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Thematic Section

Genetically Engineered (GE) Crops: A misguided strategy for the twenty-first century?

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ABSTRACT *Increasingly, genetically engineered (GE) crops are promoted as a 'twenty-first century' agricultural strategy. From trade negotiations of the Transatlantic Trade and Investment Partnership to international climate negotiations, GE crops are endorsed as a major solution to hunger and malnutrition, as well as for climate change mitigation and adaptation. This article addresses some of the central concerns that many have about GE crops, and proposes more promising, immediate alternatives.*

KEYWORDS *sustainability; agro-ecology; climate change; yield; chemicals; water*

Introduction

For at least half a century, policy and development institutions have primarily addressed hunger and malnutrition through an industrial agricultural paradigm.

But today we witness stunning statistics that debunk this approach. Around 870 million, one in eight people on the planet suffered chronic undernourishment and food insecurity in 2010–2012. In this same period, hunger in Africa increased by almost 20 million more people (FAO, 2012). Poor nutrition causes nearly half of deaths in children under five – 3.1 million children each year (Black *et al.*, 2013). And, in India, despite an impressive average economic growth rate of around 8 percent (since 2002), the number of hungry people has risen by 65 million (Bailey, 2011).

Clearly, new tactics are needed. Scientific and anthropological literature on food security and nutrition is unambiguous: 'business as usual' policies and actions need to shift away from industrial food systems to more sustainable agricultural practices (International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), 2009). Instead of advancing agriculture systems that require costly seeds, chemicals, and synthetic fertilizers that farmers in food-insecure regions cannot afford, farming practices must be low cost, low input, and multi-functional. Also key is that agriculture methods need to be appropriate to local terrain, geography, soil content, available water, as well as social and cultural constructs of a region.

Fortunately, sustainable agriculture systems, such as agro-ecological and other methods, have been shown to outperform industrial, or conventional, agriculture in terms of yield while also reducing chemical and water usage as well as simultaneously enriching soils and enhancing local ecosystems. Yet, development organizations, foundations, and other institutions still funnel the majority of funds and research towards more of the same – industrial approaches that have failed to provide food security for hundreds of millions and have also failed on environmental and socio-economic fronts.

Increasingly, genetically engineered (GE) crops are promoted as a 'twenty-first century' agricultural strategy (Grant, 2007). From trade negotiations of the Transatlantic Trade and Investment Partnership to international climate negotiations, GE crops are endorsed as a major solution to hunger and malnutrition, as well as for climate change mitigation and adaptation. This article addresses some of the central concerns that many have about GE crops, and proposes more promising, immediate alternatives.

Misguided narrative of success of GE crops

Often there is misinformation about traits offered in current GE crops. After spending hundreds of millions of dollars and over 30 years of research, only two traits dominate GE crops. Over 99 percent of GE crop acres are either: (1) herbicide-resistant crops engineered to withstand repeated broad spectrum dousing of one or more herbicides to kill weeds but not the crop; or (2) insect-resistant, *Bacillus thuringiensis* (Bt) crops that produce toxins in their tissues that kill target pests.

But the narrative is that GE crops offer nutritionally enhanced foods that will alleviate suffering in poor countries, provide higher yields that can contribute to food security, and are environmentally sound and climate friendly. Such claims are repeated widely in policy circles and media outlets. As one example, Golden Rice is often cited as a transgenic crop that could alleviate malnutrition in developing countries. For at least two decades, Golden Rice – engineered to have high levels of carotenoids, which are precursors of Vitamin A – has been promoted as a solution to blindness for millions of children who are deficient in Vitamin A.

However, a host of intellectual property issues and technical problems in field tests have hindered Golden Rice development for over a decade. As recently as March 2014, the International Rice Research Institute (IRRI) – charged with research, analysis, and testing of Golden Rice – released a report revealing that the 'average yield [of GE golden rice] was unfortunately lower than that from comparable local varieties already preferred by farmers' (IRRI, 2014a). IRRI (2014b) also stated: 'It has not yet been determined whether daily consumption of golden rice does improve the vitamin A status of people who are vitamin A deficient and could therefore reduce related conditions such as night blindness'.

Golden Rice is not an anomaly. In early 2000, based on work carried out as a post-doctoral fellow at Monsanto, African plant pathologist Florence Wambugu directed a project to develop a virus-resistant GE sweet potato to be grown in Kenya. *New Scientist Magazine* (2000) reported on the project: 'In Africa [GE] food could almost literally weed out poverty'. *Forbes* magazine reported, 'While the West debates the ethics of genetically modified food, Florence Wambugu is using it to feed her country' (Cook, 2002). However, these articles were published a few years *before* field trials were even completed. And while media headlines and opinion leaders extolled the virtues of the GE sweet potato, the results of the failed field trials were quietly published in 2004. Kenya's *Daily Nation* reported: 'Trials to develop a virus resistant sweet potato through biotechnology have failed' (Gathura, 2004).

Around this same time period, breeders in Uganda and Mozambique successfully developed disease-resistant sweet potatoes with high beta-carotene content, which also had higher productivity (Research Into Use, 2007).

Similarly, it was reported that cassava, one of the most important starch crops in Africa, was enriched with greatly increased protein content using genetic engineering. However, the research article claiming the elevated protein was later retracted when it was found that the purported increased protein did not exist. The retraction notice said that an investigation revealed that 'significant amounts of data and supporting documentation that were claimed to be produced by the first author could not be found' and 'the validity of the results could not be verified' (Portillo, 2012).

As with sweet potato and many other crops, non-GE breeding is making progress towards improving cassava for many traits, from yield and nutritional enhancement to drought tolerance. Several of these improved varieties are already being grown by farmers in Africa. Yet these successes are rarely reported. In addition, ecological-farming methods are proving successful in eliminating many plant and pest diseases. For instance, push–pull systems, mixing plants that repel insect pests (push) with plants that attract the pests (pull), have been very successful for maize cultivation in Africa. Already practiced by 70,000 farmers in Kenya and surrounding countries, the push–pull system could be scaled up dramatically with adequate funding (African Insect Science for Food and Health (ICIPE), 2014).

Low cost, systemic solutions often ignored

A major cause of malnutrition is because of decreasing diversity in diets. Often many regions that once grew diverse crops of many vegetables, fruits, millets, and grains now grow only one major export commodity crop. Nutritionists agree that an assortment of foods is the best way to alleviate malnutrition.

Instead of addressing nutrient deficiencies (such as a Vitamin A deficiency) with high cost, high-tech solutions, inexpensive approaches such as improving availability of a variety of foods provide more immediate results. For instance, promotion of home gardening has successfully fostered more diverse and nutritious diets, including alleviation of Vitamin A deficiency, for millions of poor people in Bangladesh and Thailand (Attig *et al.*, 1993). Vitamin A deficiency has also been significantly reduced in tens of thousands of African households through programmes promoting a switch to carotene-rich orange sweet potatoes from traditional white varieties (International Food Policy Research Institute (IFPRI), 2012).

Such successful solutions also resolve malnutrition at systemic levels. For instance, growing more species of plants creates biodiversity that is needed to maintain the long-term stability of any ecosystem.

GE crops: ecology and climate change

It is widely acknowledged that industrial agriculture systems are causing major environmental harms; scientists warn that we are destroying or depleting natural resources needed to grow food in the future. The ecological harms associated with massive use of agricultural chemicals are well-documented: coastal dead zones because of nitrogen run off; polluted waterways from agricultural chemicals; denuded and depleted soils; loss of wildlife and habitat; and more (Barker, 2011). As regions throughout the globe are increasingly experiencing water shortages, industrial agriculture continues to suck up at least 70 percent of the planet's fresh water (FAO, 2007).

Further, climate change and industrial agriculture are deeply intertwined. The World Bank reports that current agricultural practices account for more than 30 percent of global greenhouse gas (GHG) emissions (Thapa and Bromhead, 2010: 2). Perhaps even more alarming, 60 percent of global nitrous oxide (N_2O) emissions, a GHG 296 times more potent than carbon dioxide, is primarily due to use of synthetic nitrogen fertilizers (Stern, 2009: 92).

GE crop technology continues the *status quo*, the use of synthetic nitrogen fertilizers, a host of herbicides and pesticides, and massive amounts of water. Part of a mono-crop system, GE crops continue to diminish biodiversity.

Examining GE crop herbicide usage illustrates some of the environmental hazards. Over five of every six acres of GE crops planted in the world today (85 percent) are herbicide resistant – nearly all of them are Monsanto's Roundup Ready corn, soybeans, cotton, alfalfa, canola, and sugar beets (Benbrook, 2012). The active ingredient in Roundup, the company's flagship herbicide, is glyphosate.

Claims that GE crops reduce chemical usage have not been borne out by the scientific data. As one example: a recent, peer-reviewed assessment based on pesticide data from US Department of Agriculture (USDA) shows that around 527 million pounds (239,000 metric tons) more herbicides were sprayed in the United States than would likely have been the case without these crops (based on figures from 1996 to 2011) (Benbrook, 2012). It is frequently implied that glyphosate has displaced use of the highly toxic corn herbicide atrazine, but atrazine continues to be sprayed on over 60 percent of US corn acres even as glyphosate use on corn has soared (National Agriculture Statistics Service, 2010).

Super weeds, super problem

The enormous use of glyphosate – now roughly 200 million pounds per year (90,270 metric tons) on US corn and soybeans alone – has also generated an epidemic of glyphosate-resistant weeds, sometimes referred to as 'super weeds' (National Agriculture Statistics Service, 2010). Virtually unknown before Roundup Ready crops, these weeds now infest over 60 million acres of cropland in the United States and represent one of the major challenges facing North (and South) American farmers (*Farm Industry News*, 2013). Leading weed scientists warn that farmers are 'running out of options' to control what is rapidly becoming an 'unmanageable problem' (*Science Daily*, 2011).

For many farmers the only alternative appears to be using older, highly toxic herbicides to combat the weeds or to resort to heavy tillage. In June 2014 the Texas Department of Agriculture petitioned the US Environmental Protection Agency (EPA) to permit emergency use of the highly toxic herbicide propazine to kill glyphosate-resistant weeds infesting Texas cotton on three million acres of cotton, representing about one-quarter of US cotton production (EPA, 2014).

While it is true that pests and diseases can eventually develop resistance to chemicals, the rapid rate of Roundup-resistant weeds contrasts with original biotech industry predictions. In its submission to the USDA for approval of the first GE soy crop, Monsanto stated, '… glyphosate is considered to be an herbicide with low risk for weed resistance'. It also claimed that several university scientists agreed, 'that it is highly unlikely that weed resistance to glyphosate will become a problem as a result of the commercialization of glyphosate-tolerant soybeans' (*Center for Food Safety*, 2014).

Pest resistance

Pests as well as weeds are also developing resistance. As one example, GE corn seeds are no longer protecting Brazilian farmers in Mato Grosso state from voracious tropical bugs, according to the Aprosoja farm lobby. Farmers are asking the four major manufacturers of the Bt corn to reimburse them for the costs of up to three applications of pesticides that they have had to spray this year in attempts to control pests (Stauffer, 2014).

Next generation of GE crops – Stronger chemicals

In response to weed resistance to glyphosate, biotech companies are now seeking approval in the United States for new GE crops that are resistant to older, toxic herbicides such as 2,4-D, developed in the 1940s. Dow AgroSciences is seeking USDA approval of corn and soybeans resistant to 2,4-D, which is linked to increased rates of immune system cancer, Parkinson's disease, and other health problems (Garry *et al.*, 1996; Tanner *et al.*, 2009; Schinasi and Leon, 2014). (Upon publication of this article, the U.S. Environmental Protection Agency (EPA) approved Dow Chemical's Enlist Duo herbicide, a new blend of glyphosate- and 2,4-D-resistant GE corn and soybeans.) Likewise, Monsanto is planning to seek approval for transgenic, dicamba-resistant soybeans, corn, and cotton. Dicamba has been tentatively linked to increased rates of colon and lung cancer in farmers by the National Cancer Institute (Samanic *et al.*, 2008).

The USDA (2013) projects that 2,4-D-resistant corn and soybeans will increase use of 2,4-D by twofold to sevenfold, from 26 million pounds (11,800 metric tons) per year currently to 176 million pounds (79,800 metric tons) per year (134). In addition to the health concerns raised by next-generation GE crops, USDA and weed scientists agree that weed resistance to 2,4-D is likely to occur quickly. Further, an EPA risk assessment of 2,4-D resistant crops identifies numerous potential risks to the environment as well as economic impacts to farmers from 2,4-D drift, which can damage sensitive crops (EPA, n.d.; USDA, 2013: 133–134).

GE crops and climate change

The World Bank (2009) frames the stark situation: Almost 80 percent of global warming effects will be suffered by developing countries, even though they contribute about 30 percent of GHG emissions. This includes historical and cumulative emissions of China and India since 1850 (Herzog, 2005: 31). Given that agriculture provides livelihoods for 40 percent of the global population, with 70 percent of the poor in developing countries depending on agriculture for their subsistence, there is an urgent need for concerted adaptation strategies and actions (IAASTD, 2009: 8).

As international institutions and governments explore and enact climate adaptation and mitigation strategies, the biotech industry is strongly positioning itself. Approximately 1,663 patent applications for 'climate-ready' crops have been submitted for approval from June 2008 to June 2010. Three companies – DuPont, Monsanto, and BASF – comprise 66 percent of these patents (ETC Group, 2010: 1). Such proprietary dominance could have significant social and economic implications and raises concerns about the control of seeds, and ultimately, the food supply. But aside from a discussion of corporate consolidation of seed ownership, a critical question is: Are GE crops a way forward in times of climate change?

To date, traits of drought tolerance, salt tolerance, or other climate change-ready traits in GE crops have not been demonstrated. As one example, Brazilian farmers in the Southern state of Rio Grande do Sul reported that GE soy crops had lower yields than conventional soy during the 2004–2005 drought. This concurs with an assessment of the *New Scientist*: '... hot climates don't agree with Monsanto's herbicide-resistant soy beans, causing stems to split open and crop losses of up to 40 percent' (Doherty, 2010: 7).

An associated dynamic that has a major impact on climate change is that approximately 59 percent of Brazil's GHG emissions are because of increasing deforestation in the Amazon. Expansion of GE soybean production in Brazil has been a major cause of deforestation in the Amazon in recent years (Doherty, 2010).

In the United States, DroughtGard, a GE maize crop approved for limited large-scale, on-farm trials in the United States in 2012, was found to have only 'modest protection against moderate drought', and was not significantly better than conventionally bred drought-resistant cultivars (Gurian-Sherman, 2012). The corn does not appear to offer any advantages in severe drought conditions (Reeves *et al.*, 2010). Furthermore, the crop has no trait to improve water-use efficiency, which allows plants to produce more with less water (Gurian-Sherman, 2012).

In contrast, conventional and traditional varieties of drought-tolerant maize are being successfully grown on smallholder farms in some developing countries. Thirty-four new drought-tolerant maize varieties have been distributed to an estimated two million smallholder farmers in 13 countries. The project reports that farmers are obtaining high yields and increasing incomes, and bring improved food security (International Maize and Wheat Improvement Center, 2014). Similar projects with other non-GE drought-tolerant crops – sorghum, chickpea, rice, and more – are also producing positive outcomes (GMWatch, 2014).

But aside from examining specific climate-ready traits in crops, many are concerned that GE crop technology does not address systemic issues associated with industrial agriculture. As already noted, water scarcity is critical in many parts of the world. Currently, 1.4 billion people do not have access to clean drinking water (Water Resources Group, 2009). About 1.5 million children under the age of five die each year from waterborne diseases (Water Resources Group, 2009). The World Bank reports that by 2030, demand for water will outstrip supply by 40 percent (Water Resources Group, 2009).

As Maude Barlow, former senior advisor to the president of the UN General Assembly and national chairperson of the Council of Canadians says, 'It is not an exaggeration to say that lack of access to clean water is the greatest human rights violation in the world'. She adds, 'Water scarcity is the first face of climate change' (Barlow, 2010).

Given the grave situation, any modes of food production must align with water availability and access. Continuing industrial agricultural systems, including GE crops, which presently use the majority of the planet's fresh water, will aggravate water crises and further threaten food security.

GE crops and yield

Biotech corporations claim that GE crops result in higher yields and thus are an important tool for feeding the world and raising farmer incomes. An important precursor to discussing yield data is to note that the majority of today's GE crops are not grown for humans but are instead cultivated for livestock feed and ethanol fuel for cars (Plumer, 2014).

Regarding yield, a landmark report, *Failure to Yield*, by Gurian-Sherman (2009), found that genetic engineering has not markedly increased corn and soy productivity. This report and a major peer-reviewed research paper shows that since GE corn was introduced in 1996, the vast majority of increased corn productivity was because of conventional breeding and improved cultivation. Data from Europe shows that productivity increases of corn have been as high as in the United States without using genetic engineering (Heinemann *et al.*, 2013).

The USDA, often a proponent of GE crops, cites that 'currently available GM crops do not increase the yield potential of a hybrid variety. … in fact, yield may even decrease if the varieties used to carry the herbicide-tolerant or insect-resistant genes are not the highest yielding cultivars' (Doherty, 2010).

On-the-ground experiences in other countries confirm that GE crops have not resulted in significant gains, nor have they benefitted farmers. In many instances, claims of increased yields and incomes have spectacularly failed.

Introduction of GE cotton (also known as Bt cotton) to deeply impoverished smallholder farmers in the area of the Makhathini Flats in South Africa illustrates such a failure. In the early 2000s, the public–private partnership between Monsanto and the South African government was enthusiastically supported and claims were made that '… the cotton industry envisage that small-scale farmers could produce up to 30 percent of the total cotton crop in South Africa by the year 2005' (Gouse *et al.*, 2002). However, by 2005, smallholders in South Africa produced only a mere 7.7 percent increase of total production, and by 2010 the vast majority of farmers in Makhathini Flats stopped planting GE cotton because of yield failures and problems with controlling secondary pests (Pschorn-Strauss, 2005).

Typically, when GE crop programmes are first introduced in poor regions or developing countries, corporations and governments offer subsidies, credit, implement irrigation, and other infrastructure schemes, and also provide substantial technical support. But when supports and credit systems are reduced or withdrawn, as the case in the Makhathini region, farmers find themselves crippled with debt. While many small-scale farmers were dependent on credit systems before the introduction of Bt cotton, the higher costs of this technology, notably the 68 percent higher cost of GE seed over conventional cotton seed, increased farmers' exposure and debt (Gouse *et al.*, 2005).

Bt cotton cultivation in India is often in the forefront of conversations about GE crops in developing countries. Proponents of these crops maintain that yields have significantly increased since GE cotton has been planted in India. Yet, according to the primary cotton scientist of the Indian Central Institute for Cotton Research, K.R. Kranthi, almost all of the 59 percent yield increase in cotton between 2002 and 2011–2012 occurred by 2005, when only about 5.6 percent of cotton acres were Bt crop varieties. Kranthi attributes most cotton yield increases in India during this period to the introduction of hybrid cotton, increased irrigation, and other factors unrelated to GE cotton. In fact, between 2007/2008 and 2011/2012, when Bt cotton acreage went from 67 to 92 percent of India's cotton acreage, cotton yields fell steadily (Stone, 2012).

A forward vision for food security and full nutrition

There are alternatives to chemically driven, water-intensive agriculture systems. Extensive research demonstrates that a variety of agro-ecological and other methods outperform GE and conventional crops in generating higher yields while reducing chemical and water usage (Pretty, 2009).

Research coordinated by the Department of Biological Sciences and Centre for the Environment and Society at the University of Essex has shown that agro-ecological methods on 286 farms involving over 12 million growers in 57 poor countries covering 37 million hectares (3 percent of the cultivated area in developing countries) have increased the average crop yield by 79 percent. All crops had water-use efficiency gains, carbon sequestration, and reduced pesticide use (Pretty, 2009).

Other research concurs. The IAASTD funded by the United Nations and the World Bank, concluded that GE crops have little potential to alleviate hunger and poverty, and instead recommended agro-ecological approaches as the best means to achieve food security. IAASTD (2009) was an exhaustive, four-year effort that engaged some 400 experts from multiple disciplines.

Despite this, costly and still unproven technologies requiring massive capital investment are given the lion's share of resources at the expense of low-cost technologies and knowledge-based practices that have demonstrated great success.

Research shows that it costs around US$136 million to develop a new biotech trait (McDougall, 2011). In stark contrast, the typical cost to develop a trait for conventional grain crops is $1 million (Goodman, 2002). Yet funding for some of the world's premiere conventional crop breeding institutes have been dramatically cut. For instance, the International Maize and Wheat Improvement Center (CIMMYT) lacked the funds to even distribute conventionally bred varieties of drought-tolerant corn for Africa, and disease-resistant wheat for Asia that it had already developed (Bradsher and Martin, 2008).

Furthermore, farmer-led, public breeding efforts receive dismal amounts of funding even though much promising work shows that such programmes can be more cost effective, productive, and culturally relevant than genetic engineering and conventional breeding (Ceccarelli, 2012). Public breeding programmes that focus on improving local and traditional seeds that do not require chemicals and synthetic fertilizers are a true twenty-first century approach to building resilient, self-reliant farming systems, especially in times of climate chaos.

Serious solutions for better ensuring food security and adequate nutrition require serious re-thinking. Critically, nutritious and diverse food must be accessible at household levels. This means that farming systems must be geared toward growing food primarily for local populations. Instead of spending the majority of resources on high-cost technologies, we need to redirect substantial means towards food and farm systems that are sensitive to the complexities of local ecosystems, and incorporate broad criteria such as socio-economic policies, cultural histories, resource conservation, and social equity.

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