Food and Energy Security
Open Access

ORIGINAL RESEARCH

Genetically modified crops, regulatory delays, and international trade

Stuart J. Smyth

Department of Agricultural and Resource Economics, University of Saskatchewan, 51 Campus Drive, Saskatoon, Saskatchewan S7N 5A8, Canada

Keywords
Adoption impacts, biotechnology, Cartagena Protocol on Biosafety, environmental nongovernmental organizations, food security, risk.

Correspondence
Stuart J. Smyth, Department of Agricultural and Resource Economics, University of Saskatchewan, 51 Campus Drive, Saskatoon, Saskatchewan S7N 5A8, Canada.
Tel: 1-306-966-2929; Fax: 306-966-8413;
E-mail: stuart.smyth@usask.ca

Funding Information
No funding information provided.

Received: 30 September 2016; Revised: 16 November 2016; Accepted: 19 November 2016

***Food and Energy Security* 2017 6(2): 78–86**

doi: 10.1002/fes3.100

Abstract

Genetically modified (GM) crops have been produced in the initial adopting countries for 20 years. Over this period of time, hundreds of articles and reports have been published by academic journals, government regulatory agencies, and national science organizations on the safety aspects of biotechnology and GM crops. In addition to this, there is a growing body of quantified peer reviewed literature on the economic and environmental benefits following the adoption of GM crops in both developed and developing countries. Some estimates place the economic benefits in the billions of dollars a year range. In spite of the documentation of these economic and environmental benefits, GM crops face a challenging future. Environmental nongovernmental organizations (eNGOs) are relentless in their campaigns of misinformation about the dangers and hazards of GM crops. While eNGOs are unable to quantify their claims and accusations, their political and policy influences continue, particularly in Europe and numerous developing nations. The result of this is regulatory delays for the approval of new GM crops and frequent international commodity trade failures, where shipments have been rejected due to the low-level presence of a GM crop. Taken in combination, the regulatory and trade challenges facing GM crops are having a detrimental impact on improving food security. This article quantifies the benefits of GM crops, highlights the regulatory costs of delayed approval, and provides insights into the spillover effects from GM crop trade.

Introduction

Genetically modified (GM) crops have been internationally produced for 20 years and in spite of the substantial quantification of the economic, environmental, and health benefits from the adoption of GM crops, opposition to GM crops remains firmly rooted within many organizations and countries. While GM crops have undergone risk assessments in over 30 different countries without the detection of any increased risk to humans, livestock, or the environment, myths, rumors, and outright lies continue to be perpetuated by environmental nongovernmental organizations (eNGOs) about the damages, dangers, and threats posed by GM crops. The eNGO movement has interfered with biosafety regulatory approval frameworks in many developing countries to ensure that no GM crops are ever approved. When trace amounts of GM crops are detected in non-GM shipments, borders are slammed shut, causing trade conflicts lasting several years.

Given the 20 years of GM crop adoption, numerous studies have reported on the substantial benefits, yet regulatory and trade barriers abound. GM crops have proven to be safe and yet the eNGO community spends billions lobbying and fighting against their use (Byrne 2015). Why is this the case? What is responsible for the continued opposition? The answer is politics. Science-based regulation of innovation in numerous jurisdictions has been replaced by socioeconomic regulation, a nefarious scheme advanced by eNGOs through the liberal interpretation of the Cartagena Protocol on Biosafety (CPB). The CPB has been manipulated to such an extent by eNGOs, that it is only now revealing the hidden objective of the CPB, which is to put a halt to all forms of agricultural research and development in developing countries. Developing countries are expected to reach food security through small-scale, largely organic crop production (UNCTAD 2013).

The question of how to improve global food security when opposition to one of the proven beneficial technologies is so seemingly entrenched is indeed a modern day dilemma. This article summarizes the literature on the global economic, environmental, and health benefits of GM crops. This is followed by a discussion of the regulatory challenges that have been precipitated following the advent of the CPB. Documentation of the trade barriers that exist regarding GM crops rounds out the evidence compiled on the mistreatment of GM crops. The remainder of the article discusses the crucial steps that will be required to truly advance global food security in the face of such organized opposition.

Global Benefits of GM Crops

While GM crops have undergone risk assessments in over 30 countries, at present, they are only produced in 28 countries (James 2015). James identifies that 180 million hectares of GM crop production occurred in 2015, involving over 17 million farmers. Two thirds of the countries adopting GM crops are developing countries. While some GM crop varieties have limited production, such as papaya, eggplant, alfalfa, and sugar beets, the benefits of GM crops focus on the observed effects of the four dominant GM crops: canola, corn, cotton, and soybeans. The benefits from GM crops can be differentiated into three main categories, economic, environmental, and health.

Economic benefits of GM crops

With the adoption of GM crops rapidly expanding over the first two decades of availability, the benefits from the technology must be significant, otherwise farmers would have begun to return to previous crop options. One team of authors has annually examined the economic impacts of GM crops and their most recent data on the 2014 cropping year estimates that the global economic benefits of GM crops exceeded US$17 billion (Brookes and Barfoot 2016). Cumulatively, over the period from 1996 to 2014, the authors estimate that the economic benefits of GM crops have reached US$150 billion. The production increases from GM crops have a substantial contribution to improving global food security as Brookes and Barfoot estimate that over the 19-year period of GM crop production, an additional 158 million tons of soybeans and 322 million tons of corn have been produced that would not have resulted without the technology.

Studies on the economic benefits from GM crops first began to appear about the turn of the millennium, with many of these based on the results from experimental field trial data that were then extrapolated to the crop production area, using an estimated adoption curve. These were rudimentary studies that provided an initial sense of what degree of benefits might be observed, particularly in developing countries. By the time the technology had been adopted for a decade, studies of greater rigor began to appear, based on farmer surveys.

Several articles undertook a detailed assessment of the numerous studies that began to regularly appear following the first decade of GM crop adoption. The first of these was conducted by Carpenter (2010), which examined 168 studies on GM crop yields, finding that 124 of the studies reported yield increases, 32 no change, and only 13 reporting lower yields. Finger et al. (2011) examined 203 peer reviewed studies, concluding that yield increases are evident with GM crop adoption, but noted that these increases were due to reduced insect and weed population pressures and not due to actual genomic yield increases. Areal et al. (2013) examined 97 studies comparing yield increases between GM and non-GM, finding GM crops outperformed conventional crop in both developed and developing countries. The most recent study was conducted by Klümper and Qaim (2014), who undertook a meta-analysis of 147 studies on the impacts of GM crops, finding that chemical pesticide use decreased by 37%, crop yields increased by 22%, and farmer profits increased by 68%.

While these overarching studies provide an international sense as to the distribution of benefits observed from GM crops, it is useful to draw on some specific examples to further illustrate the level of benefits that have been observed. Subramanian and Qaim (2010) examined Bt cotton adoption in India, finding that it raised vulnerable household incomes (those defined as living on <$2/day) by 134%. Hutchison et al. (2010) led a study on the economic benefits of GM corn adoption in the United States, finding that GM corn created $6.8 billion in extra value, with 60% going to nonadopters due to lower insect pressures. Based on a farm survey of nearly 600 canola producers, Gusta et al. (2011) found that GM canola resulted in annual benefits of $350–$400 million in Western Canada. Yorobe and Smale (2012) identified that GM corn adoption in the Philippines increased household income from $400/year to $600/year, a 50% increase. Vitale et al. (2014) found Bt cotton adoption in Burkina Faso resulted in a profit of $150/ha versus $70/ha for conventional cotton. Alston et al. (2014) estimate the cumulative global benefits from GM soybeans to be $46 billion over the 15-year period from 1996 to 2010.

Environmental benefits of GM crops

The first studies examining the environmental benefits of GM crops were undertaken following the adoption of Bt cotton in China. Pray et al. (2001) surveyed Chinese farmers in 1999, finding that the adoption of Bt cotton allowed farmers to spray less frequently, in some instances dropping from 30 per season to 3, but more commonly from 12 to 3–4. Huang et al. (2010) update the Chinese Bt cotton story observing that across the entire sample region insecticide applications dropped from 14 kg/ha to 4 kg/ha.[1] The spillover of environmental benefits from the lengthy adoption of Bt cotton began to be observed as the authors reported finding that in some non-Bt cotton fields the amount of insecticide used dropped from in excess of 40 kg/ha to >10 kg/ha. Similar environmental benefits from the adoption of Bt cotton in India were quantified by Subramanian and Qaim (2010), where they found Bt cotton reduced pesticide use by 41%.

A detailed study of the environmental changes following a decade of GM canola production in Western Canada identified substantial benefits. Prior to the commercialization of GM canola, the chemicals available to be applied to canola for weed control were limited, with the majority requiring soil application. The commercialization of herbicide-tolerant varieties of GM canola allowed producers to begin to use foliar chemical applications. The result of this was that the environmental impact of the chemicals applied to canola dropped by 53% when compared to the chemicals that were previously used on canola (Smyth et al. 2011a). When comparing chemical applications between GM canola production and the alternate scenario where GM canola had not been commercialized, the authors found the total volume of chemicals applied to canola dropped by 1.3 million kg/year. The rapid adoption of GM canola provided improved weed control options, which reduced the use of tillage as a form of weed control, resulting in one million tons of carbon being either sequestered by the soil or no longer released from implement passes (Smyth et al. 2011b). Brookes and Barfoot (2016) show CO_2 emission reductions equal to removing 10 million cars for 1 year.

Recent research shows the environmental costs of not adopting GM crops. Australia approved GM canola in 2003. However, in 2004 a moratorium was implemented across Australia against growing GM canola. It was not until 2008 when the central canola producing states of New South Wales and Victoria lifted the moratorium, followed by Western Australia in 2010. An examination of the environmental costs of the Australian moratoriums was undertaken that estimated what the adoption level for GM canola could have been after one decade of production, from 2004 to 2014, had the moratorium not been implemented (Biden 2016). The delayed adoption of GM canola production in Australia cumulatively resulted in the application of an additional 6.5 million kg of chemical active ingredient. The application of these additional chemicals were done through an additional 7 million field passes, requiring 8.7 million liters of diesel. The environmental impact of the additional chemicals applied was 14% higher than would have been the case if GM canola had not been subjected to an adoption moratorium. Finally, an estimated 24 million additional kilograms of greenhouse gases were released due to the nonadoption of GM canola.

Health benefits of GM crops

Some of the most significant benefits from GM crops, yet least widely recognized, are the health and lifestyle benefits. Identified benefits in this area range from a reduction in pesticide poisonings to less time spent hand weeding fields.

One continuous criticism advanced by critics of biotechnology and GM crops, such as Vandana Shiva, is that GM cotton is responsible for thousands of small landholder farmers committing suicide every year. Shiva and her ilk intentionally ignore the facts about Indian farmer suicide and continue to perpetuate lies about the unfortunate situation of farmer suicides. Research on this subject was conducted by Gruère and Sengupta (2011) and documented a one-third reduction in the suicide rate following the release of Bt cotton among Indian farmers based on extrapolating the pre-Bt cotton commercialization suicide rate.

Research from South Africa following the adoption of GM corn documents the first lifestyle benefits of the technology. Gouse (2013) surveyed small landholders finding that GM corn adoption had resulted in 10–12 fewer days of female hand weeding per season. This research identified that the women farmers spent this time predominantly in one of two areas, hauling more water for their vegetable gardens or spending time with their children.

While the economic and environmental benefits of GM crops are important, they definitely pale in comparison to the health benefits of reduced pesticide poisoning. Vitale et al. (2014) surveyed Bt cotton farmers in Burkina Faso over the first 3 years of adoption. While the economic benefits discussed above are significant, the health benefits far outweigh the economic benefits. Their farm survey results identified that an estimated 30,000 fewer cases of pesticide poisoning per year were occurring among Bt cotton farmers.

While the health benefits in Burkina Faso are important, they are dwarfed by the health benefits identified by Kouser and Qaim (2011) regarding pesticide poisoning reductions following Bt cotton adoption in India. Their research estimated that the number of pesticide poisonings was reduced by between 2.4 million and 9 million cases a year. They estimated that the financial savings for the Indian Ministry of Health ranged between US$14 and 51 million.

Every developed and developing country that has adopted one of the available GM crops has experienced at least one of, if not all of increased yield, reduced chemical use, and/or fewer cases of pesticide poisoning. With hundreds of studies now quantifying the various benefits, where is the holdup? Why is adoption in developing countries not happening at a faster rate than it is? What or who is responsible? The article now turns its attention to a discussion of the regulatory barriers that have been systematically structured to frustrate innovations in agriculture.

Regulatory Challenges Facing GM Crops

Domestic regulatory systems are now part of corporate investment strategies (Smyth et al. 2014). In January 2012, BASF announced that it was moving its agricultural research division from Europe to the United States due to the timeliness of regulatory decisions in Europe (BASF, 2012). It is even possible to view the Bayer acquisition of Monsanto as being a mechanism for Bayer to move underutilized, if not stranded, capital invested in plant variety development in Europe to the United States, given the European aversion to agriculture innovations in plant technologies.

Regulatory systems in some jurisdictions are being driven by politics, not science. Politicization of risk has occurred in the European Union (EU) as they have fully incorporated a rigid version of the precautionary principle into their regulatory framework for GM products (Smyth et al. 2015). The EU's rigid application is an inappropriate interpretation of the precautionary principle. As was established by the World Trade Organization's (WTO) ruling in the 2006 case by Argentina, Canada, and the USA against the EU's moratorium on GM crops, the precautionary principle requires some form of evidence to be invoked.

This has reduced the EU regulatory system for GM crop approvals to utter gridlock with only a single variety being approved for commercial production in the past decade. Even decisions regarding approval for import take longer in the EU than in the United States. Smart et al. (2016) found that approvals in the United States required an average of 686 days compared to 995 days in the EU. Currently, >10% of global industry research and development (R&D) on agriculture is spent in the EU versus one-third 20 years ago (Little 2015). While it would not be possible to attribute all of this loss in R&D investment to the EU's present regulatory regime, the regulatory framework has to be considered as having a substantial impact on this investment decline. Pardey et al. (2016) have completed a thorough analysis of agricultural R&D spending, finding that in 2011, global investments totaled US$69 billion. High-income countries accounted for 55% (down from 69% in 1980), while middle-income countries accounted for 43% (up from 29% in 1980).

The lack of coordinated regulatory capacity for GM crops is causing untold delays in the adoption and diffusion of the technology. For example, by October 2015, EU Member States had to inform the European Commission as to whether they would opt out of EU-wide GM crop approvals as has been mandatory since 2003. By this deadline, 19 of 28 MS indicated they would opt out (Smyth et al. 2016). The EU is no longer capable of approving GM crops for production and is struggling to manage to approve GM crops for import. Varieties of GM crops submitted in 2005 for import approval (predominantly for animal feed use) still have not been approved over 11 years later.

While existing and previous technologies to develop new crop varieties has posed a significant quandary for EU regulators, new plant breeding techniques may be an even greater challenge. New plant breeding techniques that provide no identifiable markers that can be used to verify the technology utilized to create the new variety now have their initial varieties undergoing risk assessment and approval. Examples of these technologies are targeted mutagenesis techniques such as oligonucleotide-directed mutagenesis (ODM), zinc finger nuclease (ZFN), meganuclease technique, and transcriptional activator-like effector–nuclease (TALEN), and gene silencing techniques such as clustered regularly interspaced short palindromic repeats (CRISPR). Many of these technologies have been classified as forms of mutagenesis in the United States, with the resulting products not subject to GM crop regulations. Examples such as Innate potatoes developed by Simplot and Arctic apples developed by Okanagan Specialty Fruits document the acceptance of innovative plant breeding technologies in some parts of the world. In an open letter to the European Commission, leading eNGO groups across Europe have attacked these new breeding techniques (NBTs), calling for every single new NBT to be classified as a GMO technology and therefore rejected for use within the EU (Panella et al. 2015).

The easing of regulatory burdens on innovative agricultural biotechnologies does not seem to be on the horizon as recent and ongoing trade negotiations have not satisfactorily addressed the subject. The recent Comprehensive Economic and Trade Agreement (CETA) between Canada and the

EU does have provisions for addressing regulatory issues, but in the era of biotechnology, there is no ability to resolve disputes. Therefore, regulatory issues will simply be discussed and discussed for years with no mechanism for resolution. The CETA clearly states that trade barriers such as the low-level presence of EU-unapproved GM varieties will be referred to the Dialogue on Biotech Market Access Issues. Even though it is clearly acknowledged that there are outstanding trade and regulatory barriers, CETA does nothing to resolve these other than to refer the topics to an ongoing dialog process that lacks any formal definition. The language used in the CETA documents is also present in the language of the Trans-Pacific Partnership and the current negotiations between the US and the EU on the Transatlantic Trade and Investment Partnership (T-TIP).

Perhaps the single biggest regulatory barrier to biotechnology is the inappropriate interpretation and application of the Cartagena Protocol on Biosafety (CPB). The CPB was negotiated at the end of the last millennium as an environmental response to the WTO's unwillingness to open to the Sanitary and Phytosanitary (SPS) Agreement to consumer aversion to biotechnology and GM crops. In December 2000, agreement was reached on the CPB, as a supplement agreement to the Convention on Biological Diversity. The CPB came into effect as an international agreement in 2003, focusing solely on the trans-boundary movement of living modified organisms (LMOs). The EU pushed heavily for the establishment of the CPB, which incorporates the precautionary principle to the fullest extent. The EU had previously lobbied the WTO to have the SPS Agreement revised to reflect consumers' socioeconomic concerns, however, they were unsuccessful in these efforts. Currently, 170 countries have ratified the CPB, while leading GM crop-producing countries such as Argentina, Australia, Canada, and the United States are not parties.

One consequence that was not clearly evident at the time of the CPB's negotiation and coming into effect was the disastrous effect that would be created from the movement away from science-based regulation. With the hidden agenda of undermining agricultural research and development (R&D) in developing countries, the eNGOs that lobbied vociferously for the ratification of the CPB have been successful at ensuring the inclusion of socioeconomic issues that have no data, no methodology, and no ability to contribute meaningfully to biosafety (Ludlow et al. 2014). The eNGO community has advanced nebulous socioeconomic considerations (SECs) such as gender impacts; farmers' rights; cultural, spiritual, and ethical aspects; land tenure; labor and employment; rural–urban migration; impacts on consumer choice; and impacts on market access as issues that require assessment prior to the approval of a GM crop. Virtually all of these have limited or nonexistent data in developing nations, lack credible methodologies that would be required to undertake an assessment, and lack any benchmark capability to know if the resulting impact would be positive or negative. Given all of these attributes, it is clear that SECs are simply a disguised objective to ensure that all agricultural R&D is delayed, if not outright prevented, in most developing nations. The extreme of SEC inclusion is evidenced by the biosafety regulations of Mali, whereby no negative socioeconomic impact from the commercialization of a GM crop is allowable (CBD 2014). In the history of innovative products and technologies, there is not a single one that has resulted in zero adverse effects occurring. The adoption of fire to heat caves resulted in burns; learning how to sail boats resulted in people drowning; and the invention of cell phones resulted in deaths due to texting while driving. Mali's regulatory barrier to GM crops makes it abundantly clear that the CPB is a disguised barrier to all crop R&D in developing countries.

Regulatory barriers of this nature have substantial impacts on R&D investment decisions, as demonstrated by BASF's decision to transfer all of its agricultural R&D assets out of Europe to North America. While private companies have the luxury of being able to relocate assets in an effort to secure a higher return on investment (ROI), public sector investors are not afforded such luxury. In most developing countries, public research centers invest in the development of local crop variety improvements and will frequently partner with international agencies, organizations, and companies in the development of new plant varieties. These centers will have minimal ROI expectations as the royalties from new crop varieties will be a low percentage of seed prices. A 2-year delay in the regulatory approval of a new crop variety with a ROI rate of 20% has been shown to eliminate all positive returns (Smyth et al. 2014). With national research centers relying on ROI revenue to fund new variety R&D, the revenue loss will have devastating effects.

Not only is biotech research jeopardized in developing countries, but all agriculture research is in danger of being ended, especially if the eNGO community is successful in getting the various new breeding techniques to be regulated as GMO technologies. Should the full list of NBTs be classified as GMOs by eNGOs for developing country regulators, investment in agricultural R&D could be expected to virtually cease, given the very low probability that any resulting product could ever be approved through an SEC-based regulatory system.

Trade Impacts From GM Crops

International commodity trade has never taken place at a purity level of 100%. This is particularly impossible as the purity level for certified seed, the seed that the pedigreed seed industry sells to farmers, is sold at a purity level of 99.5%. At this level, there is an allowance of one quarter of a percent for weed seeds and one quarter of a percent for other crop varieties. Given that the grain, pulse, and oilseed production process starts with 0.5% impurities, commodities cannot make it through the entire growing, harvesting, and transportation stages without an increase in the presence of impurities or off-types. While challenging to verify due to the private nature of commodity contracts, conversations with those in the grain trade industry indicate that contracts are typically written with impurity thresholds of 3–5%. The lower the threshold, the higher the price the importer has to pay.

Shortly after the commercialization of GM crops, adoption and import moratoriums began to be enacted. The most significant of these was the GM crop moratorium that the EU implemented from 1998 to 2003. While this was ultimately ruled as a trade barrier in 2006 by the WTO, the damage had already been done. Global commodity trade has been adversely affected by the low-level presence (LLP) of approved GM varieties as well as the adventitious presence (AP) detection of unapproved GM varieties in non-GM markets.

Prior to 2003, regulation and approval of GM crops in Europe was done individually by Member States. When issues of LLP and AP occurred, the resulting fields were either destroyed or harvested and the resulting crop contained (Hobbs et al. 2014). Incidents of this nature happened over several years without international borders being closed to commodity trade. In 2003, the EU removed its GM crop moratorium and established the European Food Safety Authority (EFSA), which coincided with an end to rational approaches to LLP and AP detection. Following 2003, any LLP or AP detection results in an immediate closure of EU borders to commodity trade, costing billions in lost trade opportunities (Smyth et al. 2015). In some instances, this has resulted in shipments of conventional commodities being destroyed due to false-positive GM crop detections (Kalaitzandonakes et al. 2016). Examples exist in American exports of corn and rice to the EU, while Canada's flax market was adversely affected by the closure of the EU border to Canadian flax exports.

In September 2009, GM flax was detected in Canadian flax exports to the EU. The EU immediately closed the border to all flax shipments from Canada. The border closure lasted 4 months, until an industry stewardship testing protocol could be developed, agreed upon, and implemented. This stewardship protocol ensures that every field of Canadian flax is tested for GM flax and this testing protocol continues all the way along the flax handling system, rail, interlake freighters, and transoceanic vessels. The 4-month export loss cost the Canadian flax industry C$30 million, while in the EU the border closure resulted in losses of €40 million to their flax processing industry and over 600 jobs (Ryan and Smyth 2012). The initial agreement regarding the stewardship testing protocol was to test all shipments for a period of 5 years, costing $1 million per year. This testing protocol was to have ended in 2014; however, no incentives to end the testing program exist and it will continue to cost the Canadian flax industry $1 million per year for the foreseeable future. The EU was Canada's leading flax export market, so Canada cannot risk ending testing protocols given the importance of the EU market, while on the other hand, the EU is not going to suddenly drop requirements that Canadian flax no longer be tested, given how political the issue of GM comingling is in Europe. Unless a sunset clause is agreed to upon negotiation of a testing protocol, the testing for LLP of GM crops will continue to cost the commodity trade industry in perpetuity.

American commodity exports have similarly been adversely affected. Herculex I corn was approved in the United States and was submitted to the EU for import approval in 2000. When import approval was not shortly received, the industry undertook export testing to ensure this variety did not reach the EU. The EU's regulatory system managed to approve the import of Herculex I corn, taking 6 years to do so; however, during this period, traces of Herculex R corn were detected in EU shipments. The corn industry's challenge of perfectly ensuring that zero Herculex R corn entered the EU animal feed market caused corn gluten feed exports from the US to the EU to drop by 30–40%. By 2009, Herculex R was approved for import, but the corn market was disrupted for 3 years, all over a variety of corn that was used as an ingredient in livestock feed.

Rice exports from the US to the EU suffered a similar fate. Trace amounts of LL601 rice were detected in EU in 2006. The problem in this instance was that LL601 had not received variety approval in the United States, so its AP in rice shipments was a major concern for the rice industry. Over 1000 lawsuits were launched against Bayer, the developer of LL601, ultimately costing over $2 billion in settlement costs. By 2012, the issue was finally resolved with the last of the court cases being completed, however, the US rice export market to the EU was only 40% of what it had previously been.

The message that these commodity trade problems send to developing countries considering the adoption of GM crops is resoundingly negative. If industrial countries like Canada and the United States struggle to manage identity preservation systems and export GM-free shipments to the EU, how would developing countries be able to exceed the Canadian or American systems, especially given the limited resources and inland testing capability? Developing countries that rely on EU markets for exported products see the GM crop LLP trade backlash and ongoing costs, which negatively impacts developing country decisions to adopt GM crops. In fact, the EU has gone as far as threatening developing countries into ensuring that they do not adopt GM crops. In 2014, the EU's Ambassador to Kenya, Lodewijk Briet was quoted as saying: "Local farmers will find it difficult to export their crops to Europe if they adopt the Genetically Modified (GM) crops" (Gathura 2014).

If threatening developing countries is not despicable enough, the EU also blackmails countries into ensuring that they adopt the innovation-killing interpretation of the CPB if they want to export agricultural products to the EU. The WTO allows countries to apply different tariff rates to specific countries for specific products that are not granted to all other trading partners. Essentially this allows countries to export their products at a lower tariff rate than competing export countries. The EU requires that any country wanting the lower tariff rate to have ratified the CPB: "the CPB aims to ensure a balance between the sustainable use of modern biotechnology and economic interests. The protocol governs the trans-boundary movement of Genetically Modified Organisms (GMOs), and authorizes states to prevent the import of GMOs according to the precautionary principle" (European Commission, 2016: 13).

The CPB is the biggest international barrier to innovative agricultural technologies, GM crops, and NBTs presently in existence. In addition to this, the EU forces developing countries wanting preferred tariff rates to be a member of the CPB and the EU threatens developing countries that if they adopt GM crops, they will lose access to EU markets. Developing countries witness how the EU shuts its borders to Canadian and US exports when the LLP of approved and unapproved GM crops are detected. The EU and its vigorous application of the CPB leaves most developing nations feeling they simply have no option when it comes to domestically deciding whether or not to adopt GM crops and rather that this decision has already been made for them by the EU and particularly by EU-based eNGOs.

If all this was not deemed a significant enough deterrent to developing countries, in the spring of 2016, the European Parliament completely abandoned a previous G7 commitment to improving food security. In 2012, the G7 group of countries launched the New Alliance for Food Security and Nutrition program in an effort to lift 50 million people out of poverty. In June 2016, Members of the European Parliament (MEP) called on developing countries to reject the program, calling it "a mistake." MEPs demanded "that the G7 abandon its commitment to GMOs in this public-private partnership" and this type of farming practice "destroys family farming and reduces biodiversity" (The Guardian, 2016).

The EU and its eNGOs spend billions annually to prevent GM crops from being adopted in developing countries. In 2015, it is estimated that the anti-GM movement spent US$10 billion fighting biotech around the globe (Byrne 2015). In 2011, the big six multinational biotechnology development companies spent US$8.6 billion on agriculture R&D (Hobbs 2014). Clearly, GM crops and their benefits is a political issue for eNGOs and given their investments opposing the technology, it is too financially lucrative for them to ever back away from. With the relentless pressure from the eNGO community to erect regulatory barriers against commercializing GM crops taken together with the EU's rejection of the peer reviewed scientific evidence GM crop benefits, its intimidation of developing countries into signing the CPB, and blackmailing developing countries to not adopt GM crops, global food security is not going to increase given the present state of international regulation and trade for GM crops.

Breaking the Food Security Barriers

Politics, not science, is driving the international agenda pertaining to GM crop approval, adoption, and trade. If science was the determining factor for the debate about the benefits of GM crops, then the opposition to GM crops should have waned considerably over the past decade. Sadly, it has not. If, as Byrne (2015) identifies, the eNGO movement is spending in the region of US$10 billion annually fighting against GM crops, then one would expect that these eNGOs would be generating even larger sums of revenue. The continuation of eNGO opposition to GM crops in the face of mounting economic, environmental, and health benefits can be attributed to two factors. First, it is obviously profitable for the eNGO movement to maintain its opposition to GM crops. This allows them to raise more revenue, hire additional staff, and grow their movements, thus increasing their ability to ensure that developing countries implement socioeconomic-based regulatory systems that must reject GM crop variety approval applications. Second, the eNGO movement has gained substantial political influence with governments regarding biotechnology. Nowhere is this more clearly evident than in Europe, where when given the choice of approving or rejecting GM crops at the domestic level, two thirds of EU members chose to reject the technology. Continued eNGO opposition to GM crops is both profitable and powerful.

The eNGOs have a 20-year head start on those in industry and academia in vociferously opposing GM crops and have seemingly successfully adopted the tobacco industry's strategy whereby they criticize those that engage in research on the benefits of GM crops. The CPB has been operating for nearly 15 years to entrench structural opposition to agriculture R&D and innovation. Agricultural innovations face a decade worth of work to remove the barriers to improving global food security so that there is a chance to feed the world of 2050. Global food security can improve, if and only if, two radical changes are made.

The first change will be to aid and assist developing countries in opting out of the Cartagena Protocol on Biosafety. As long as the CPB is a tool for the EU and its cadre of eNGOs, to dictate and manipulate food security in developing countries, these countries will continue to face starvation and malnourishment. Academics need to be engaged in quantifying the benefits of various types of GM crop adoption (and NBTs) as well as the costs of not adopting GM crops. Australia's GM canola moratorium cost farmers nearly $500 million in lost revenue (Biden 2016). Federal governments and philanthropic organizations need to partner to establish matching funding programs, allowing for the submission of peer reviewed research grant applications, thus ensuring that rigorous methodologies are employed to undertake research on the cost of delayed GM crop adoption. Grants of this nature could fund the research necessary for developing countries to better appreciate the costs that the CPB is inflicting and to develop the research and data required to opt out of the CPB.

The second requirement will be to develop a means of fencing Europe out of global commodity trade. GM crop adopting nations like Canada, USA, and Australia need to seek new regional trade agreements with developing countries regarding agricultural commodity trade. This will especially be the case for products developed via NBTs. All agriculture trade ties between the EU and developing countries need to be severed. The EU threat must be removed so that developing countries can freely decide for themselves whether or not to adopt new technologies such as GM crops. The eNGO community's ability to dictate first world food choices to malnourished developing countries has to end. To successfully achieve this, political lobbying will be required to encourage governments to the benefits of developing country trade agreements.

Mid-century food security is achievable, but it will require some difficult decisions to be made. The political power wielded by European-based eNGOs has thoroughly corrupted these organizations as they have successfully manipulated the CPB into becoming an agreement that encourages the rejection of scientific innovation and one that ultimately supports environmental and biodiversity degradation. Continuing with the situation of EU and eNGO manipulation and corruption will only ensure that the future of food security is thoroughly jeopardized, placing the lives of hundreds of millions of developing world citizens at risk. Humanity dictates that the EU and these nefarious eNGOs be expeditiously removed from the formula for food security.

Conflict of Interest

None declared.

Note

[1]The authors do not state whether these figures are kilograms of active ingredient applied. It is expected that this reduction would be in kilograms of active ingredient applied per hectare, but this is not explicitly stated by the authors.

References

Alston, J. M., N. Kalaitzandonakes, and J. Kruse. 2014. The size and distribution from the adoption of biotech soybean varieties. Chapter 45. Pp. 728–751 *in* S. J. Smyth, P. W. B. Phillips, D. Castle, eds. Handbook on agriculture, biotechnology and development. Edward Elgar Publishing Ltd, Cheltenham, U. K..

Areal, F. J., L. Riesgo, and E. Rodriguez-Cerezo. 2013. Economic and agronomic impact of commercialized GM crops: a meta analysis. J. Agric. Sci. 151:7–33.

BASF. 2012. News release: BASF to concentrate plant biotechnology activities on main markets in North and south America. Available at http://www.basf.com/group/pressrelease/ P-12-109.2012. (accessed 17 September 2012).

Biden, S. 2016. Comparing the Adoption of Genetically Modified Canola in Canada and Australia: The Environmental and Economic Opportunity Costs of Delay. University of Saskatchewan Masters' of Science Thesis.

Brookes, G., and P. Barfoot. 2016. Global income and production impacts of using GM crop Technology. 1996–2014. GM Crops Food 7:38–77.

Byrne, J. 2015. Presentation by President of v-Fluence Interactive at the Agricultural Bioscience International Conference. Melbourne.

Carpenter, J. 2010. Peer-reviewed surveys indicate positive impact of commercialized GM crops. Nat. Biotechnol. 28:319–321.

Convention on Biological Diversity. 2014. Global overview of the information on socioeconomic considerations arising from the impact of living modified organisms on the conservation and sustainable use of biological diversity. UNEP/CBD/BS/AHTEG-SEC/1/2, Montreal, Canada.

European Commission. 2016. The EU Special Incentive Arrangement for Sustainable Development and Good Governance ('GSP+') covering the period 2014 – 2015. Available at http://trade.ec.europa.eu/doclib/docs/2016/January/tradoc_154178.pdf (accessed 26 September 2016).

Finger, R., N. El Benni, T. Kaphengst, C. Evans, S. Herbert, B. Lehmann, et al. 2011. A meta analysis on farm-level costs and benefits of GM crops. Sustainability 3:743–762.

Gathura, G. 2014. Europe to shun Kenya's GM crops, farmers told. The Standard. June 20th. Available at: http://www.standardmedia.co.ke/article/2000125446/europe-to-shun-kenya-s-gm-crops-farmers-told (accessed 26 September 2016).

Gouse, M. 2013. An evaluation of the gender differentiated impact of genetically modified crop adoption: A pilot study in South Africa - GM maize and gender: Evidence from smallholder farmers in KwaZulu-Natal, South Africa. Project report to the Program for Biosafety Systems, International Food Policy Research Institute.

Gruère, G., and D. Sengupta. 2011. Bt cotton and farmer suicides in India: an evidence-based assessment. J. Dev. Stud. 47:316–337.

Gusta, M., S. J. Smyth, K. Belcher, P. W. B. Phillips, and D. Castle. 2011. Economic benefits of genetically-modified herbicide-tolerant canola for producers. AgBioForum 14:1–13.

Hobbs, J. E. 2014. The private sector: MNEs and SMEs. Chapter 4. Pp. 56–70 *in* S. J. Smyth, P. W. B. Phillips, D. Castle, eds. Handbook on agriculture, biotechnology and development. Edward Elgar Publishing Ltd, Cheltenham, U. K..

Hobbs, J. E., W. A. Kerr, and S. J. Smyth. 2014. The perils of zero tolerance: technology management, supply chains and thwarted globalisation. Int. J. Technol. Globalisation 7:203–216.

Huang, J., J. Mi, H. Lin, Z. Wang, R. Chen, R. Hu, et al. 2010. A decade of Bt cotton in Chinese fields: assessing the direct effects and indirect externalities of Bt cotton adoption in China. Sci. China Life Sci. 53:981–991.

Hutchison, W. D., E. C. Burkness, P. D. Mitchell, Moon, R. D., Leslie, T. W., Fleischer, S. J., et al. 2010. Areawide suppression of European corn borer with Bt maize reaps savings to non-Bt maize growers. Science 330:222–225.

James, C. 2015. 20th Anniversary (1996 to 2015) of the Global Commercialization of Biotech Crops and Biotech Crop Highlights in 2015. ISAAA Brief 51. Available at: http://www.isaaa.org/resources/publications/briefs/51/default.asp (Accessed 14 September 2016).

Kalaitzandonakes, N., P. W. B. Phillips, J. Wesseler, and S. J. Smyth, eds. 2016. The coexistence of genetically modified, organic and conventional foods: government policies and market practices. Springer Science+Business Media LLC., New York.

Klümper, W., and M. Qaim. 2014. A meta-analysis of the impacts of genetically modified crops. PLoS ONE 9:1–7.

Kouser, S., and M. Qaim. 2011. Impact of Bt cotton on pesticide poisoning in smallholder agriculture: a panel data analysis. Ecol. Econ. 70:2105–2113.

Little, J. 2015. Smart regulation and innovation for EU agriculture. Presentation to the 7th European Innovation Summit. December 7-10.

Ludlow, K., S. J. Smyth, and J. Falck-Zepeda, eds. 2014. Socio-economic considerations in biotechnology regulations. Springer Publishers, New York.

Panella, F., N. Holland, R. Steinbrecher, A. Ferrante, M. Schimpf, H. Wallace, et al. 2015. Open letter to the Commission on new genetic engineering methods. Available at: http://www.genewatch.org/uploads/f03c6d66a9b354535738483c1c3d49e4/New_Breeding_Techniques___Open_Letter_27_Jan_2015.pdf (Accessed 23 September 2016).

Pardey, P. G., C. Chan-Kang, S. P. Dehmer, and J. M. Beddow. 2016. Agricultural R&D is on the move. Nature 537:301–303.

Pray, C., D. Ma, J. Huang, and F. Qiao. 2001. Impact of Bt cotton in China. World Dev. 30:931–948.

Ryan, C. D., and S. J. Smyth. 2012. Economic implications of low-level presence in a zero-tolerance European import market: the case of Canadian Triffid Flax. AgBioForum 15:21–30.

Smart, R. D., M. Blum, and J. Wesseler. 2016. Trends in approval times for genetically engineered crops in the United States and the European Union. J. Agric. Econ. doi:10.1111/1477-9552.12171.

Smyth, S. J., M. Gusta, K. Belcher, P. W. B. Phillips, and D. Castle. 2011a. Changes in herbicide use following the adoption of HR Canola in Western Canada. Weed Technol. 25:492–500.

Smyth, S. J., M. Gusta, K. Belcher, P. W. B. Phillips, and D. Castle. 2011b. Environmental impacts from herbicide tolerant canola production in Western Canada. Agric. Syst. 104:403–410.

Smyth, S. J., J. McDonald, and J. Falck-Zepeda. 2014. Investment, regulation and uncertainty: managing new plant breeding techniques. GM Crops Food 5:1–14.

Smyth, S. J., P. W. B. Phillips, and W. A. Kerr. 2015. Food security and the evaluation of risk. Global Food Secur. 4:16–23.

Smyth, S. J., P. W. B. Phillips, and W. A. Kerr. 2016. EU failing FAO challenge to improve global food security. Trends Biotechnol. 34:521–523.

Subramanian, A., and M. Qaim. 2010. The impact of Bt cotton on poor households in rural India. J. Dev. Stud. 46:295–311.

The Guardian. 2016. European parliament slams G7 food project in Africa. June 8th. Available at: https://www.theguardian.com/global-development/2016/jun/08/european-parliament-slams-g7-food-project-in-africa (Accessed 26 September 2016).

United Nations Conference on Trade and Development. 2013. Trade and environmental review 2013: wake up before it is too late. United Nations, New York.

Vitale, J., G. Vognan, and M. Ouattarra. 2014. Cotton. Chapter 38. Pp. 604–620 *in* S. J. Smyth, P. W. B. Phillips, D. Castle, eds. Handbook on agriculture, biotechnology and development. Edward Elgar Publishing Ltd, Cheltenham, U. K..

Yorobe, J. M., and M. Smale. 2012. Impacts of Bt maize on smallholder income in the Philippines. AgBioForum 15:152–162.

