Lessons from the Genetically Engineered Crop Debate

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Gene drives are one of the latest installments of the application of molecular biology to agriculture and medicine. The history of previous developments in biotechnology, such as crop genetic engineering (GE), can inform the development of this newer technology. Although there are aspects of gene drives that are unique compared to other applications of genetic engineering, there are also some common aspects that allow some lessons to be learned from our experience with the development of crop and plant genetic engineering.

Gene drives are also not unique in terms of concern about spread through the environment, and affecting large populations or entire species. For example, debate about the spread of genes from crops to wild, often weedy, crop relatives captured considerable attention, especially in the early to mid-2000s[1], and with the escape of engineered glyphosate herbicide resistant creeping bentgrass in Oregon.[2] A National Research

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[1] Ellstrand, NC. 2003. Dangerous Liaisons, When Cultivated Plants mate with their Wild Relatives. https://jhupbooks.press.jhu.edu/content/dangerous-liaisons

[2] Reichman, J et al. 2006. Establishment of transgenic herbicide-resistant creeping bentgrass (Agrostis stolonifera L.) in nonagronomic habitats. Molecular Ecology (2006) 15, 4243–4255

Council report in 2004 was dedicated to issue of gene flow.[3] And there has been considerable discussion about engineered trees, such as cold-tolerant eucalyptus or American chestnut, which can spread in the environment. Genes that confer greater fitness are predicted by population genetics theory to greatly increase in frequency in a species,[4] although likely at a considerably slower rate than gene drives.

Having been involved with the debate about engineered crops from the beginning, starting as a PhD student in the 1980s, I will base my talk on a mix of experience and my reading of the research on several aspects of the technology. And in the interest of time, I will stick to highlights…or in many cases lowlights, depending on your point of view. I am not a social scientist, but I hope that my observations will be of value nonetheless.

Central to discussion about crop genetic engineering has been public resistance to the technology. The public resistance to GE can be characterized by a perhaps surprising tenacity and adaptability of critics, that suggests deep causes of concern rather than more superficial and passing motivations. So I will focus on my understanding of how this has come about. My purpose is not to provide a key to unlock the door to public acceptance per se, but to present what I believe are legitimate public concerns that have often been dismissed or downplayed. Public concerns,

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[3] NRC. 2004. Biological Confinement of Genetically Engineered Organisms. https://www.nap.edu/catalog/10880/biological-confinement-of-genetically-engineered-organisms

[4] Haygood, R. et al. 2004. Population genetics of transgene containment. Ecology Letters, 7: 213–220

based on risk, process, and deeper social issues, need to be meaningfully addressed, even at the risk of these technologies moving forward more slowly than some desire, or in some cases, perhaps not at all.

Different Frames, Different Facts, Contested Visions

It is difficult to untangle all of the factors that have affected the GE debate, but several have been frequently mentioned. These may reflect to some extent differing world views of the scientists and companies involved in developing GE crops compared to activists, critical scientists, and the interested public.

From the perspective of supporters, GE was a revolutionary new technology that greatly increased the possibility of improving food and farming. The ability to access genetic diversity beyond the genus level was interpreted to mean that more traits, and more powerful traits, could be developed. Second, the ability to avoid other undesirable linked genes involved in conventional breeding was billed as providing greater precision, and third, it was said to be faster than breeding.

All of this was to lead to a revolution in farming and food: fewer pesticides, tastier and more nutritious foods, cheaper foods and so forth. And it would all be safe and adequately regulated. Instead, close to 99% of commercialized GE acreage consists of crops resistant to herbicides, or that produce Bt insect toxins. On balance, these crops have not generally improved agriculture based on broad social criteria. They have not improved nutrition, have not generally reduced pesticide use,[5] improved nitrogen use efficiency[6] or water use efficiency[7], nor improved drought tolerance,[8] to take several examples.

The National Research Council recently found that these crops have not increased yield in aggregate in the United States, nor reliably improved livelihoods of poor farmers in developing countries.[9] The NRC report also found that increased no-till, which reduces soil erosion and energy use, has not been caused by GE herbicide resistant crops, contrary to many earlier claims. This has been one of the major environmental benefits claimed for GE crops. Other studies have found that insecticide use has been reduced, but this is more than offset by increased herbicide use.[10] And most studies have not recognized that the area of land treated and exposed to insecticides has actually greatly increased compared to before the introduction of these crops, potentially increasing risk, despite lower

[5] Perry, D. et al. 2016. Genetically engineered crops and pesticide use in U.S. maize and soybeans. Science Advances Vol. 2, no. 8, e1600850DOI: 10.1126/sciadv.1600850

[6] Gilbert, N. 2014. Cross-bred crops get fit faster: Genetic engineering lags behind conventional breeding in efforts to create drought-resistant maize. Nature 513, 292 doi:10.1038/513292a

[7] Gurian-Sherman, D. 2012. High and Dry: Why Genetic Engineering Is Not Solving Agriculture's Drought Problem in a Thirsty World. Union of Concerned Scientists, Washington, DC. http://www.ucsusa.org/sites/default/files/legacy/assets/documents/food_and_agriculture/high-and-dry-report.pdf

[8] Gilbert, N. 2014 id; Gurian-Sherman, D. 2012 id.

[9] National Research Council. 2016. Genetically Engineered Crops: Experience and Prospects. https://www.nap.edu/catalog/23395/genetically-engineered-crops-experiences-and-prospects

[10] Perry, D. et al. 2016 id

volume.[11] While some of this is contested, it is clear that GE has not lived up to the hype of the early days of the technology. That this vision has not materialized is one cause for public skepticism.[12]

Several events not long after the first commercialization of GE crops raised their profile and concern with the public. Established scientist Arpad Pusztai appeared on TV appearance in England in 1998, and raised concerns about possible dietary risks from transgenic potatoes he was studying. His subsequent mistreatment also suggested an industry that was willing to resort to strong-arm tactics, and that the established science community would support it. Those two themes have been repeated numerous times.

This has may have begun to erode trust in the science community involved in developing GE crops among the people most concerned about them, and beyond.

These events were followed in 1999 by a paper by Cornell's John Losey, which suggested that pollen from Bt corn may harm monarch butterflies. Additional research showed most of this corn was not a threat, but occurred several years later.

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[11] Douglas, MR and Tooker, J. 2015. Large-Scale Deployment of Seed Treatments Has Driven Rapid Increase in Use of Neonicotinoid Insecticides and Preemptive Pest Management in U.S. Field Crops. Environmental Science and Technology DOI: 10.1021/es506141g

[12] There have been some significant likely benefits, such as reduced insecticide exposure of farmers, especially in developing countries. I am not suggesting that there have been no benefits from GE, but rather they have fallen far short of early expectations and claims, and are arguably more than counterbalanced by harms.

And the Starlink incident compounded these problems in 1999 and 2000, when corn for human consumption was widely contaminated by a Bt gene approved by EPA for use only for livestock because of possible allergenicity to humans. That revelation, discovered by environmental groups rather than the government regulators, reflected badly on EPA's role as public protector, and showed how hard it is to contain the technology, in addition to revealing that GE might indeed be harmful.

All of this provided a narrative that 1) the technology may indeed by risky and 2) the regulatory agencies and many scientists associated with the technology were in cahoots with the industry and could not be trusted.

Meanwhile, then Monsanto CEO Shapiro was telling European consumers that GE was inevitable and they better just accept it. As might be expected, that did not go over particularly well.

It should be noted that in all of these incidents and processes, independent doctorate-level scientists were fundamentally involved in the critiques of the technology, or its development, and especially its regulation. The frequent claim that the movement critical of GE was merely a bunch of misinformed Luddites is factually incorrect. Certainly there were activists who greatly exaggerated, got the science wrong, and so forth. But that is true for virtually any issue of public interest, especially technical ones. That should not serve to obscure thoughtful and substantive concerns, but often these were buried under broad claims by vocal GE advocates, including academic scientists, that criticism of GE was anti-science. These categorical criticisms were often reported by the mass media, and so clearly available to the broader public

Activists who read these broad attacks understood that qualified scientists had reasoned critiques, while the industry and supportive scientists attacked them in ways that often went beyond mere scientific disagreement, but instead tried to discredit critical scientists.[13] Again, while intended to strengthen the case for the technology, this has appeared to backfire.

More recently, revelations through the Freedom of Information Act showed that several of the most prominent and vocal, and supposedly independent, academic scientists that promote GE were in fact intimately collaborating behind the scenes with the industry, accepting no-strings funding or perks, and failing to disclose these relationships.[14]

This recalls, at least formally, infamous scientist collaboration with the tobacco, asbestos, PCBs, pesticides and other industries to cover up

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[13] Waltz, E. 2009. Battlefield: Papers suggesting that biotech crops might harm the environment attract a hail of abuse from other scientists. Nature 461: 27-32.; Waltz, E. 2009. Under wraps: Are the crop industry's strong-arm tactics and close-fisted attitude to sharing seeds holding back independent research and undermining public acceptance of transgenic crops? Nature Biotechnology 27(10): 880-882

[14] Lipton, E. Food Industry Enlisted Academics in G.M.O. Lobbying War, Emails Show. New York Times, Sept. 2015 http://www.nytimes.com/2015/09/06/us/food-industry-enlisted-academics-in-gmo-lobbying-war-emails-show.html?_r=2; Krantz, L. Harvard professor failed to disclose connection. Boston Globe, Oct 2015 https://www.bostonglobe.com/metro/2015/10/01/harvard-professor-failed-disclose-monsanto-connection-paper-touting-gmos/lLJipJQmI5WKS6RAgQbnrN/story.html

dangers. And it raises questions about the supposed objectivity of scientists supporting GE.

Social value of the technology …Farmer benefit vs. consumer value

A widely recognized reason that the technology has failed to attract public support is the lack of products with substantial direct benefits to consumers. Better flavor, nutritional enhancement, lower price, or humanitarian benefits have all been mentioned as possible consumer targets, but have not materialized. The direct benefits of GE have gone to farmers and the seed/pesticide industry, while consumers are left with whatever risks the technology may present. So far, cost savings have been mostly been captured by farmers and the seed industry.

Nutritionally enhanced crops have also been touted on a humanitarian basis, but these have not materialized. The premier and most widely touted and promoted crop, golden rice, serves as a good example of how not to advance engineered organisms. As recently as a few months ago, over 100 Nobel laureates signed a letter castigating GreenPeace for opposing beta-carotene enhanced engineered "golden rice," implying that they have been impeding the development this crop.[15] Over the years, opposition to or criticism of GE crops has been used by their advocates to accuse critics of responsibility for the numerous deaths in developing countries.

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[15] Achenbach, J. 107 Nobel laureates sign letter blasting Greenpeace over GMOs. Washington Post. June 2016 https://www.washingtonpost.com/news/speaking-of-science/wp/2016/06/29/more-than-100-nobel-laureates-take-on-greenpeace-over-gmo-stance/

However, as shown recently in a paper by Stone and Glover (2016), technical deficiencies have been responsible for the delays, not activism: from low expression of beta-carotene in the first products, to low yields in the latest, to unproven efficacy and safety, to instability at ambient temperatures encountered in tropical countries.[16] There are also questions about the likelihood of acceptance of yellow rice, a culturally important food. At the same time, vitamin A deficiency has dropped rapidly in the Philippines were it is being developed, due to use of supplements.

In fact, the debate about golden rice epitomizes the overall debate about GE crops: Shrill and extreme accusations by proponents of the technology toward critics, coupled with overly optimistic and premature pronouncements about benefits, often made by outspoken scientists.

Social Context and Expansion of the Movement

Much of the discussion about public concern about GE has centered on dietary risk of GE foods. Although it is probably true of the general public, this assessment may underestimate the cumulative weight of other concerns and their impact on public opinion that together include harm to the environment, corporate control of the seed supply, reduction in crop diversity, and loss of small farms, all of which are highly relevant to several activist communities that reach well beyond those primarily working on GE.

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[16] Stone, GD and Glover, D. 2016. Disembedding grain: Golden Rice, the Green Revolution, and heirloom seeds in the Philippines. Agriculture and Human Values DOI: 10.1007/s10460-016-9696-1

The recent fight over mandatory labeling of GE foods, where polls show that about 90 percent of consumers want clear mandatory labels, where tens of millions of dollars were spent by the food industry to stop labeling, and where attempts to pit arguments about the safety of GE foods against the democratic "right to know," may have contributed to the industry winning the immediate battle, but ultimately losing the public relations war.

Perhaps inevitably, opposing fundamental principles of transparency and public choice, and free market principles, serves to suggest that the industry is hiding something. If GE is safe, and as wonderful as the industry suggests, they should be proud to label it.

The corporate greed narrative, and corporate overreach

I suggest that over time, concern about GE has spread in communities beyond those originally most concerned about it, and to encompass issues beyond food safety. Even where not a primary topic, it has been a fixture as an example for other social movements critical of the current dominant neo-liberal global economic paradigm.

And part of that concern probably also reflects broader social trends, including growing mistrust of major social institutions such as regulatory agencies, the transnational corporate sector, and possibly even scientists.

On the political left-of-center, the growing disparities of wealth and power in the US are also reflected in antipathy toward transnational corporations. And the GE sector contains one of the most visible examples in Monsanto.

Therefore GE issues are probably connected more tightly than perhaps is generally realized to broader concerns about democracy and equity, and taps into many of the same sentiments that motivate supporters of Bernie Sanders or Elizabeth Warren.

Alternative Visions

Finally, many connected to the GE sector have been aggressive in dismissing alternative agriculture systems, such as organic or agroecology, characterizing them as at best niche systems. Especially in terms of the latter, there is substantial and growing evidence that many of the challenges of agriculture can be addressed through these ecological farming systems, and that they can be highly productive and profitable.[17]

In fact, there is widespread belief that not only is GE not needed to feed the world, but also that it will not answer the large environmental and social challenges of industrial agriculture.

In addition, the bucolic vision of alternatives to GE and industrial agriculture like organic, is generally popular with much of the public. Attacks on these farming systems by GE supporters are therefore viewed with hostility by many in the food movement.

It is not helpful to the technology that the industrial agriculture system, linked to many global harms despite its high productivity, is fundamentally

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[17] Davis, AS et al. 2012. Increasing Cropping System Diversity Balances Productivity, Profitability and Environmental Health. PlosOne http://dx.doi.org/10.1371/journal.pone.0047149

dependent on inputs, such as pesticides and seeds, sold by transnational GE corporations, while sustainable alternative farming systems are much less dependant on these inputs. Once again, this suggests a narrowly self-serving corporate technology—such as occurs with fossil fuels and climate change debate—that is motivating advocacy for GE, rather than broad social benefit.

Some academic scientists have recognized the public perception risk of GE being too closely associated with an unpopular industry, and have tried to distance themselves from it. They have suggested that public sector GE could provide many social benefits and could and should be used in conjunction with more sustainable farming systems like organic.[18]

But this view has been undercut by revelations of the ties between a number of academic scientists and the industry, attacks on organic farming by many of these scientists, and by the unwillingness of most of these scientists to distance themselves from the transnational industry.

Summary and Conclusions

What are we to make of all this? What lessons might be applied to gene drive technologies? The recommendations that follow, which are not intended to be complete, mostly involve developing public confidence.

[18] See, e.g. Ronald, PC and RW Adamchak. 2008. Tomorrow's Table. Oxford University Press

However, public confidence must be anchored in substance, not superficial assurances. The publics that follow these issues are often sophisticated, and even when they may not fully understand the science, may have a grasp of challenges with the assessment of these technologies based on whether evaluating institutions are faithful to democratic principles. Processes that are ostensibly democratic, such as evaluation by expert public agencies, or academic scientists, may loose credibility when it is perceived that scales are tilted by biases in those processes and among those institutions. Half-measures are unlikely to fool the environmental and social movements that have concern about these technologies, and that have learned over the past several decades how democratic institutions can be more or less compromised.

First, GE crop technologies have been oversold to the public and have not provided clear benefits to consumers. This has likely led to skepticism about their value. The lesson here is modesty by the industry and academics—where there has usually been hubris—and modesty is inherently difficult when one goal is attracting investment or impressing stockholders.

Second, the intimate relationship and co-dependence between the industry and public sector scientists and regulatory agencies erodes public trust. Many public institutions talk glowingly of "public-private partnerships" without acknowledging the potential for conflicts with the broader public interest, or negative public perceptions. There needs to be distance between public sector applications of gene drive technologies and scientists and agencies evaluating these technologies. And there must be ongoing involvement by members of the publics most concerned about these technologies and affected by them, based on a high level of transparency and participation at all stages of the regulatory an decision-making process.

Generally the most affected stakeholders need to be meaningfully at the table at all times—e.g. representative members of the communities most affected. This meeting itself does not to include members of the non-expert general public.

Similarly, several regulatory agencies both promote GE, or are rewarded for approval of GE crops, at the same time that they are supposed to regulate them. This is true of both USDA and US EPA. That creates an inherent internal conflict of interest that must change, perhaps by creating a new agency whose only purpose is regulation, to insulate it from those parts of the government that may support the technologies. This mistake should not be replicated for gene drive organisms.

Regulations should substantially prioritize broad public safety and benefit over commercial interest. That means more rigorous testing of potentially harmful applications of the technologies, especially concerning indirect risks and public harms, and systems and ecosystem-level effects, which are currently poorly assessed. It means seriously considering social consequences. In other words, technologies are inevitably embedded in society and social institutions. The implications of this embeddedness should be evaluated rather than appealing to a non-existent objectivity of scientific risk assessment alone, which leaves the actual public use of the technology to flawed markets that ignore externalities unless they are deliberately addressed.

It means a reasonably precautionary approach, which puts the burden on showing that the technology is safe, rather than a burden being to prove harm. And it means a willingness to actually forego these technologies if they cannot be shown to be safe with high confidence.

This must include extensive assessment of costs and benefits. Current assessments are usually not very robust in their consideration of possible alternatives to GE approaches. For example, the National Environmental Policy Act mandates consideration of alternatives to the considered action in both environmental assessments and environmental impact statements. However, USDA EIS's and EA's conducted for the approval of GE crops routinely consider only complete lack of approval as an alternative option, and do not consider ecologically-based farming practices or systems as possible alternatives.

In sum, in the case of crop GE, those who share concerns about it, from activists to critical academic scholars, see it primarily as a tool of corporate industrial agriculture that is mostly not in the broader public interest. If gene drives are ever to be accepted, they must avoid similar pitfalls.