The Rise and Fall of Agricultural Biotechnology

E. Ann Clark, Plant Agriculture, Univ. of Guelph, Guelph, Ontario N1G 2W1 CANADA (e aclark@uoguelph.ca)
©2001 E. Ann Clark

Presented to the International Institute for Advanced Studies in Systems Research, Baden Baden, Germany August 2001

Abstract

Genetic modification (GM) is a technology which has been released prematurely into the marketplace. As a result, GM crops are vulnerable to documented agronomic problems, as well as to potential environmental and food safety concerns. The utility and longevity of ag biotech have been fatally compromised by a) misrepresenting GM crops as solutions to real world problems, when their true function is simply profit generation, and b) subscribing to the same linear paradigm which has guided - and doomed - conventional agriculture.

Keywords: genetic engineering, genetic modification, golden rice, Roundup, Bt

The Attraction Of GM Agriculture

The promises made for GM crops already in the marketplace appeal to virtually every sector in the agri-food system. Seemingly everyone will benefit, from farmers to consumers, including the Third World and the environment, as well as governments seeking to enhance competitiveness in the global marketplace. Among the promises made are a) higher yields, and hence, the potential to better feed the world, b) lesser dependence on toxic biocides, allowing a softening of the ecological footprint of agriculture, c) improved farm income, resulting from the combination of higher yields and lower input costs, and d) cheaper and better quality food for consumers.

Many of these promised improvements appear plausible and commendable. As a result, based on little more than enthusiastic government and industry assurances¹, many citizens - including farmers and scientists - have been persuaded that GM is the way of the future. Indeed, faith in biotechnology compelled Ingo Potrykus, the father of ‘golden rice’, to demand that ‘those opposing it should “be held responsible for the foreseeable unnecessary death and blindness of millions of poor every year” ’ (cited in Schnapp and Schiermeier, 2001)

The spirited endorsement of GM-proponents may be challenged from at least two perspectives: a) the actual track record of GM crops already in the field; and b) the problematic simplicity of

¹The virtual absence of refereed information on potential risks of GM crops has been documented by Domingo (2000) for human health and by Wolfenbarger and Phifer (2000) for the environment
the linear arguments used to justify GM crops.

**Performance Of First Wave GM Crops**

In his Pulitzer Prize winning text, *Guns, Germs, and Steel*, Jared Diamond argued that while we say “necessity is the mother of invention”, it would be more accurate to say that “**invention is the mother of necessity**”. GM is arguably an invention seeking to become a necessity, with profit - not problem solving - being the primary motivation. GM is a *solution* in search of a *problem* - not a solution to a problem, as evidenced by the GM products chosen as first wave offerings: herbicide tolerant (HT) or pesticidal crops (e.g. Bt2).

In support of this provocative position, consider first that to be a solution to a problem, GM crops would have to have been designed to address an identified problem. Herbicide tolerant and pesticidal crops were not identified through *a priori* consultation with the supposed beneficiaries of GM innovation - e.g. farmers, consumers, environmentalists, or the Third World. Because the decisions were made for reasons of profit, the net effect has been:

a. *increased dependence* on proprietary herbicides and on plants which continuously produce their own pesticide3, supporting strong corporate profits, while providing

b. *limited and inconsistent delivery of the promised benefits*, and hence, little or no returns to farmers, society, and the environment.

**Bt Corn.** Bt corn is a perhaps the clearest illustration of invoking GM technology to solve a problem that didn’t - and doesn’t - exist. The crop was sold to farmers and regulators on the premise that self-synthesized pesticides would reduce dependence on synthetic pesticides. However, Benbrook (1999) calculated that no more than 1-2 % of all the insecticide applied to US corn is actually used to control European cornborer - the target of Bt corn. Most corn insecticides are used to control rootworm and other soil pests - which are unaffected by the currently commercialized Bt corn hybrids. Furthermore, most US corn hybrids already have substantial resistance to ECB (in Obrycki et al., 2001). Thus, the ‘reduced-insecticide-through-growing-Bt-corn-argument’ is invalid as a justification for GM.

Another supporting argument that surfaced after Bt corn was in commerce is that it reduces incidence of mycotoxins, which can be deleterious to both livestock and humans. Mycotoxins are produced by pathogens which invade corn already damaged by ECB. While mycotoxin levels were lower in Bt than in non-Bt corn under artificially high ECB infestations in the lab (Munkvold et al., 1997), Bt-corn reduced mycotoxin levels only 1 year in 3 under more normal

---

2 Bt or *Bacillus thuringiensis*, a soil microbe that naturally produces an array of selective Bt insecticides

3 The pesticide produced is specific to a single pest in each crop, e.g. Colorado potato beetle in Bt-potatoes, and could, at best, diminish insecticide use for that single pest. All other pests are still treated with insecticides.
levels of ECB infestation in the field (Munkvold et al., 1999). Thus, justification of Bt corn on
the basis of reduced mycotoxin levels awaits validation under commercial conditions.

Promises of higher yield and improved profit are likewise proving difficult to demonstrate in the
field, as reviewed by Clark (2000a). Therefore, based on several years of farmer experience, Bt
corn has served primarily to separate farmers from an ever larger fraction of their farmgate
receipts, rather than to actually reduce pesticide use - the premise on which it was sold.

Roundup Ready (RR) Soybean. Of all the commercialized GM crops, RR soybeans have
arguably had the poorest record of fulfilling the promised benefits of enhanced yield, reduced
herbicide use, and increased profit - yet they remain wildly popular with farmers, accounting for
60% or more of soybeans planted in the U.S.:

Yield? Opplinger et al. (1999) and Benbrook (1999 and 2001) present overwhelming
evidence from literally thousands of research trials that RR soybeans typically yield 5-10% less
not more - than conventional soybeans.

Herbicide Use? Rigorous analysis of USDA database information demonstrated
unequivocally that RR soybeans use more - not less - herbicide active ingredient/ha than
competing herbicides (Benbrook, 2001). Using typical tank mixes, herbicide rates ranged 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, 2001). Weed control in RR soybeans today - after several years in
commerce - requires either additional herbicides or multiple applications of Roundup. Further,
alternative herbicides such as FirstRate, Classic, Assure II, and Pursuit, typically require very
much lower dosages than Roundup. 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, 2001).

Profit? Benbrook (2001) showed that the cost of weed control is indeed lower in RR
soybeans - but not because of the RR trait. Gianessi and Carpenter (2000) attributed an
impressive $220 million annual savings in herbicide costs paid by US producers to the use of RR
soybeans in 1998. However, much of that savings came from drastic price cutting by Monsanto
and especially their competitors (Table 1).

Thus, the calculated $220 million in savings arose from $360 million in reduced herbicide bills
(Table 1), offset in part by a $160 million increase in the “technology fee” for RR soybean
(payable directly to Monsanto). Clearly, then, the savings to American producers - which
amounted to about $20/ha on the 11 million ha of RR soybeans grown in 1998 - reflected
competition-driven reductions in the prices charged for herbicides - not any biological or
agronomic efficiency of the RR trait itself.
Table 1. Herbicide price war instigated by the arrival of RR soybeans (adapted from Benbrook, 2001)

<table>
<thead>
<tr>
<th>Company</th>
<th>Product</th>
<th>$/ha Before RR</th>
<th>$/ha After RR</th>
<th>% reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dupont</td>
<td>Classic (sulfonylurea; chlorimuron)</td>
<td>37</td>
<td>&lt;20</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Sencor (metribuzin)</td>
<td>23</td>
<td>15</td>
<td>33</td>
</tr>
<tr>
<td>American Cyanamid</td>
<td>Pursuit (imidazolinone; imazethapyr)</td>
<td>34</td>
<td>20</td>
<td>42</td>
</tr>
<tr>
<td>Monsanto</td>
<td>Roundup (glyphosate)</td>
<td>44</td>
<td>25 (or less)</td>
<td>44</td>
</tr>
</tbody>
</table>

So Why Grow It? If they don’t yield more, use less herbicide, or make more money, why are farmers so happy with RR soybeans (and canola)? Because they are convenient. Particularly on the very large farms which are the major adopters of GM technology, it is very much easier to control weeds in a RR crop than to worry about the complexities of rate, timing, and rainfall using conventional herbicides, or rotations and cultivation in organic or integrated protocols.

The scientifically credible evidence of commercial performance to date supports the hypothesis that a) corporate profit and b) enhanced producer dependence on proprietary inputs are the major achievements of GM crops realized to date - not reduced insecticide dependence or the other promised benefits.

The Linear Paradigm Of GM Crops

GM crops are based on the same linear thinking which has sustained conventional agriculture since WWII. Applying technologies based on linear thinking to holistic systems - like nature and indeed agriculture - necessarily engenders unintended and often expensive side-effects.

To illustrate, an herbicide is intended to do one and only one thing - to kill or suppress weeds. We now know - after decades of use - that herbicides do more than kill weeds. They can also: a) shift weed populations to more tolerant or even resistant biotypes, necessitating use of higher dose, more frequent, or more toxic herbicides; b) leach to groundwater, as in the case of atrazine - a persistent corn herbicide. At groundwater concentrations, atrazine interacts with nitrate to elicit immune system responses in rats which were not detected with either component alone (Porter et al., 1999); and c) increase the incidence of birth defects in children. Children
born to certified pesticide applicators in Minnesota experience an increased likelihood of birth
defects, as do all children born in regions of high usage of specific herbicide combinations
(Garry et al., 1996).

The above unfortunate byproducts of herbicide use profile two generalizable outcomes which
accrue when linear thinking is applied to holistic agricultural systems:

a. **Nature abhors a vacuum.** Overreliance on any single approach to address a problem, selects
for tolerance or even resistance in the target species, as has also, already, occurred in GM crops.

b. **Costs are externalized, involuntarily, to others.** Many of the costs associated with GM- as
well as biocide-based farming are not borne by the user but by society and the environment
(Pimentel et al., 1992; Pearce, 1999). The apparent profitability of linear-based farming depends
on externalizing costs involuntarily to others (e.g. genetic pollution, Clark, 2000b).

Evidence that GM manifests the same linear thinking will be discussed at the levels of a) basic
metabolism, using the example of RR soybeans, and b) application, through discussion of golden
rice.

**RR Soybeans.** The RR trait acts on the shikimic acid pathway, a major metabolic pathway with
many outcomes. To a physiologist, it is implausible in the extreme to presume that altering
metabolite flow within a major pathway could effect a single outcome (only). And so it has
proved.

Crops engineered with the RR trait exhibit increased susceptibility to sudden death syndrome,
caused by *Fusarium solani*, a soil pathogen (soybean; Sanogo et al., 2000), increased
susceptibility to root knot nematode (cotton; Colyer et al., 2001), and decreased N fixation under
water stress conditions (soybean; King et al., 2001). In each of these cases, the deleterious effect
was discovered by farmers, post-commercialization, and was missed entirely by both industry
and regulators. Further, the effects were observed early enough to have already been studied and
reported in the refereed literature - after just a few years in commerce. What other traits,
whether agronomic performance or environmental or food safety risk, are also affected by the
RR trait?

As stated by Facchini et al. (2000), “...these efforts to alter plant metabolic pathways....have
often produced unpredictable results, primarily due to our limited understanding of the network
architecture of metabolic pathways...most current models of metabolic regulation in plants ... do
not consider the integration of several pathways sharing common branch points....”.

**Golden Rice.** Golden rice illustrates with unusual clarity the linearity which shapes and channels
the expectations of GM proponents. The logic goes like this:
a. Vitamin A deficiency is unquestionably the major source of childhood blindness in the
developing world.
b. Rice is a major foodstuff but does not contain beta-carotene (precursor to Vitamin A) in the
grain.
c. Inserting genes enabling rice to produce beta-carotene could therefore prevent childhood
blindness. Ingo Potrykus 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).

Critics have dismantled this linear reasoning as follows:

a. Vitamin A is just one of a long list of deficiencies which compromise nutrition in the
developing world, including zinc, Vitamins C and D, folate, riboflavin, selenium, and calcium.
No single nutrient supplement - as golden rice - can resolve dietary deficiencies (Nestle, 2001).
b. Bioavailability of consumed beta-carotene is 10% or less, and absorption requires dietary fat
(Nestle, 2001). Children with Vitamin A deficiency typically suffer overall malnutrition, as well
as intestinal infections that interfere with absorption. “Many children go blind even though
they consume sufficient provitamin A” according to Francis Reed, because “dietary lipid is in
notoriously short supply in many Third World diets” (in Schnapp and Schiermeier, 2001).
c. Vitamin A requirements of a pre-school child can be met by as little as 2 tablespoons of
yellow sweet potatoes, ½ cup of dark green leafy vegetables, OR two-thirds of a medium mango
daily.
d. Vandana Shiva calculated that one would have to consume several kg of rice in order to
intake enough beta-carotene to meet daily requirements (150 and 300 g are a realistic diet for
children and adults, respectively). Gordon Conway of the Rockefeller Foundation
acknowledged that the best current golden rices could only supply up to 15-20% of daily
Vitamin A requirements. He agreed with Vandana Shiva, that “the public relations uses of
Golden Rice have gone too far....”
e. Diets are deficient not because food is unavailable, but because it is inaccessible due to
poverty. Golden rice will not alleviate poverty. People are hungry, and children are going blind,
for reasons that have remarkably little to do with crop genetics.
f. No one has asked the poor what is their preferred way for alleviating childhood blindness.

In sum, golden rice and other GM promises appear altruistic specifically because they ignore the
complex causes of the problems they claim to rectify. Will GM actually fulfill the many
promises that have been made for it? Performance of first wave agronomic trait offerings is not
encouraging. Only time will tell if the expanding circle of inadvertent adverse side-effects
reflect simply start-up problems or are a portend of things to come. What is known for sure,
however, is that the billions of dollars of scarce societal research resources which governments
continue to commit to GM agriculture are necessarily denied to every other research endeavor.
The long term legacy of the current obsession with GM crops will be that by the time
government, academics, and others acknowledge what little GM can actually do, we won’t have
the horses to do anything else.


Northwest Science and Environmental Policy Center, Sandpoint, Idaho. AgBioTech Info Net

Clark, E. Ann. 2000a. AgBiotech Issues that Matter to Farmers: yield and profitability
Presented to the Canadian Wheat Board Grain World Conference, Winnipeg, February 2000.

Clark, E. Ann. 2000b. Who is going to pay the externalized costs of GMOs? Presented to the
Royal Commission on Genetic Manipulation, Wellington, New Zealand (4 Dec 2000)
(www.plant.uoguelph.ca/research/homepages/eclark/starlink.htm).

reproduction and root galling severity on related conventional and transgenic cotton cultivars. J.
Cotton Sci. 4:232-236.

Domingo, J.L. 2000. Health risks of GM foods: many opinions but few data. Science 288:1748-
1749.

decarboxylases: evolution, biochemistry, regulation, and metabolic engineering applications.
Phytochemistry 54:121-138.

and birth defects in rural Minnesota. Environmental Health Perspectives 104(4).


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).

King, C., L. Purcell, and E. Vories. 2001. Plant growth and nitrogenase activity of glyphosate-


