Enlightened oversight of genetically engineered crops for the next generation

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Abstract
Risk-disproportionate regulatory oversight has hampered the use of genetic engineering to sustainably improve crops for the duration of a human generation (≈25 years). There is scientific consensus that transgenic breeding methods are safe. Current regulations are often driven by unfounded public fear and hamper crop improvement that is critical to meeting current environmental and nutritional needs and future food security. The public good requires progressive nations to enact policies that enlighten the oversight of modern breeding methods so that current nutritional needs can be met, future food crises can be averted, and agriculture can become more sustainable.

A GENERATION OF RISK-DISPROPORTIONATE OVERSIGHT OF GENETICALLY ENGINEERED CROPS

The Enlightenment, also called the Age of Reason, was a period starting about the early 18th century that saw a focus on reason over superstition. The Enlightenment was a continuation of the Scientific Revolution, which had marked a turning away from mysticism and ushered in the emergence of modern science. We invoke the imagery of superstition and mysticism of previous eras here to highlight that official government oversight of genetically engineered (GE) crops (and in some geographies genome edited crops) has often been driven by misinformation, unsubstantiated public fears, tightly held beliefs, and doctrinism not supported by scientific understanding of potential health and environmental risks (often coupled with dismissal of scientifically substantiated benefits) (Blancke, Breusegem, Jaeger, Braekman, & Montagu, 2015; Herman, Zhuang, Storer, Cnudde, & Delaney, 2019). In the same way that anti-vaccine sentiment, fear of food preserved with irradiation, and the popularity of new-age medicine signal a wider anti-science sociological phenomenon (Beyerstein, 2001; Diehl, 2002; Lewandowsky, Oberauer, & Gignac, 2013), irrational fear of GE crops is prevalent and has been stoked by advocacy groups purporting to protect the public from danger (Herman, Storer, & Delaney, 2019; Porterfield, 2017). As a result, biotechnology-enabled knowledge-driven breeding techniques with improved precision are increasingly overseen under complex, costly, time-consuming, and ever-evolving regulations that have severely hampered the use of these techniques in crop improvement (Conko, Kershen, Miller, & Parrott, 2016; Potrykus, 2010; Scott, Inbar, & Rozin, 2016). This situation has persisted for more than 25 years (the approximate average human generation time). The result is that only a few widely grown crops have benefited from these breeding methods (primarily maize [Zea mays L.], soybean [Glycine max (L.) Merr.], cotton [Gossypium hirsutum L.], and canola [Brassica napus L. var. napus]), only a handful of very high value traits have been brought forward (primarily herbicide tolerance and pest resistance), and only large companies have had the resources to navigate the global quagmire of regulations, continual
questions, and scientifically unwarranted requests for more studies and data (Bradford, Deynze, Gutterson, Parrott, & Strauss, 2005; Herman, Zhuang, Storer, Cnudde, & Delaney, 2019). For a generation, valuable breeding techniques with improved precision have had limited impact due to unfounded fears. Here, we briefly discuss this unfortunate situation and suggest a path forward for enlightening GE crop regulation.

2 | GENETICALLY ENGINEERED CROPS ARE VERY SAFE

As a backdrop, the most credible scientific organizations concur that use of modern breeding techniques to improve crops is no riskier than the preceding breeding techniques used safely for many decades with little or no regulatory burden (Matthespian, 2015; National Academies of Sciences et al., 2016). We have now been using modern GE techniques to safely enhance commercial crop varieties for a quarter of a century (ISAAA, 2018; Romeis, Naranjo, Meissle, & Shelton, 2019; Van Eenennaam & Young, 2014). Even so, some of the most effective tools of modern agriculture are frequently under attack due to public perceptions and ideology, which limits farmers’ options in becoming more sustainable. Often, nonexperts in food safety assert that there are flaws or gaps in the scientific evidence supporting safety, but in fact, scientific experts agree that overwhelming evidence supports the health and environmental safety of GE crops. Alternatively, some reject the evidence of GE crop safety because it conflicts with an ideology that “natural” is somehow safer and better than what they perceive as unnatural (Blancke et al., 2015; Scott et al., 2016). In both of the aforementioned situations, facts and evidence are ignored or contorted to fit a tightly held belief (information bias). If one rejects the science behind macroevolution or an expanding universe, little direct harm is likely to occur, but when rejection of a beneficial technology significantly affects our ability to sustainably increase food production to feed a growing population or delays the development and introduction of nutritionally enhanced food to stave off malnutrition and disease, the resulting human cost can be real and very high (Box 1).

3 | WASTED RESOURCES

Over the last quarter century, massive resources have been diverted to conduct studies on GE crops evaluating weakly supported hypotheses of risk. These studies often investigated potential unintended changes in the crop without any meaningful connection to health or nutrition (Box 2). While some have justified these studies in the name of increasing public trust in these technologies, such investigations have often become enshrined in the product testing requirements of the government regulatory agencies entrusted to protect human and environmental health (Cantley, 2004; Delaney, Hazebroek, Herman, Juberg, & Storer, 2019). As such, scientifically unwarranted tests required by regulatory agencies have diverted substantial resources from crop improvement research into symbolic gestures intended to convince the public that safety evaluations are rigorous. In fact, such overregulation may have had the unintended opposite effect of giving the public perception that these techniques have inherently increased risks and thereby require onerous oversight (Herman, Fedorova, & Storer, 2019).

Additionally, diversion of public resources and taxpayer monies to confirmatory studies robs human society of the ability to further develop new agricultural technologies and approaches. As just one example, by 2010, over a period of 15 years, at least €130 million had been spent on GE safety and acceptance issues (paid for by European Union taxpay- ers) (European Commission, 2010).

4 | GOOD PUBLIC POLICY

Improvement in sustainable agricultural production is critical to the well-being of people and the planet (Klümper & Qaim, 2014; Mellor, 2017). As such, government policies should support technologies that have the potential to help safely achieve this goal (Gaffney, Challender, Califf, & Harden, 2019). When lack of public acceptance threatens human well-being, such as witnessed recently with measles outbreaks due to insufficient vaccination, governments often reevaluate public policy (Woodland, 2019), but reacting to such crises rather than being proactive has a price in human lives and suffering. We have solid scientific predictions on future food needs based on both human population-growth estimates and the impacts of continuing climate change on crop yields (FAO, 2009) such that we can be proactive in using modern technology to improve crops before a food crisis develops (Godfray

Core Ideas
- Oversight of genetically engineered (GE) crops is risk disproportionate.
- Scientific consensus exists that modern GE breeding techniques are safe.
- Onerous oversight has impeded the application of GE technology to improve crops.
- Benefits are unrealized, and resources diverted from sustainably improving crops.
- Enlightened policies from progressive countries are needed to meet food needs.
**BOX 1: HUMAN COST OF REJECTING GENETICALLY ENGINEERED CROPS**

In addition to the economic cost of impeding the adoption of beneficial GE crops, there is also a cost in human life and suffering. In India alone, resistance to adoption of a single GE food crop, vitamin-A enriched rice (*Oryza sativa* L.), has been estimated to have caused the loss of 1.4 million life-years over a 10-year period (Wesseler & Zilberman, 2014). While Bangladesh recently approved GE brinjal (eggplant [*Solanum melongena* L.]) that reduces insecticide use, resulting in a 10% lower rate of pesticide poisoning (Ahmed et al., 2019), India placed a moratorium on GE brinjal cultivation even though it has been estimated that adoption of insect-resistant GE cotton in India reduced pesticide poisonings by several million cases per year (Kouser & Qaim, 2011). Similar reductions in pesticide poisonings have also been reported in China after adoption of GE insect-resistant cotton, but cultivation of GE food crops has not yet been permitted in this country (Pray, Huang, Hu, & Rozelle, 2002). Insect-resistant maize has been shown to significantly reduce mycotoxin contamination associated with cancers and birth defects but is largely cultivated only in the Americas due to regulatory barriers (Parrott, 2010). The adoption of GE glyphosate-tolerant crops has greatly lessened erosion on farmland through enablement of conservation tillage, reducing the pollution of the fresh water that we all depend on for survival (but cultivation again is largely restricted to the Americas) (Givens et al., 2009). Delays in regulatory approvals of GE crops developed specifically for sub-Saharan Africa have equally dire consequences on the health and survival of people in this region (Wesseler, Smart, Thomson, & Zilberman, 2017). These are but a few examples of the human cost of rejecting beneficial GE crops.

et al., 2010; McGuire, 2017; Qaim & Kouser, 2013). This is a matter of national and global food security.

**5 | LEADING ENLIGHTENED OVERSIGHT**

Countries that embrace science- and evidence-based decision making must lead the way in adopting policies that are in the public interest (Figure 1). Continuation of the false security associated with overly precautionary approaches to agricultural technology will perpetuate the status quo. Effective risk communication, separate from regulatory oversight, will likely be key in sustaining policies that are contentious among the subgroups harboring misguided or ideological beliefs that conflict with the use of these technologies (McPhetres, Rutjens, Weinstein, & Brisson, 2019; Nicolia, Manzo, Veronesi, & Rosellini, 2014). Truly sustainable agriculture is complex. Farmers, consumers, and the entire planet need to consider all the tools available (Gaffney et al., 2019). As such, redirecting resources from regulatory oversight of modern breeding techniques into public communication of the low risks, the many benefits, and the critical need for these technologies is good public policy (Herman, Fedorova, & Storer, 2019). Perhaps risk-disproportionate crop-improvement regulation can be enlightened by such policy enhancements so that the generations to come can use these techniques more effectively to sustainably improve crop production.

**BOX 2: RESEARCH AND ENVIRONMENTAL COST OF TESTING WEAK RISK HYPOTHESES**

Even though genetic engineering is one of the safest technologies ever introduced to agriculture, the time and cost to gain regulatory approvals of GE crops for cultivation and/or import are increasing. Studies designed to assess the risk of a new genetically modified crop to human health and the environment are based on the weight of evidence. Developers conduct up to 105 different studies across multiple scientific disciplines to establish duplicative lines of evidence that contribute to this “weight,” and these studies are then reviewed by regulatory authorities in multiple cultivating and importing countries around the world before commercialization (Herman et al., 2018). The weight-of-evidence safety studies and subsequent review period cost developers up to US$35 million per new GE event (McDougall, 2011). Yet this direct cost pales in comparison to the numerous other costs associated with delays in technology approval and adoption. Biden, Smyth, and Hudson (2018) quantified the lost opportunity cost of delayed GE canola adoption in Australia, which included 6.5 million kg of pesticide active ingredient applied to crop land, 8.7 million L of diesel fuel burned, 24.2 million kg of greenhouse gas emissions released, and AU$485 million of economic loss to rural communities (Biden et al., 2018). These costs could have been avoided with timely approval of the GE canola variety.
CONFLICT OF INTEREST
The authors are employed by a company that develops and markets transgenic seed.

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REFERENCES
Ahmed, A. U., Hoddinott, J. F., Islam, K. M. S., Rahman Khan, A. S. M. M., Abedin, N., and Hossain, N. Z. (2019). Impacts of Bt brinjal (eggplant) technology In Bangladesh. Retrieved from https://pdf.usaid.gov/pdf_docs/PA00T7Z7.pdf
Beyerstein, B. L. (2001). Alternative medicine and common errors of reasoning. Academic Medicine, 76, 230–237.
Biden, S., Smyth, S. J., & Hudson, D. (2018). The economic and environmental cost of delayed GM crop adoption: The case of Australia’s GM canola moratorium. GM Crops & Food, 9, 13–20.
Blancke, S., Breusegem, F. V., Jaeger, G. D., Braeckman, J., & Montagu, M. V. (2015). Fatal attraction: The intuitive appeal of GMO opposition. Trends in Plant Science, 20, 414–418.
Bradford, K. J., Deynze, A. V., Gutterson, N., Parrott, W., & Strauss, S. H. (2005). Regulating transgenic crops sensibly: Lessons from plant breeding, biotechnology and genomics. Nature Biotechnology, 23, 439–444.
Cantley, M. (2004). How should public policy respond to the challenges of modern biotechnology? Current Opinion in Biotechnology, 15, 258–263.
Conko, G., Kershon, D. L., Miller, H., & Parrott, W. A. (2016). A risk-based approach to the regulation of genetically engineered organisms. Nature Biotechnology, 34, 493–503.
Delaney, B., Hazenbroek, J., Herman, R., Juberg, D., & Storer, N. P. (2019). Untargeted metabolomics are not useful in the risk assessment of GM crops. Trends in Plant Science, 24, 383–384.
Diehl, J. F. (2002). Food irradiation: Past, present, and future. Radiation Physics and Chemistry, 63, 211–215.
European Commission. (2010). A decade of EU-funded GMO research. Retrieved from https://ec.europa.eu/research/biosociety/pdf/a_decade_of_eu-funded_gmo_research.pdf
FAO. (2009). How to feed the world in 2050. Rome: Food and Agricultural Organization.
Gaffney, J., Bing, J., Byrne, P. F., Cassman, K. G., Ciampitti, I., Delmer, D., … Warner, D. (2019). Science-based intensive agriculture: Sustainability, food security, and the role of technology. Global Food Security, 23, 236–244.
Gaffney, J., Challender, M., Califf, K., & Harden, K. (2019). Building bridges between agribusiness innovation and smallholder farmers: A review. Global Food Security, 20, 60–65.
Givens, W. A., Shaw, D. R., Kruger, G. R., Johnson, W. G., Weller, S. C., Young, B. G., & Jordan, D. (2009). Survey of tillage trends following the adoption of glyphosate-resistant crops. Weed Technology, 23, 150–155.
Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., … Toulmin, C. (2010). Food security: The challenge of feeding 9 billion people. Science, 327, 812–818.
Herman, R. A., Ekmay, R. D., Schafer, B. W., Song, P., Fast, B. J., Papineni, S., … Juberg, D. R. (2018). Food and feed safety of DAS-44406-6 herbicide-tolerant soybean. Regulatory Toxicology and Pharmacology, 94, 70–74.
Herman, R. A., Fedorova, M., & Storer, N. P. (2019). Will following the regulatory script for GMOs promote public acceptance of gene-edited crops? Trends in Biotechnology, 37, 1272–1273.
Herman, R. A., Storer, N. P., & Delaney, B. (2019, February). Genetically engineered crops are seen through a warped lens. The Scientist.
Herman, R. A., Zhuang, M., Storer, N. P., Cnudde, F., & Delaney, B. (2019). Risk-only assessment of genetically engineered crops is risky. Trends in Plant Science, 24, 58–68.
ISAAA. (2018). Global status of commercialized biotech/GM crops in 2017: Biotech crop adoption surges as economic benefits accumulate in 22 years. Retrieved from https://www.isaaa.org/resources/publications/briefs/53/executivesummary/default.asp
Klitmø, W., & Quim, M. (2014). A meta-analysis of the impacts of genetically modified crops. PLoS One, 9, e111629.
Kouser, S., & Qaim, M. (2011). Impact of Bt cotton on pesticide poisoning in smallholder agriculture: A panel data analysis. Ecological Economics, 70, 2105–2113.
Lewandowsky, S., Oberauer, K., & Gignac, G. E. (2013). NASA faked the moon landing—therefore,(climate) science is a hoax: An anatomy of the motivated rejection of science. Psychological Science, 24, 622–633.
Matthesian. (2015, January 22). The PILE of evidence on GMO safely. [Blog post]. Retrieved from https://matthesian.wordpress.com/2015/01/22/the-pile-of-evidence-on-gmo-safely
McDougall, P. (2011). The cost and time involved in the discovery, development and authorisation of a new plant biotechnology derived trait. Brussels: CropLife International.
McGuire, A. M. (2017). Agricultural science and organic farming: Time to change our trajectory. Agricultural & Environmental Letters, 2, 170024. https://doi.org/10.2134/ael2017.08.0024
McPhetres, J., Rutjens, B. T., Weinstein, N., & Brisson, J. A. (2019). Modifying attitudes about modified foods: Increased knowledge leads to more positive attitudes. *Journal of Environmental Psychology, 64*, 21–29.

Mellor, J. W. (2017). *Agricultural development and economic transformation: Promoting growth with poverty reduction*. Cham, Switzerland: Springer Nature.

National Academies of Sciences, Engineering, and Medicine, Division on Earth and Life Studies, Board on Agriculture and Natural Resources, Committee on Genetically Engineered Crops: Past Experience and Future Prospects. (2016). *Genetically engineered crops: Experiences and prospects*. Washington, DC: National Academies Press.

Nicolia, A., Manzo, A., Veronesi, F., & Rosellini, D. (2014). An overview of the last 10 years of genetically engineered crop safety research. *Critical Reviews in Biotechnology, 34*, 77–88.

Parrott, W. (2010). Genetically modified myths and realities. *New Biotechnology, 27*, 545–551.

Porterfield, A. (2017, April 20). Ten advocacy groups putting ideology before GMO science. Retrieved from https://principia-scientific.org/ten-advocacy-groups-putting-ideology-gmo-science

Potrykus, I. (2010). Regulation must be revolutionized. *Nature, 466*, 561.

Pray, C. E., Huang, J., Hu, R., & Rozelle, S. (2002). Five years of Bt cotton in China: The benefits continue. *The Plant Journal, 31*, 423–430.

Qaim, M., & Kouser, S. (2013). Genetically modified crops and food security. *PloS One, 8*, e64879.

Romeis, J., Naranjo, S. E., Meissle, M., & Shelton, A. M. (2019). Genetically engineered crops help support conservation biological control. *Biological Control, 130*, 136–154.

Scott, S. E., Inbar, Y., & Rozin, P. (2016). Evidence for absolute moral opposition to genetically modified food in the United States. *Perspectives on Psychological Science, 11*, 315–324.

Van Eenennaam, A., & Young, A. (2014). Prevalence and impacts of genetically engineered feedstuffs on livestock populations. *Journal of Animal Science, 92*, 4255–4278.

Wessler, J., Smart, R. D., Thomson, J., & Zilberman, D. (2017). Foregone benefits of important food crop improvements in sub-Saharan Africa. *PloS One, 12*, e0181353.

Wessler, J., & Zilberman, D. (2014). The economic power of the Golden Rice opposition. *Environment and Development Economics, 19*, 724–742.

Woodland, D. L. (2019). Measles on the march: A call to action. *Viral Immunology, 32*, 160.

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