrook (2001b) cited USDA data showing that insecticide use for ECB has actually increased since the advent of Bt-corn, increasing from 6.75 to 7.3% of sown acres in 1995 and 2000, respectively. It should also be recognized that Bt-corn has arguably the least possibility of reducing insecticide use, simply because very little insecticide is actually used to control the target of Bt corn. Most of what is applied is intended to control root pests, which are not affected by existing Bt corn hybrids.

**Bt-cotton**: Fernandez-Cornejo and McBride (2002; Fig 10) contended that the introduction of Bt-cotton in 1996 was responsible for reducing subsequent insecticide use in cotton. However, Benbrook (2001b) demonstrated that insecticide use aimed specifically at the BBW complex dropped from about 0.5 lb/ac in the early 1990's to 0.28 lb/ac in 2000 for several reasons - only one of which was the introduction of Bt-cotton.

1. The largest decrease occurred through reduced use of such highly toxic organophosphate insecticides as methyl parathion and profenofos, which were phased out at the end of 1996, before Bt-cotton came on line, and
2. the boll weevil (*Anthonomous grandis*) eradication program and other grower-based managerial initiatives earlier in the 90's reduced dependence on insecticides for boll weevil, allowing beneficials - and hence, biocontrol for the BBW complex - to return.

Pimentel (1997) estimated that global pest control relied 50% on natural enemies, 40% on host plant resistance, and just 10% on pesticides. Thus, the return of beneficials should be acknowledged when monitoring trends in insecticide usage.
Indirect support for this interpretation comes from stark inconsistencies in the Bt-cotton effect on pesticide use in different, high-Bt-cotton-adoption states. The dramatic reduction in insecticide use which accompanied the introduction of Bt cotton in Arizona, a state which had also implemented a rigorous ecologically-based grower initiative to control BBW, did not occur in Alabama, which had not benefitted from a similar initiative.

Thus, the effect of GM crops on pesticide use is mixed to say the least, varying among crop types and even among states within crop types. The most likely candidate for a beneficial effect in reducing insecticide use is Bt-cotton. However, it should be noted that cotton is among the most heavily sprayed crops grown in North America, specifically because of how it is grown. It should also be noted that Bt-cotton does not control many cotton pests, which continue to be sprayed.

Fernandez-Cornejo and McBride (2002) claimed a net reduction of 2.5 million pounds active ingredient attributable to adoption of GM crops. According to ERS-USDA figures (www.ers.usda.gov/Data/cropproductionpractices/ShowTables.asp), total pesticide use on the 3 main GM crops in the US in 2000 was:

- corn - 73.77 million ac @ 2.2 lb a.i./ac = 162.29 million lb
- soy - 71.01 million ac @ 1.1 lb a.i./ac = 71.01 million lb
- cotton 14.42 million ac @ 6.0 lb a.i./ac = 86.49 million lb
- TOTAL (these 3 crops) 326.90 million lb

Thus, the magnitude reduction in pesticide use attributable to converting

- 68% of US soybean acreage to HT soybean,
- 56% of US cotton acreage to HT cotton,
- 19% of US corn acreage to Bt corn, and
- 37% of US cotton acreage to Bt cotton

was a net reduction of 2.5 of 326.9 million lb or a barely distinguishable 0.7% in pesticide a.i. applied to these three crops (calculated from Fernandez-Cornejo and McBride, 2002). The premise that GM crops would reduce dependence on pesticides has received limited, and crop-specific support.

**Premise 3. GM is better, cheaper, faster, and more effective?** The foregoing evidence challenges the validity of this point, simply because GM hasn’t yet delivered on its many promises. In contrast, virtually all of the crops, varieties, and traits employed in contemporary agriculture are, unquestionably, the product of conventional plant and animal breeding.

If it really hasn’t delivered, then **why have farmers adopted and retained a technology that produces grain that can be sold - both domestically and globally - only by force?**
• The predominant GM technology is HT crops, which unquestionably simplify weed management. Making weed control less challenging, particularly for large farms, is the one clear advantage conferred by HT technology to date, and this is not a small point. But dumbing down weed control was not what was promised.
• For cotton producers in particular, GM represents one last magic bullet, as pest resistance and product toxicity have almost completely exhausted their pesticidal options. Resistance to Bt cotton will follow, just as with other over-used pesticides, and then they will have to turn to other, more ecologically based options.
• For all farmers, access to non-GM varieties with desirable characteristics is becoming problematic, both because the seed itself is contaminated with GM seed, making them liable for patent infringement, and because many desirable varieties are being made available, in sufficient supply, only in the GM version. The choice to buy GM seed has been made for them.

Synthesis

Seven years of commercial experience with GM crops dispute the foundational premises used to sell this technology to farmers, consumers, and policymakers. Many if not most of the problems addressed with GM technology are in fact created not by some genetic lapse in the crops themselves, but by the ecologically dysfunctional production systems in which they are grown. Applying GM technology to allow dysfunctional systems to limp along for a few more years simply puts off the day of reckoning while allowing problems to worsen, much like putting a band-aid on skin cancer.

Addressing agricultural weeds and pests not as problems, per se, but as symptoms of a larger system failure opens up a wide range of non-proprietary approaches to problem avoidance through system design. In today's 'matching funds' research climate, however, it has proven difficult to access public funds to do 'public good' research

LITERATURE CITED


GRAIN, 2001. Grains of delusion: golden rice seen from the ground. Published by BIOTHAI (Thailand), CEDAC (Cambodia), DRCSC (India), GRAIN, MASIPAG (Philippines), PAN-Indonesia, and UBINIG (Bangladesh) (www.grain.org/publications/reports/delusion.htm)


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