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Economic Issues in the Coexistence of Organic, Genetically Engineered (GE), and Non-GE Crops

Catherine Greene, Seth J. Wechsler,
Aaron Adalja, and James Hanson

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Abstract

Two decades after the first genetically engineered (GE) seeds became commercially available for major field crops, GE varieties have been widely adopted for U.S. corn, soybean, cotton, canola, and sugar beet production. The small, longstanding market for organically grown food (which excludes GE seed and material) continues to expand and a market for conventionally grown foods produced without GE seed has also emerged. In order to maintain the integrity of GE-differentiated markets, organic farmers—and other farmers using non-GE seeds—employ a variety of practices to avoid the accidental mixing of GE material in their crops. This report examines organic and conventional product markets in the United States. It describes commonly used coexistence practices and discusses the economic impacts when GE material is detected in organic crops.

Keywords: Coexistence, organic crops, USDA organic standards, genetically engineered crops, identity preservation, non-GE, non-GMO, adoption, prices, economic impacts, corn, soybeans

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Find the full report at *www.ers.usda.gov/publications/eib-economic-information-bulletin/eib-149*

Economic Issues in the Coexistence of Organic, Genetically Engineered (GE), and Non-GE Crops

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What Is the Issue?

In 1996, U.S. farmers began using genetically engineered (GE) crop varieties containing traits to tolerate herbicides and resist pests in major field crop production. As of 2014, GE varieties had been adopted on over 90 percent of U.S. corn, soybean, cotton, canola, and sugar beet acreage to help producers manage crop pests more easily and effectively. A much smaller percentage of alfalfa, sweet corn, squash, and papaya crops were cultivated using GE varieties. Recently, USDA deregulated (approved) GE varieties for two of the most widely grown fruits and vegetables in the United States—apples and potatoes. Potatoes are the top U.S. vegetable crop in terms of acreage, with over a million acres in 2014, and account for 15 percent of total vegetable farm sales. Bearing apple trees occupied 322,000 U.S. acres in 2014, and apples are the second most popular fresh fruit (after bananas) in America. The addition of these two commodities to the GE roster may heighten issues related to GE/non-GE commingling of crops and products.

GE crops are now widely used to produce processed foods and food ingredients, such as corn chips, breakfast cereals, soy protein bars, corn syrup, cornstarch, corn oil, soybean oil, and canola oil. The small, longstanding market for organically grown food (which excludes GE seed and material) continues to expand and a market for conventionally grown foods produced without GE seed has also emerged. The coexistence of organic, conventional non-GE, and GE production systems has its challenges, however, because GE crop production can increase costs for organic and non-GE producers via accidental pollination or the commingling of materials all along the supply chain.

Many U.S. food retailers sell organically grown food, including their own organic product lines, and some have recently begun developing their own non-GE brands as well. U.S retailers are seeking additional assurance that foods labeled organic and other non-GE foods contain little or no GE material. Many processors, manufacturers, and retailers now require the use of avoidance protocols and testing and have independently set tolerance levels for the unintended presence of GE traits. In order to receive the price premiums associated with organic and non-GE offerings, producers need to minimize the presence of GE materials in their crops. Maintaining

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the integrity of GE-differentiated markets relies on practices such as buffer strips to isolate identity-preserved crops from nearby GE crops and product segregation throughout the supply chain.

This report synthesizes data on all three GE-differentiated sectors and compares their magnitudes in terms of U.S. crop production. It also examines the practices used by organic and non-GE producers to avoid the unintended presence of GE material in their product streams, and discusses the economic impacts when GE material is detected in organic crops.

What Did the Study Find?

Of the 390 million cropland acres in the United States in 2012, producers planted nearly half, 182 million acres, with ***GE seed***. Ninety percent of GE acreage is in corn and soybeans, and GE varieties are also widely used in U.S. cotton, sugar beet, and canola production. In contrast, only 0.6 percent of U.S. vegetable acreage and 0.03 percent of U.S. fruit acreage were planted with GE varieties in 2012.

The United States had 5.4 million acres managed under certified ***organic*** farming systems in 2011, with just over half for cropland and the rest for pasture and ranchland. Only 0.3 percent (234,000 acres) of U.S. corn acres and 0.2 percent (132,000 acres) of U.S. soybean acres were certified organic in 2011 despite large organic price premiums—USDA's Agricultural Marketing Service reports organic corn and soybean prices that are generally two to three times higher than conventional crop prices. A larger share (over 4 percent) of fruit and vegetable acreage is certified organic; organic lettuce, carrots, and squash exceeded 10 percent of total U.S. production in 2011.

In 2014, U.S. farmers planted 6.4 million acres of corn using ***non-GE seed***, and 5.1 million acres of soybeans with certified non-GE seed. About 59 percent of the non-GE conventional soybean producers sold their crop in a market for identity-preserved (IP) non-GE soybeans in 2012. Survey respondents who sold non-GE soybeans (food and feed) in an IP market, reported receiving an average price premium of $2.50 per bushel, about 18 percent higher than USDA's reported average price for all soybeans in 2012. USDA recently began publishing a non-GE price report, which shows non-GE price premiums of $0.75 per bushel for food soybeans (8-9 percent higher than for all soybeans) and $1.13 per bushel for feed soybeans (12-14 percent higher than for all soybeans) in fourth quarter 2015.

Among the challenges of organic and conventional non-GE corn and soybean production is preventing accidental comingling with GE crops and pollen in order to protect price premiums. The top practices that help reduce the risk of commingling include the use of buffer strips, which also reduce the risk of pesticide drift—69 percent of organic corn and soybean acres had buffer strips during USDA survey years. Many organic corn producers delay planting to reduce the likelihood that their crops pollinate at the same time as nearby GE crops. The average planting date for organic corn producers was 2-4 weeks later than for conventional corn producers in 2010. While delayed planting helps prevent the commingling of GE and non-GE pollen, it may also lower yields.

In 2014, 1 percent of all U.S. certified organic farmers in 20 States reported that they experienced economic losses (amounting to $6.1 million, excluding expenses for preventative measures and testing) due to GE commingling during 2011-2014. The percentage of organic farmers who suffered economic losses would be higher if calculated only for those organic farmers growing the nine crops with a GE counterpart (commodity-specific estimates could not be reported due to data limitations and concerns about respondents' privacy). While less than 1 percent of all organic farmers in California, Indiana, Maine, Minnesota, and Michigan suffered losses due to the unintended presence of GE material in their crops, 6-7 percent of organic farmers in Illinois, Nebraska, and Oklahoma suffered losses.

How Was the Study Conducted?

This study analyzes data on crop production and practices from several USDA producer surveys, including the Agricultural Resource Management Survey (ARMS), the annual USDA Acreage Survey, and the 2014 National Organic Producer Survey. ARMS collects detailed information about the production practices, costs, and returns in major U.S. farm sectors. In 2005, ERS began periodically adding targeted samples from organic producers to ARMS, to enable statistically reliable analyses of the organic sectors. The 2010 ARMS corn survey included a targeted organic oversample and questions on GE testing and shipment rejection in the organic corn sector. The 2012 ARMS soybean survey included questions about non-GE soybean production and marketing. Data on demand for organic and non-GE conventional products were obtained from several privately funded sources. Estimates of U.S. organic food retail sales are based on data from the *Nutrition Business Journal*, and estimates of non-GE product sales are derived from data provided by the private group—Non-GMO Project Verified—that provides verification services for most retail products with a non-GE label.

Economic Issues in the Coexistence of Organic, Genetically Engineered (GE), and Non-GE Crops

Introduction

U.S. farmers provide most of the domestic food supply and contribute greatly to the worldwide supply for a number of crops. They do so by adhering to three basic types of production systems. ***Conventional*** production techniques include the use of synthetic fertilizers and pesticides, which were developed in the early part of the 20th century and are currently widespread due to their relatively low cost and efficacy in controlling weeds and pests that reduce yields and damage crops (MacIntyre, 1987). Conventional production systems using chemical inputs can be used with either GE or non-GE crop varieties.

Organic agriculture is an alternative to conventional production systems that use synthetic chemical inputs, which instead puts more emphasis on soil fertility, nutrient cycling, and plant health (Heckman, 2006). U.S. farmers who observe organic rules do so in order to reduce input use, conserve nonrenewable resources, capture high-value markets, and boost farm income (Greene, 2001). The first State laws to regulate organic standards, certification, or labeling were passed in the 1970s. The National Organic Program (NOP), authorized under the Organic Foods Production Act of 1990, set consistent, uniform organic standards that require all but the smallest farmers—earning $5,000 or less in annual organic sales—to be certified by a USDA-accredited certifier (USDA-AMS, 7 CFR Part 205, 2000). USDA's Agricultural Marketing Service announced the final rule establishing the NOP in 2000 and oversees the program today.

U.S. agricultural output has more than doubled since the late 1940s. The rise in crop yields was due partly to an increase in the use of herbicides, insecticides, and other pesticides, which grew more than tenfold between 1948 and 1980 (Wang et al., 2015). Interest in developing GE crops that could help reduce synthetic pesticide use in agriculture began emerging in the 1980s (Greene and Gianessi, 1988). Interest in the potential for GE crops to increase crop yields and to rapidly create new products with investor appeal also emerged during the 1980s (Hueth and Just, 1987). The White House Office of Science and Technology Policy announced a comprehensive regulatory framework for the approval of commercial biotechnology (genetically engineered) products in the mid-1980s which assigned regulatory and oversight responsibility to three agencies—USDA, the U.S. Environmental Protection Agency (EPA), and the U.S. Food and Drug Administration (FDA)—using their existing statutory authorities (see box, "U.S. Regulations on Organic Agriculture and Genetic Engineering for Agriculture"). Agricultural seed and chemical companies subsequently commercialized varieties of corn, soybeans, and other crops with GE traits for herbicide tolerance and resistance to insects. Farmers have adopted GE seeds with these traits because they simplify management of weed and other pests and provide time and labor savings (Fernandez-Cornejo et al., 2014). By 2012, 47 percent of U.S. cropland was planted with GE seed varieties (table 1).

While U.S. farmers have widely adopted GE varieties for corn, soybeans, and several other major U.S. crops, U.S. consumers have continued to fuel the small but fast-growing market for organic food. GE crops are now widely used to produce processed foods and food ingredients, such as corn chips, breakfast cereals, soy protein bars, corn syrup, cornstarch, corn oil, soybean oil, and canola oil.[1] As a result, a market for food produced using ***conventional production techniques but without GE seed*** has also emerged.

USDA envisions a key role for GE conventional, non-GE conventional, and organic production in meeting global and domestic food needs, increasing sustainability, and enhancing farm profitability (USDA, 2015). As such, USDA supports the success of all three sectors. As GE crops and ingredients become more widespread, the potential for GE material to accidentally mix with organic and non-GE crops and products also grows. Organic producers must abide by USDA regulations as well as buyer contracts prohibiting the use of GE material in production and processing. The detection of GE material in organic and (conventional) non-GE seed and crops imposes costs on organic/non-GE producers due to market-based thresholds.

[1]DNA testing can detect GE traits in some processed food products that are made from GE crops, but not in others.

Table 1
U.S. cropland managed under genetically engineered (GE), non-GE, and organic systems

Crop	U.S. crop acreage, 2012-2014[1]	GE varieties		Non-GE varieties	
		GE trait[2]	Estimates based on data from 2009-2014[3]	Conventional systems[3]	Organic systems[4]
			Percent of U.S. crop acreage		
Total U.S. cropland	387,598,860		47	52	0.8
Field, hay and forage crops					
Field corn	90,597,000	HT and/or Bt	93	7	0.3
Soybeans	84,100,000	HT	94	6	0.2
Alfalfa	18,300,000	HT	29	70	1.4
Cotton	11,400,000	HT and/or Bt	96	4	0.1
Canola	1,700,000	HT	94	6	(d)
Sugar beets	1,200,000	HT	98	2	--
Total field, hay, and forage	380,019,881		48	51	0.8
Vegetables					
Sweet corn	554,970	HT and/or Bt	8	90	2
Squash	40,050	Virus resistance	12	71	17
Total vegetables	4,492,086		0.6	96	4
Fruits					
Papaya	2,272	Virus resistance	68	32	--
Total fruits	3,086,893		0.03	95.7	4

[1]Total U.S. cropland, vegetable and fruit acreage (2012 USDA Census of Agriculture); planted acres of soybeans, cotton, canola, and sugar beets; harvested acres of alfalfa, squash, sweet corn, and papaya (USDA, National Agricultural Statistics Service, Ag Stats, 2014).

[2]In 2014, GE varieties with both HT (herbicide tolerant) and Bt (insect resistant) traits were used for 76 percent of field corn acres and 79 percent of cotton acres.

[3]Corn, soybeans and cotton (USDA, National Agricultural Statistics Service, Acreage, 2014); Canola and sweet corn (National Research Council, 2010); Canola, alfalfa, sugar beets, squash (International Service for the Acquisition of Agribiotech Applications, 2014); Papaya (USDA, National Agricultural Statistics Service and Hawaii Department of Agriculture, 2009).

[4]Field crops (USDA, Economic Research Service, Organic Production, 2011); Vegetables (USDA, National Agricultural Statistics Service, Organic Survey, 2014)

(d) Not disclosed to protect producer confidentiality; -- = no acres reported.

Managing Coexistence for GE-Differentiated Crops and Markets

USDA's Advisory Committee on Biotechnology and 21st Century Agriculture defines the coexistence of organic, non-GE conventional (hereafter non-GE), and GE crop production as the concurrent production of crops using these three production systems consistent with underlying consumer preferences and choices.

Organic and non-GE producers, in order to receive the price premiums associated with organic and non-GE production, need to minimize the accidental occurrence of GE materials in their crops, which can happen in a number of ways, including:

- accidental presence of GE traits in the seed stock used to produce non-GE and organic seed;
- cross-pollination via wind or insects for crops such as corn, canola, and apples that are out-crossing;[2]
- accidental commingling (having contact or mixing) of organic and non-GE crops with GE crops during planting (GE seeds in planters, for example);
- accidental commingling of organic and non-GE with GE crops during harvest;
- accidental commingling of crops during onfarm storage;
- accidental commingling during transportation of crops to the buyer; and
- accidental commingling during processing, storage, and other activities beyond the farmgate.

Accidental commingling of GE crops with organic and non-GE crops can occur at every stage in the supply chain, from seed production through food/feed processing and transportation. Avoidance practices such as product segregation and monitoring are necessary at every stage in the supply chain to preserve the integrity of differentiated products. These practices may vary depending on the farm-to-retail stage and the crop being produced and processed.

U.S. organic and non-GE ***farmers*** use a number of production practices—field buffers, maintaining separate bins for GE and non-GE crops, cleaning equipment prior to use with non-GE crops, staggered planting dates for corn, canola, and other crops that out-cross during pollination—to sequester GE materials. ***Collective*** efforts to facilitate coexistence of organic and GE crops include FieldWatch™, a registry devised by Purdue University to help pesticide applicators and specialty crop growers communicate more effectively and manage the effects of GE drift. ***Plant breeders*** are commercializing organic corn varieties that cannot be cross-pollinated by pollen from a GE plant. For example, an Iowa-based seed company, Blue River Hybrids, offers corn hybrids containing a PuraMaize® gene blocking system that impedes GE fertilization by strongly favoring its own PuraMaize® pollen. Several ***county governments*** are also exploring limited GE crop prohibitions as an avoidance strategy. Also, producers negotiated a voluntary restriction on GE commercialization in one region. Alfalfa hay producers in California's Imperial Valley, the largest hay exporting region in the United States, worked with seed companies to restrict commercialization of GE alfalfa in that region due to its lack of acceptance by some foreign markets (Northwest Farm Credit Services, 2015).

[2]Plants can be largely self-pollinating with their own pollen, like soybeans, or they can out-cross during pollination and cross-pollinate with pollen from different plants carried by wind or insects. Corn plants are out-crossing, for example, and GE corn plants can accidentally pollinate organic corn plants if they are nearby and are pollinating at the same time.

U.S. Regulations on Organic Agriculture and Genetic Engineering for Agriculture

The first private group to offer organic certification services was the Maine Organic Farmers and Gardeners Association in 1971, and Massachusetts was the first State to regulate organic agriculture in 1978 (Anton, 1992). Maine passed organic legislation the following year that established standards for foods labeled or advertised as organic, organically grown, and biologically grown. Congress passed the Organic Foods Production Act in 1990 after nearly half of the States had set standards for organic agriculture (USDA-AMS, 7 CFR Part 205, 2000). The White House announced the U.S. interagency approach for GE regulation in 1986. In contrast with the U.S. process-based organic standards, the GE standards are product-based.

U.S. organic standards prohibit GE methods. USDA defines organic production as a system that responds to site-specific conditions "by integrating cultural, biological and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity" (USDA-AMS, 2000, p. 80640). The standards address the methods, practices, and substances used in producing and handling crops, livestock, and processed products, and are largely process-based—they apply to the way the product is created, not to measurable properties of the product itself. USDA organic regulations allow the use of natural substances and prohibit the use of synthetic substances in organic production unless they have been evaluated and placed on the national list of allowed synthetic and prohibited natural substances (USDA-AMS, 2000, pp. 80656-80658).

USDA explicitly excludes from organic production and processing the use of recombinant DNA and other GE processes that "genetically modify organisms or influence their growth and development by means that are not possible under natural conditions or processes and are not considered compatible with organic production" (USDA-AMS, 2000, p. 80639). Products engineered by cell fusion, micro-encapsulation, macroencapsulation, and recombinant DNA technology—including when it is used for gene deletion, gene doubling, introduction of a foreign gene, or changing the positions of genes—are among the exclusions (USDA-AMS, 2000, p. 80639). Traditional breeding for genetic variation, conjugation, fermentation, hybridization, in vitro fertilization, and tissue culture are allowed (USDA-AMS, 2000, p. 80639). Producers must provide each year to their USDA-accredited certifier a documented plan that describes the substances and practices that will be used, including physical barriers to prevent contact of organic crops with the products of genetically modified organisms.

While the USDA organic regulation did establish a tolerance level for accidental pesticide residues, set at 5 percent of the U.S. residue tolerance level for conventional crops, a tolerance level for GE materials was not established. USDA indicated that there was not a sufficient consensus for a threshold and that baseline data on testing methods and on the efficacy of practices to mitigate accidental GE presence were not sufficient to develop a threshold at that time (USDA-AMS, 2000, p. 80632). USDA recently reaffirmed that the presence of detectable GE residue in an organic product would not constitute a violation of the organic regulation, although detection could trigger an investigation by the certifying agent to determine if a violation occurred (USDA-AMS, 2011). Any certified organic operation found to use genetically modified organisms may face loss of certification and incur financial penalties. Even if the accidental presence of trace amounts of GE material does not violate the organic standard, it may diminish the value of the organic product based on tolerance levels set by private buyers.

U.S. regulatory framework on genetic engineering. In 1986, the Executive Office of the White House issued the U.S. Coordinated Framework for the Regulation of Biotechnology outlining the "comprehensive federal regulatory policy for ensuring the safety of biotechnology research and products" (Office of Science and Technology Policy, 1986).[1] The framework describes the approval process for then nascent GE technologies such as recombinant DNA, recombinant RNA, and cell fusion (Office of Science and Technology Policy, 1986).[1] The three major tenets of U.S. GE regulations are that (1) products developed by genetic engineering will not differ fundamentally from conventional products, (2) existing regulations are sufficient to approve GE products, and (3) evaluation should be based on the measurable properties of the GE product, not on the GE process. A 1992 update to the Coordinated Framework affirmed that "Federal oversight should focus on the characteristics of the product, the environment into which it is being introduced, and the intended use of the product, rather than the process by which the product is created" (Office of Science and Technology Policy, 2015). According to the U.S. Food and Drug Administration, "credible evidence has demonstrated that foods from the GE plant varieties marketed to date are as safe as comparable non-GE foods" (FDA, 2015).

The U.S. Coordinated Framework assigned regulatory responsibilities to three agencies, which have missions to protect plant health (USDA), human health (FDA), and the environment (EPA). The FDA regulates genetically engineered organisms under the authority of the Federal Food, Drug, and Cosmetic Act (FFDCA). The FDA is responsible for ensuring the safety of all plant-derived foods and feeds, including those that are genetically engineered. Within USDA, the Animal and Plant Health Inspection Service (APHIS) is responsible for protecting agriculture from pests and diseases. Under the Plant Protection Act (PPA), USDA-APHIS has regulatory oversight over products of genetic engineering that could pose a risk to plant health. The PPA provides authority to regulate the importation, interstate movement, or release into the environment of certain GE organisms and products. The EPA, under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and FFDCA, regulates the sale and distribution of all pesticides, including those produced through genetic engineering. This includes microorganisms, bio-chemicals isolated from organisms, and "plant-incorporated protectants"—a type of pesticide intended to be produced and used in living plants. Under the Toxic Substances Control Act (TSCA), EPA has oversight responsibilities for a wide range of commercial, industrial, and consumer applications of microbial biotechnology. New chemicals produced through microbial biotechnology applications are subject to pre-manufacturing review under TSCA.

[1]The Coordinated Framework was last updated in 1992, and the Office of Science and Technology Policy issued a memorandum on July 2, 2015 directing the Federal agencies to develop a long-term strategy to ensure that the regulatory system is "equipped to efficiently assess the risks, if any associated with future products of biotechnology while supporting innovation, protecting health and the environment, promoting public confidence in the regulatory process, increasing transparency and predictability, and reducing unnecessary costs and burdens..." (Office of Science and Technology Policy, 2015).

Depending upon a country's regulatory approach, organic and non-GE producers and consumers, or GE seed developers and users, or any of these groups may incur costs to prevent commingling. The United States supports voluntary arrangements between neighboring farmers to enable coexistence. If cross-pollination or crop mixing occurs, organic and non-GE producers and consumers are the ones who assume the full costs and liability of accidental commingling.

International markets can also be disrupted if a new GE crop trait is approved (deregulated) in the United States and that crop is exported before the new trait is also approved in the export market. For example, U.S. corn exports to China were disrupted during 2013-14 when inspection and quarantine officials began rejecting U.S. corn shipments containing a corn variety with a GE trait that Chinese agricultural officials had not approved (Gale et al., 2015). The rejections began in November 2013 and continued until China approved the variety in December 2014; Chinese officials reported rejecting 1.25 million metric tons of U.S. corn shipments by mid-2014.

Many countries have set a ***GE tolerance level*** for the amount of GE material that may be found in organic or identity-preserved non-GE products. The European Union has set a 0.9-percent tolerance level, Australia and New Zealand a 1-percent tolerance level, and Japan a 5-percent level. Processors, retailers, and other buyers in countries without regulatory requirements may also set tolerance levels, and buyers may set more stringent levels in those countries that do have regulatory requirements.

USDA has not established an official tolerance level for the specific amount of unintended GE material that can be found in organically grown and other non-GE products (see box, "U.S. Regulations on Organic Agriculture and Genetic Engineering for Agriculture"). However, many U.S. processors and retailers have set their own GE tolerance levels that both domestic and foreign organic producers must meet. Most U.S. buyers allow a small amount of GE material (generally under 1 percent) in organic and non-GE products. Most U.S. organic and non-GE food manufacturers and retailers adhere to the 0.9-percent tolerance level used under the Non-GMO Project Verified protocol, an independent verification system launched in 2005.

Many countries, including all of the European Union, have mandatory GE labeling policies. All products marketed in the EU for which the content of a product exceeds 0.9 percent of GE material must be labeled as GE. Only a limited number of GE seed varieties may be produced or marketed in the EU. As a consequence, U.S. corn exports to the EU fell sharply in 1997 after U.S. producers began using GE corn varieties, although U.S. soybean exports to the EU for use as livestock feed are still substantial (USDA-Foreign Agricultural Service, 2015). During the 2013/14 marketing year, the United States was the EU's second largest supplier of soybeans and was the third largest supplier of soybean meal (USDA-FAS, 2015).

Consumer Demand for GE-Differentiated Products

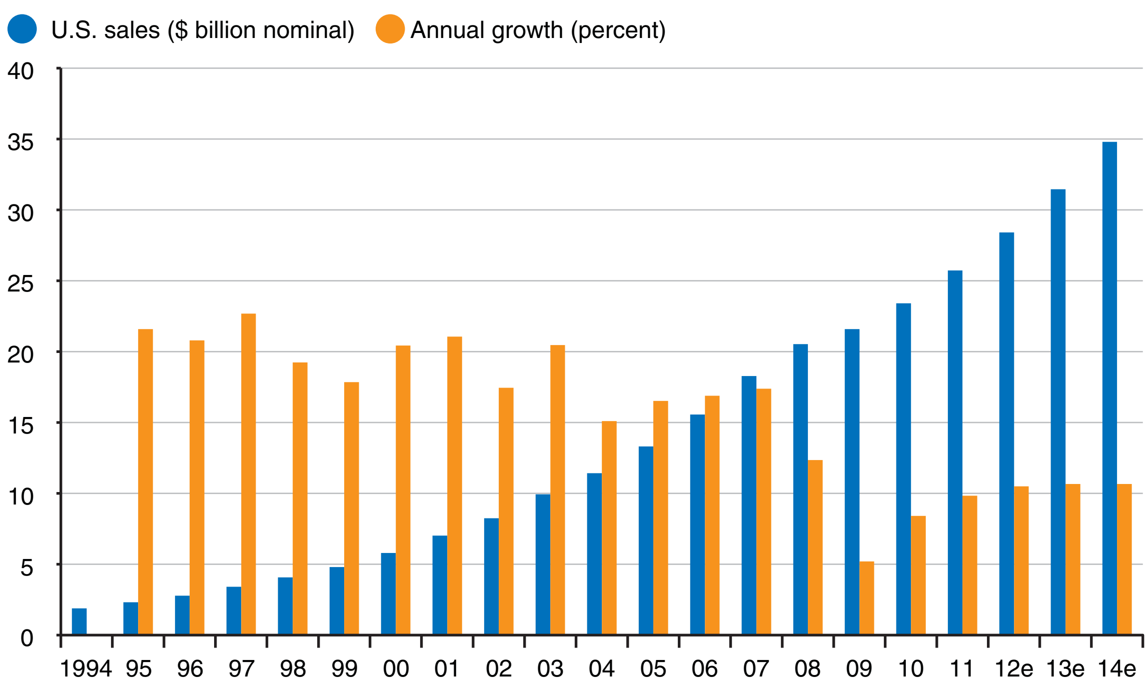
The coexistence of organic and conventional non-GE production systems with GE production would not pose a challenge if producers had nothing to lose from accidental commingling of these crops. However, U.S. consumer demand for organic products has grown steadily for decades, and organic farmers earn substantial price premiums for their products. A market for identity-preserved non-GE products has also emerged in recent years, although non-GE price premiums are typically much smaller than for organic products. As supermarkets, processors, and other buyers fulfill consumer demand for foods made without GE ingredients, organic and non-GE farmers have grown concerned about GE crop commingling, which jeopardizes their ability to earn price premiums for their products and could undermine consumer confidence in the organic and non-GE sectors.

U.S. Retail Sales of Organic Products

Annual growth in U.S. organic food sales was over 15 percent or more prior to the downturn in the U.S. economy in 2008 and has generally exceeded 10 percent since. U.S. organic food sales approached an estimated $35 billion in 2014 (fig. 1). In addition, U.S. sales of organic personal care products, linens, and other nonfood products were an estimated $3.2 billion in 2014.

The Organic Trade Association estimates that organic food purchases now account for nearly 5 percent of total U.S. food sales. Fresh fruits and vegetables—which have very few genetically engineered counterparts—are the top selling organic category, followed by dairy products. Organic

Figure 1
Retail sales of organic food have expanded rapidly since the early 1990s[1]



[1]Estimate
Source: USDA, Economic Research Service based on data from the *Nutrition Business Journal* and *Natural Food Merchandiser*.

dairy sales have been increasing rapidly, as have sales for organic bread, packaged foods, snacks, beverages, meat/poultry, and condiments. According to ERS analysis of producer survey data, grower prices for fresh organic apples and organic apples for juice were more than twice as high as for conventionally grown apples in 2007, and premiums for organic milk averaged 69 percent in 2010 (Slattery et al., 2011; Greene and McBride, 2015).

The United States also has a growing export market for organic products. Nearly three dozen organic exports, mostly fresh fruits and vegetables, are currently tracked, and total organic export value increased from $412 million in 2011 to $553 million in 2014 (Greene, 2014). Apples were the top organic export in 2014, at an estimated $115 million.

Few fruit and vegetable growers use GE crop varieties because few have been commercialized for this sector. However, organic dairy farmers grow or purchase many crops that do have GE offerings, including organic corn, soybeans, and alfalfa. Many organic food manufacturers also use corn, soybeans, and other grain crops in organic snack foods and packaged/prepared foods.

U.S. Retail Sales of Non-GE Products

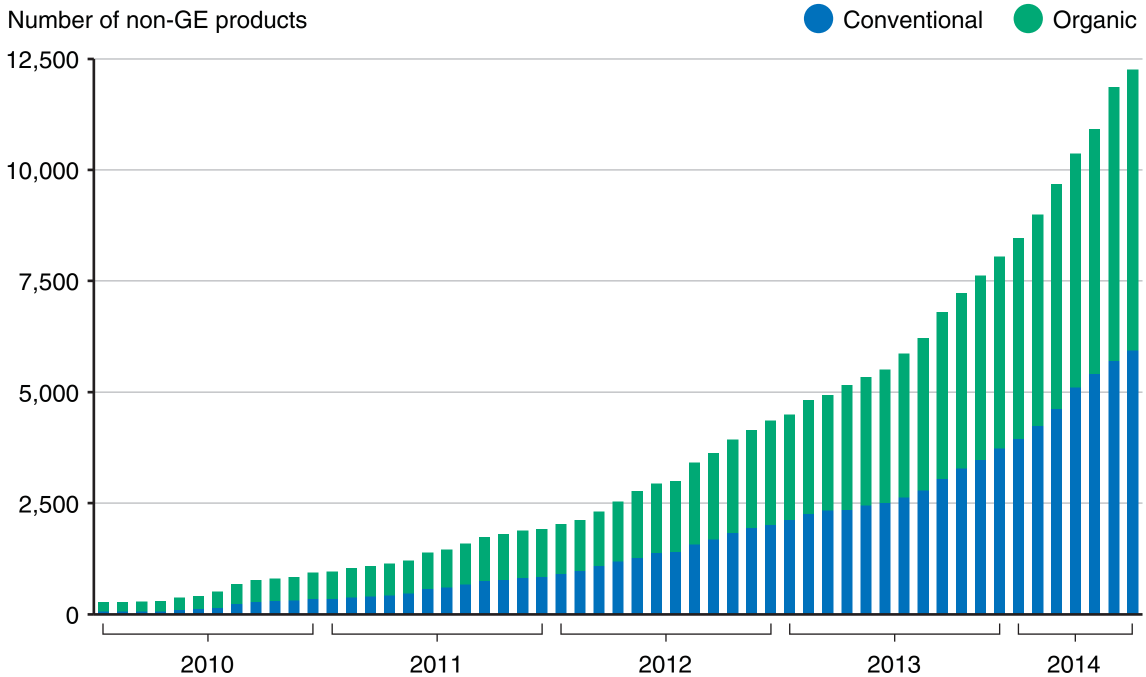
Whole Foods Market, the largest U.S. natural foods supermarket chain, has sold conventionally produced non-GE products as well as organic products for many years. In 2009, Whole Foods began requiring verification of GE avoidance practices for all of its own private-label product line. Many other supermarket chains and big-box stores sell organic products and have their own organic product lines and some are also developing non-GE product lines. In addition, a number of U.S. grain processors and brokers export processed non-GE soybeans and corn to other countries, although trade data are not available to quantify the size of this market.

Although USDA has not set product-based standards to minimize the risk of GE material in organic and non-GE products, the private sector has developed standards. A nonprofit group based in Bellingham, Washington, launched an independent verification system in 2005 for products made according to best practices for GE avoidance. Their "Non-GMO Project Verified" label claim is based on verifying that producers and handlers used practices to prevent commingling and tested products that have GE counterparts (the GE tolerance level for foods and grains is 0.9 percent, which is consistent with the EU tolerance for foods and grains). Organic and non-GE producers and processors pay for GE product testing as well as product verification, and these extra costs may be passed along to consumers through higher prices.

The use of the Non-GMO Project Verified label has increased rapidly since 2010, when major manufacturers and retailers began adopting this protocol (fig. 2). In 2014, the label was used for nearly 12,500 products with unique Universal Product Codes (UPC), according to ERS analysis. Many of the food products verified under this protocol, and bearing the Non-GMO Project butterfly logo, do not contain ingredients that have GE counterparts. Over half of the labeled products are organic, even though USDA already prohibits the use of GE in organic production. The Non-GMO Project reported that products worth $11 billion in annual sales were verified under their protocol in 2015. Some consumers may be substituting purchases of the less expensive non-GE products for organic products because they care more about avoiding GE products than about the additional organic attributes, or because they may fail to differentiate between a non-GE product and an organic product.

Although the privately operated non-GMO Project Verified program currently accounts for most U.S. products that have non-GE verification and labeling, a Federal option recently emerged. USDA's

Figure 2
Cumulative monthly Non-GMO Project verified products, 2010-14[1]



[1]Data exclude brands owned by Whole Foods Market (365, Whole Foods Market, and Whole Pantry), which accounted for 608 Non-GMO (genetically modified organism) Project-verified products as of July 2014.
Source: USDA, Economic Research Service analysis based on data from non-GMO Project Verified.

Agricultural Marketing Service (AMS) administers a fee-based Process Verified Program that provides independent verification, by a qualified AMS auditor, of company standards (USDA-AMS, 2015). In mid-2015, USDA announced that this program would be used for the first time to verify a private company's non-GE product claim, based on the company's own non-GE standard. Another new private option, the non-GMO True North program, was also launched in mid-2015 by an international nonprofit certification group and will offer non-GE certification for intermediate and retail products (NSF International, 2015).

Consumer Interest in GE Products

The first GE product commercialized in the United States was the Flavr Savr tomato, which was genetically engineered to stay ripe longer and be more flavorful (Bruening and Lyons, 2000). Sales of the GE-labeled Flavr Savr tomato began in 1994 and demand remained high for several years (Bruening and Lyons, 2000). The Flavr Savr tomato was subsequently withdrawn from the market partly because of high production/distribution costs and lack of demand by major supermarkets (Bruening and Lyons, 2000; Fernandez-Cornejo et al., 2014).

An estimated 60 percent of all processed foods on U.S. supermarket shelves—including pizza, chips, cookies, ice cream, salad dressing, corn syrup, and baking powder—contain ingredients made from GE soybeans, corn, or canola, though they are not labeled as such (Ackerman, 2015). Consumer studies suggest that GE foods could be a draw for some consumers if they contain enhanced quality traits, such as added vitamins (Fernandez-Cornejo et al., 2014).

GE-Differentiated Crop Production in the United States

While modern crop breeding includes many techniques, the private sector has focused mostly on GE breeding techniques for corn, soybeans and several other major U.S. crops in recent decades. The seed industry has increased private research and development activities in both absolute terms and relative to public expenditures (Fernandez-Cornejo, 2004). Among agricultural input industries, the most rapid growth in research and development expenditures during 1994-2010 was for the crop seed and biotechnology sector, where annual spending "increased from about $1.5 billion in the mid-1990s to nearly $3.5 billion in 2010 (constant 2006 U.S. dollars)" (Fuglie et al., 2011). Using GE techniques has enabled firms "to capture more value from the seeds they develop" (Heisey and Fuglie, 2011). ERS research indicates that GE herbicide- and insect-resistant traits have protected yield rather than increased potential yield during the first 15 years of commercial use (Fernandez-Cornejo et al., 2014).[3] Adoption of GE insect-resistant corn is associated with an increase in net returns to the producer, while herbicide-resistant GE soybean adoption increases farm household income and leads to household labor savings (Fernandez-Cornejo et al., 2005, Fernandez-Cornejo et al., 2014; Fernandez-Cornejo and Wechsler, 2012).

U.S. farmers have widely adopted GE varieties for five major field crops—over 90 percent of corn, soybean, cotton, canola, and sugar beet acreage was planted with GE varieties in 2014 (table 1). Nearly half of total U.S. cropland acreage—but less than 1 percent of total U.S. fruit and vegetable acreage—is currently cultivated with GE varieties.

Adoption of GE Varieties for Corn and Soybeans

GE corn and soybeans are grown on more acres than any another crop in the United States. GE varieties of corn and soybeans were commercialized in 1996. By 2001, a quarter of the U.S. corn crop and over two-thirds of the soybean crop were planted with GE seed (fig. 3). In 2015, U.S. producers planted 89 million acres of corn and 85 million acres of soybeans with GE seed, accounting for 92 and 94 percent of the total planted acres for these crops (USDA-National Agricultural Statistics Service, 2015a) (fig. 3). One of the major uses of these crops is for animal feed, but they are also used to produce vegetable oil and as ingredients in many processed foods. A substantial amount of the corn crop—44 percent in 2015—is now used to produce alcohol for fuel use (USDA-ERS, 2015a).

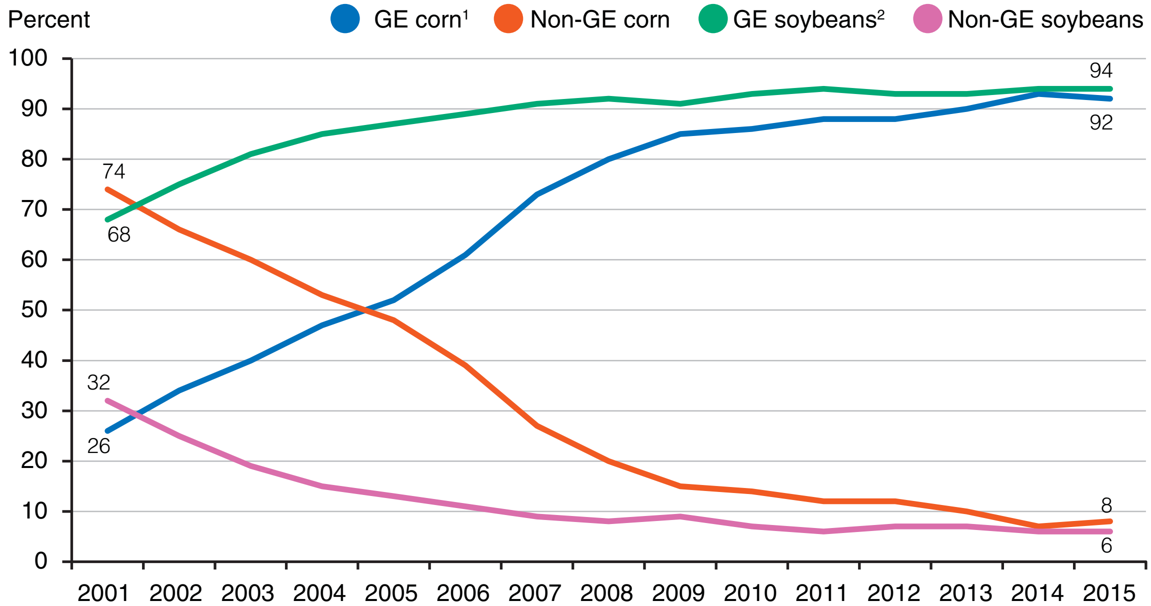
GE soybean varieties have been genetically engineered to withstand direct applications of an herbicide applied to control weeds. The most widely used herbicide-tolerant (HT) soybean varieties are resistant to glyphosate, the active ingredient in the popular herbicide product Roundup™. Other soybean varieties have been engineered to tolerate glufosinate, 2, 4-D, and other herbicides. Some varieties are "stacked" to tolerate two or more herbicides and others have modified oil content. While several studies have examined the impacts of adopting herbicide-tolerant soybeans, findings on net returns are inconclusive.

Most GE corn varieties have been genetically engineered with both herbicide tolerance and insect resistance. Insect-resistant corn varieties incorporate genes that produce insecticidal proteins from the soil-dwelling bacterium *Bacillus thuringiensis* (*Bt*). The share of U.S. corn acreage planted with GE varieties that are stacked with both HT and Bt traits increased from 6 percent in 2004 to

[3]A recent ERS report—*Genetically Engineered Crops in the United States* (Fernandez-Cornejo et al., 2014)—provides detailed analysis of the farm-level economic impacts of GE crop adoption, changes in input use, evolution of pest resistance, and other GE adoption issues.

Figure 3

Most U.S. corn and soybean acreage planted with genetically engineered (GE) seed varieties



[1]In 2014, 76 percent of the GE corn acreage was planted with stacked gene varieties (with both herbicide tolerance and insect-resistance traits) and the rest was planted with single-trait GE varieties. [2]GE soybeans are genetically engineered with herbicide tolerance traits only.

Source: USDA, Economic Research Service (ERS). 2013. *Adoption of Genetically Engineered Crops in the United States* data product.

47 percent in 2010 to 77 percent in 2015. USDA survey data from 2010 indicate that stacked corn varieties have higher yields than non-GE varieties or varieties with only one GE trait (Fernandez-Cornejo et al., 2014).

U.S. trade data report overall corn and soybean imports and exports, but do not include separate estimates for GE and non-GE corn and soybeans. The United States is the world's largest producer and exporter of corn (although its share of world corn trade is diminishing), which is mostly used for animal feed (USDA-ERS, 2015b). The United States is also the world's largest producer and exporter of soybeans (USDA-ERS, 2015c). The share of U.S. exports in global soybean trade has declined as foreign soybean output and exports has dramatically increased.

Other Crops Produced With GE Varieties

GE seed varieties of cotton, canola, and sugar beets have been deregulated (approved for use) for over a decade, and are now widely adopted in the United States; 94-98 percent of these crops were planted with GE varieties in 2009-2014 (table 1). GE alfalfa was deregulated more recently, in 2011. Most of the U.S. alfalfa crop is still planted with non-GE seed: 29 percent of alfalfa (5.3 million acres) was planted with GE seed in 2009-14. Only 0.6 of U.S. vegetable acreage and 0.03 percent of U.S. fruit acreage was planted with GE varieties (table 1). Only three GE fruits and vegetables were produced commercially in the United States in 2014. Market size may partly explain the discrepancy. While corn, soybeans, and other field crops account for over three-quarters of the global market for proprietary seeds, vegetables account for less than 14 percent (Fuglie and Heisey, 2011). Eight percent of U.S. sweet corn acreage, 12 percent of U.S. squash acreage, and 68 percent of U.S.

papaya acreage are grown using GE varieties (table 1). Papaya is grown only in Hawaii, and parts of Florida, California, and Texas.

Recently, USDA deregulated GE varieties for two of the most widely grown fruits and vegetables in the United States—apples and potatoes. In November 2014, USDA's Animal and Plant Health Inspection Service (APHIS) deregulated a new variety of potato genetically engineered to have late blight resistance, low-acrylamide potential, reduced black spot bruising, and other desirable traits.[4] Unlike other current GE crop varieties, which have traits designed to appeal to farmers and make production easier, the new GE potato variety is designed partly to appeal to consumers. In particular, one trait keeps potatoes looking fresh longer after they are cut, and another trait reduces the amount of a potentially toxic substance, acrylamide, which is found in fried potatoes. Potatoes are the top U.S. vegetable crop in terms of acreage, with over a million acres in 2014 (USDA-NASS, 2015b), and account for about 15 percent of total vegetable farm sales.

In February 2015, USDA deregulated a genetically engineered apple, Okanagan's Arctic® apple, which delays browning after exposure to air (USDA-APHIS, 2015). The Arctic® apple is potentially the first major GE fruit crop with large domestic and export markets. Currently, only one GE fruit, papaya, has been commercialized in the United States. While total U.S. papaya acreage is only 2,300 acres, the United States had 322,000 acres with bearing apple trees in 2014 and apples are the second most popular fresh fruit (after bananas) among U.S. consumers (USDA-ERS, 2015d). Many fruit crops, including apples, are harvested from trees that produce fruit for many years, which could slow the spread of GE varieties in these crops.

Adoption of Organic Production Systems

Converting from conventional to organic production systems requires the use of approved practices in every phase of crop production. This adherence often decreases crop yields and increases labor requirements, at least in corn and soybean production (McBride et al., 2015). Moreover, farmers cannot be certified organic and receive organic price premiums for their crops until 3 years after they have adopted organic practices.

U.S. certified organic farmland has expanded over the last several decades, but not as fast as organic sales, and growth has slowed for a number of organic grain crops in recent years (Greene, 2014). While nearly 5 percent of total U.S. fruit acreage and over 10 percent of some U.S. vegetable crops were certified organic in 2011, only 0.3 percent of U.S. corn acres and 0.2 percent of soybean acres were certified organic.

USDA defines and regulates organic farming as an integrated system that fosters resource cycling, ecological balance, and biodiversity, and prohibits the use of nearly all synthetic pesticides in organic crop production (see box on Organic Regulation). Pesticide drift from neighboring GE and conventional non-GE fields can disqualify organic crops from being marketed as organic, if pesticide residues exceed 5 percent of EPA-established thresholds (Maynard et al., 2012). Some pesticides are more prone to drift than others, so organic farmers need to be mindful of the type of pesticide being used by neighbors (California Department of Pesticide Regulation, 2015).

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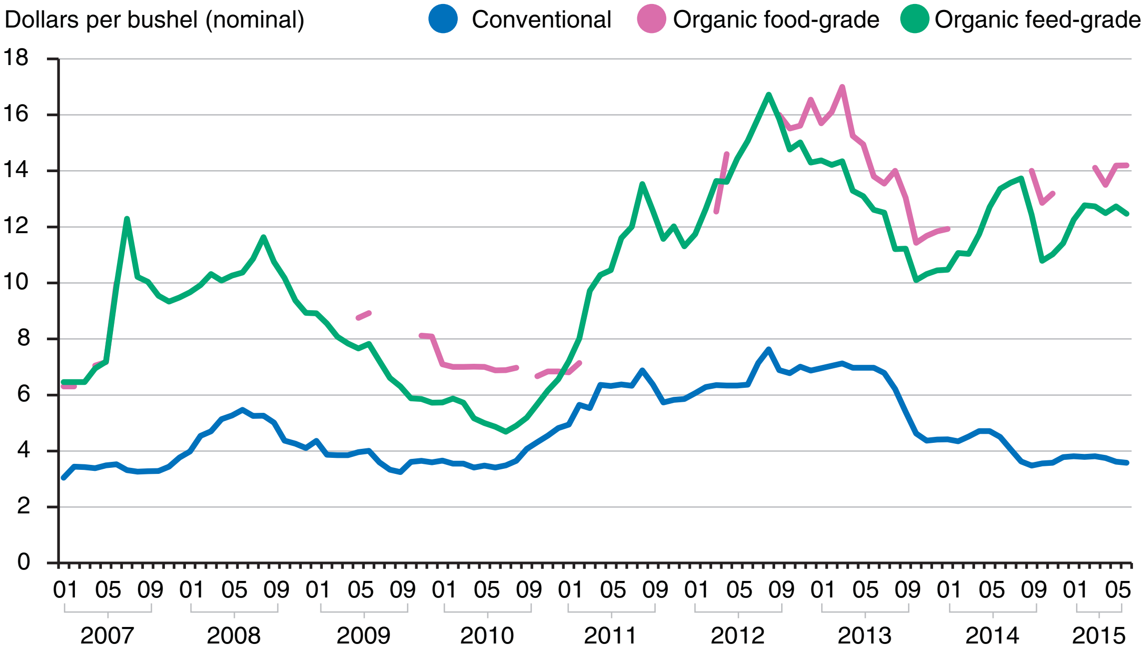
[4]USDA deregulated an insect-resistant GE potato in 1995, which was commercialized in the late 1990s but withdrawn from the market in 2001 due to poor sales.

Figure 4

U.S. organic and conventional corn prices, 2007-2015[1]



[1]USDA's Agricultural Marketing Service did not report organic food-grade corn prices when too few reports were received to maintain confidentiality of survey respondents.

Source: Organic prices from USDA, Agricultural Marketing Service; conventional prices from USDA National Agricultural Statistics Service.

According to findings from USDA producer surveys, many conventional producers use tillage, crop rotations, cover crops, and other non-chemical practices for pest and nutrient management, but organic producers rely almost exclusively on these practices (Osteen et al., 2012; McBride et al., 2015). Organic corn producers in one State reported the use of two biological pesticides in 2012, but there were too few observations to report estimates. In 2006, the most recent survey of organic soybean producers, NASS did not report any use of biological or other pesticides in organic soybean production.[5]

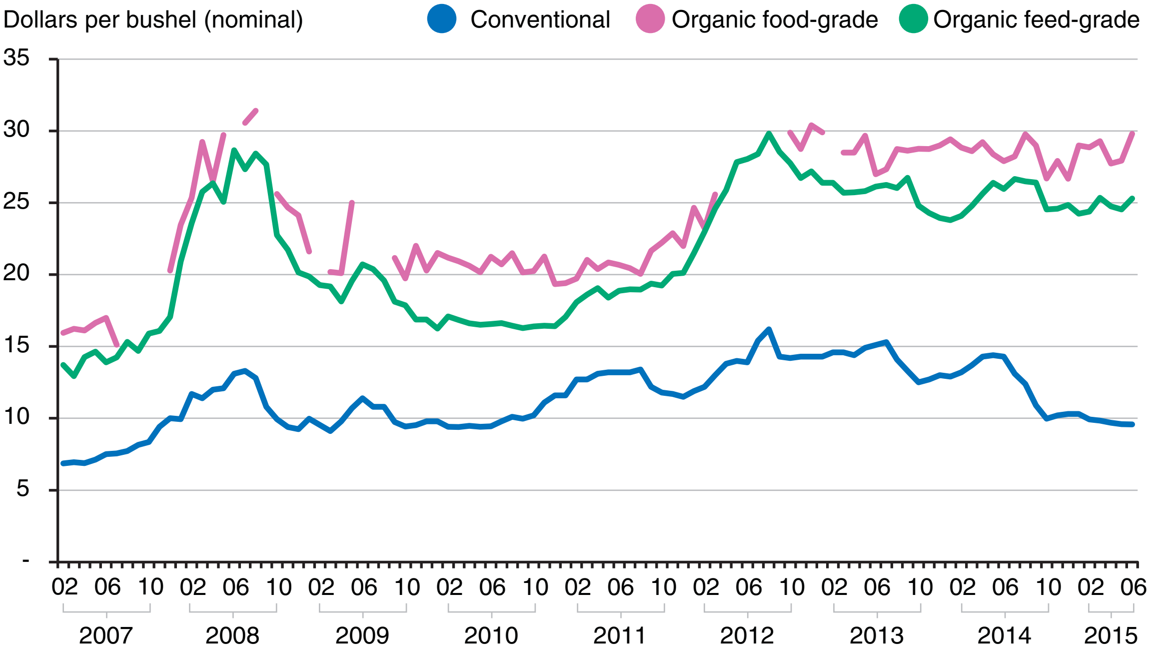
Organic corn and soybean operations are often more profitable than conventional operations, despite higher economic costs and lower yields, because organic prices tend to be much higher than conventional prices (McBride et al., 2015; Greene et al., 2009). In fact, price premiums for organic corn and soybeans are often more than double, and sometimes triple, conventional prices (figs. 4 and 5). U.S. field crop producers may be slow to adopt organic practices for many reasons, including

- the 3-year transition period required before earning organic price premiums;
- the relative ease of producing for the conventional market, with seed and chemicals readily available from local dealers and markets at the local elevator (organic farmers must find organic approved seed, learn to manage fertility and pests through natural methods and locate their own markets, which may require storage on the farm until pickup);

[5]While organic field crop production has almost no pesticide use, a number of biological pesticides and other approved substances are used in organic fruit and vegetable production (UC Davis, 2015; Slattery et al., 2010).

Figure 5

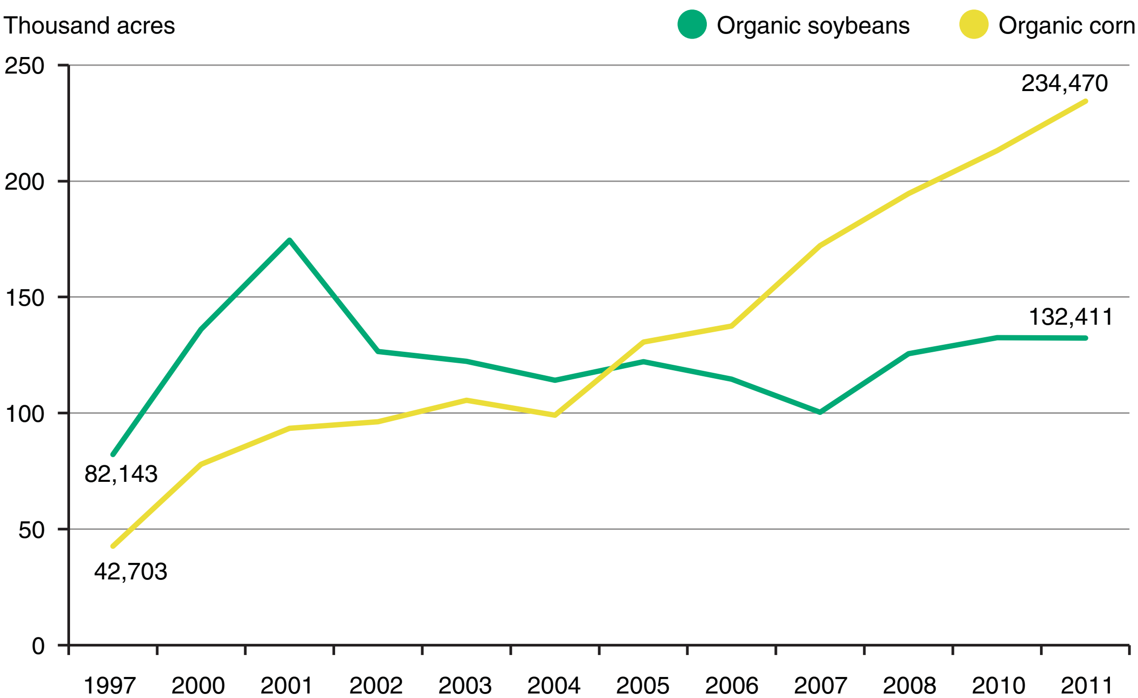
U.S. organic and conventional soybean prices, 2007-2015[1]



[1]USDA's Agricultural Marketing Service did not report organic food-grade soybean prices when too few reports were received to maintain confidentiality of survey respondents.
Source: Organic prices from USDA, Agricultural Marketing Service; conventional prices from USDA National Agricultural Statistics Service.

Figure 6

Certified organic corn and soybean acreage in the United States, 1997-11[1]



[1]USDA, ERS estimates based on data from USDA-accredited organic certifiers.
Source: USDA, Economic Research Service. 2013. Organic Production, data product.

- the lack of information about the relative costs and returns of organic versus conventional production;
- unfamiliarity with the financial performance of farms that are choosing the organic approach; and
- uncertainty about future returns (McBride et al., 2015).

An estimated 234,000 acres of organic corn and 132,000 acres of organic soybeans were certified in 2011. Despite the high organic price premiums and growing demand for organic feed grains and consumer products such as soymilk, data from USDA-accredited organic certifiers show that organic soybean acreage peaked in 2001 and stagnated between 2001 and 2011 (fig. 6) (USDA-ERS, 2014). While certified organic corn acreage increased 24 percent between 2011 and 2014 and soybean acreage increased 3 percent, according to more recent estimates from USDA producer surveys, domestic supply has not kept up with demand (USDA-NASS, 2015c). In addition to the reasons mentioned above, import competition may also discourage the adoption of organic systems. The widespread use of GE varieties for corn and soybeans and the associated costs for non-GE crop verification (and of potential commingling with GE crops) may also be a factor (Greene and Smith, 2010).

Demand for organic corn and soybeans has outpaced domestic supply over the last decade so the United States is importing organic corn and soybeans from a number of countries (Greene, 2014; Greene et al., 2009). The United States produced organic soybeans worth $72 million in 2014 and imported organic soybeans worth over $183 million—the U.S. share of domestic organic soybean supply was only 28 percent (table 2). India, China, and Canada were the top organic soybean import sources in 2014. The United States produced over 80 percent of the value of the U.S. organic corn supply in 2014. Romania, Turkey and the Netherlands were the top suppliers for the remainder.

Table 2

U.S. domestic and import value of organic corn and soybeans, 2014[1]

Organic soybeans			Organic yellow dent corn		
	Value (thousand dollars)	U.S. share (percent)		Value (thousand dollars)	U.S. share (percent)
Total value	255,159		Total value	190,610	
U.S. production	71,530	28	U.S. production	154,910	81
U.S. imports	183,629		U.S. imports	35,700	
Top U.S. States		State share (percent)	**Top States**		State share (percent)
Michigan	7,362	10	Iowa	15,134	10
Iowa	12,801	18	Michigan	26,840	17
Minnesota	7,502	10	Minnesota	16,724	11
Illinois	10,043	14	Nebraska	15,601	10
Missouri	6,257	9	Illinois	3,636	2
Other States	27,565	39	Other States	76,975	50
Top import countries		Country share (percent)	**Top countries**		Country share (percent)
India	73,839	40	Romania	11,604	33
China	39,542	22	Turkey	6,797	19
Canada	16,964	9	Netherlands	6,519	18
Ukraine	16,608	9	Canada	6,419	18
Argentina	14,183	8	Argentina	3,677	10
Other countries	22,493	12	India	684	2

[1]Imported crop value excludes seed; U.S. crop value includes seed.

Sources: USDA-FAS, Global Agricultural Trade System Database; USDA-NASS, National Organic Producer Survey 2014.

Identity-Preserved Conventional Non-GE Crop Production

While markets for certified organic food predate the commercialization of GE crops, markets for conventional non-GE crops, particularly soybeans, emerged after the introduction of GE corn and soybeans. In order to sell in markets for non-GE crops, producers must follow identity-preservation (IP) protocols and their crops must usually meet a specific non-GE tolerance level (Carter and Guillaume, 2003).

U.S. farmers grew identity-preserved non-GE conventional soybeans on approximately 14 million acres in 2003 (Elbehri, 2007). By 2012, only 5.4 million acres of soybeans were planted with non-GE seed, and only about 59 percent of the non-GE soybean producers sold their crop in a market for identity-preserved non-GE soybeans (table 3). The average non-GE soybean price premium reported by producers in 2012 was $2.50 per bushel, about 17 percent higher than USDA's reported marketing year average price for all soybeans that year (USDA NASS, 2015d). Non-GE price premiums help compensate for the practices needed to prevent commingling and the lower yield of some non-GE varieties. The non-GE premium is much smaller than the organic premium because organic production requires alternative pest management practices and other system-wide management changes, as well as GE avoidance practices, and organic consumers are willing to pay more for organically produced products.

Price premiums for identity-preserved non-GE soybeans have declined since 2012, according to USDA's Market News Service and private-sector estimates.[6] Mercaris, a Maryland-based market data services firm, conducts weekly surveys of first handlers of non-GE grain (mostly in the central United States). Reported prices represent the volume-weighted average delivered prices to the first handler. Mercaris estimates that U.S. average price premiums for non-GE feed soybeans were $1.21 per bushel in 2013 and $1.57 per bushel 2014 (9 percent higher than USDA's marketing year average price for all soybeans in 2013 and 12 percent higher in 2014); food-grade non-GE soybeans were estimated at $1.48 per bushel in 2013 and $2.13 per bushel in 2014 (11 percent higher in 2013 and 16 percent higher in 2014). Mercaris also estimates that U.S. average premiums for non-GE feed corn were $0.51 per bushel in 2013 and $0.11 in 2014 (11 percent higher in 2013 and 3 percent higher in 2014).

Table 3
Characteristics of non-GE soybean operations in the United States, 2012

Non-GE soybean producers who sold their crop through a market specifically for non-GE soybeans in 2012 (percent)	59
Production characteristics:	
Non-GE soybean producers that used certified non-GE seed (percent)	63.5
Non-GE soybean producers using seed tested for GE traits (percent)	34.6
Non-GE soybean producers that grew non-GE soybeans under a contract that specified the use of a particular seed variety (percent)	31.5
Marketing characteristics:	
Non-GE soybean price premium (dollars per bushel)	2.50

Source: USDA, Economic Research Service and National Agricultural Statistics Service, Agricultural Resource Management Survey, 2012.

[6]USDA's Market News Service and Mercaris conduct weekly surveys of first-handlers of grain crops about the prices paid to producers for non-GE grain crops, and these estimates are not strictly comparable to the estimate obtained from USDA's producer survey.

In September 2015, USDA's Agricultural Marketing Service issued its first national weekly Market News report on non-GE grain prices (USDA Livestock, Poultry & Seed Program, 2015). The report includes future delivery contract prices and spot market cash prices paid to the producer by the elevator. Non-GE food-grade soybeans commanded a price premium of $0.75 per bushel (8-9 percent higher than for all soybeans) and feed-grade soybeans $1.13 per bushel (12-14 percent higher) in the 4th quarter of 2014.

Except for the practices used to avoid commingling of GE and non-GE crops and pollen, the production practices used for conventional and non-GE corn and soybeans are similar. Nearly all corn and soybean producers (GE and non-GE) use synthetic pesticides for weed control, although in different combinations. Organic farmers thus face challenges in coexisting with non-GE crops as well due to the potential for pesticide drift. GE corn producers treated a significantly higher share of planted acres with glyphosate (77 percent) than did non-GE producers (39 percent) in 2010, while non-GE producers treated a significantly higher percentage with atrazine and other pesticides (table 4). GE soybean producers treated a significantly higher share of their planted acres with glyphosate (96 percent) than did non-GE producers (41 percent) in 2012, while non-GE producers treated a higher share of their planted acres with fomesafen and other pesticides (table 5).

Table 4

Top pesticides applied to non-GE and GE and organic corn planted acres, 2010

Pesticide	Non-GE	GE	Difference	Non-GE	GE	Difference	Certified Organic	
	Planted acres treated			Average rate applied			Acres treated	Average rate applied
	Percent			Pounds per acre			Percent	Pounds per acre
Glyphosate	39	77	39***	0.35	0.82	0.47***	0	0
Atrazine	82	60	-22***	0.94	0.60	-0.34***	0	0
Acetochlor	23	26	3	0.36	0.34	-0.02	0	0
Metolachlor	1.4	0.4	-1	0.02	0.00	-0.01	0	0
2,4-D	9.2	9.2	0.03	0.04	0.03	-0.01	0	0
Simazine	3.9	2.3	-2	0.04	0.03	-0.01	0	0
Dimethenamid	4.3	5.7	1	0.03	0.04	0.002	0	0
Mesotrione	26	17	-9	0.03	0.02	-0.01*	0	0
Glufosinate	0.6	2.1	1**	0.00	0.01	0.004*	0	0
Other pesticides[1]	78	53	-26***	0.64	0.34	-0.31***	(D)	(D)
Total pesticides	99.6	99.9	0.33	2.48	2.24	-0.24	--	--
Total acres planted	5,513,661	74,161,786					216,000	

Note: Asterisks denote a statistically significant difference at the 5-percent (**) and 1-percent (***) levels.

[1]Two biological pesticides (Beauveria and Trichoderma Harzianumm) were used in one State, but there were too few observations to report estimates of the rate or acres treated. (D) = Disclosure

Source: USDA, Economic Research Service and National Agricultural Statistics Service, Agricultural Resources Management Survey ARMS), 2010.

Table 5
Top pesticides applied to non-GE and GE and organic soybean planted acres, 2012[1]

Pesticide	Non-GE	GE	Difference	Non-GE	GE	Difference
	Planted acres Treated			Average rate applied		
	Percent			Pounds per acre		
Glyphosate	41	96	54***	0.48	1.49	1.01***
Metolachlor	17	7	-10*	0.2	0.07	-0.13*
2,4-D	22	15	-6	0.1	0.08	-0.02
Acephate	1	1	1	0.02	0.01	-0.004
Chlorpyrifos	4	6	3	0.01	0.03	0.014
Pendimethalin	17	2	-16***	0.12	0.02	-0.11**
Trifluralin	6	2	-4***	0.06	0.02	-0.05
Fomesafen	27	3	-25***	0.05	0.02	-0.04***
Glufosinate	5	3	-2	0.03	0.11	0.12***
Other pesticides	84	51	-33***	0.24	0.11	0.12***
Total pesticides	99.95	99.84	-0.1	1.32	1.86	0.54***
Total acres planted	2,087,854	69,687,455				

Note: Asterisks denote a statistically significant difference at the 5-percent (**) and 1-percent (***) levels.
[1]Estimates for organic production are not included because organic producers were not sampled in the 2012 USDA Agricultural Resources Management Survey (ARMS). The most recent ARMS soybean survey with an organic producer sample was in 2006; NASS reported that no pesticides were used on organic soybean acres in 2006.
Sources: USDA, Economic Research Service and National Agricultural Statistics Service, Agricultural Resources Management Survey, 2012; NASS Agricultural Chemical Use Survey, 2006.

GE Detection and Avoidance Practices

Both organic and non-GE producers use third parties to test and verify non-GE seed. They also use buffer strips and delayed planting to segregate their non-GE crops spatially and temporally. Crop testing for GE traits is usually done by middlemen in the supply chain, but organic and non-GE producers sometimes test their own crops. Organic and non-GE producers who grow crops with GE counterparts are encouraged to keep records of GE test results on inputs and to be mindful of neighbors' crops and planting dates. The largest marketing cooperative of organic grain producers in the United States, the Organic Farmers Agency for Relationship Marketing (OFARM), has established a detailed set of avoidance practices for members to follow in order to minimize GE presence in organic crops (see box).

OFARM Policies and Protocol To Minimize GE Presence in Organic Crops[1]

Onfarm practices

- Use third-party tested seeds and feeds of concern to ensure purity
- Keep records of test results on feed and input sources
- Keep tested seeds separate from GE seeds
- Use appropriate field buffers based on specific crop distances
- Clean and visually inspect planter and drill boxes before use
- Use physical separation or minimum-foot border rows
- Report actual non-GE acres planted for OFARM contracts to certifier
- Be aware of neighbor's crops and planting dates
- Use alternative planting dates for corn and canola
- Maintain planting history for non-GE contract fields
- Clean combines, grain drills, planters, and other equipment
- Visually verify that custom/shared combines are free of other grain
- Use a flush run to assure equipment is free of contaminants
- Use identity-preserved stickers or other methods to label non-GE bins
- Clearly instruct drivers about the identity preserved nature of shipments

Product loading and shipment practices:

Producer responsibilities

- Ensure proper documentation for identity-preserved grain
- Take and maintain representative sample(s) as grain is loaded into storage
- Clearly instruct drivers about the identity preserved nature of shipments
- Inspect truck for cleanliness

Driver responsibilities

- Clean and inspect all equipment used for loading and transporting grain
- Clean and wash trucks according to protocol
- Complete a truck inspection affidavit as the truck is loaded

[1]OFARM (Organic Farmers Agency for Relationship Marketing) is a marketing cooperative—member groups include: Buckwheat Growers Association of Minnesota, Kansas Organic Producers Association, Midwest Organic Farmers Co-op, Montana Organic Producers Co-op, NF Organics, Organic Bean and Grain, and Wisconsin Organic Marketing Alliance.

Use of third party-tested non-GE input seed

The seeds used by organic and non-GE producers are a potential source of unintended GE traits in their harvested crop. Seeds may unintentionally contain GE traits because they were produced without adequate protocols to prevent gene flow or through unintentional commingling during production, handling, or transportation (AC21 Committee, 2012). Most countries, including the United States, have not set a specific threshold level for the unintended presence of GE traits in non-GE seeds (Kalaitzandonakes and Magnier, 2013).

According to findings from USDA's 2012 ARMS survey of soybean producers, nearly two-thirds of the producers who planted non-GE soybean varieties used certified non-GE seed (table 3). Seed certification is done by agencies such as the Minnesota Crop Improvement Association to preserve the genetic identity of crop varieties and involves the use of eligible seed stocks, field inspection of the growing crop, representative sampling, and laboratory analysis. Nearly a third of non-GE producers grew non-GE soybeans under a production contract that specified the use of a particular seed variety in 2012. Similar questions have not been asked in USDA's corn producer surveys or USDA's organic producer surveys.

Accessing adequate organic production inputs, including crop seed, is a problem for many organic producers. In USDA's 2014 national organic producer survey, 40 percent of organic farmers reported that acquiring a sufficient amount of organic seed was a challenge (USDA NASS, 2015c).

Spatial and temporal mitigation practices.

USDA's 2010 ARMS corn survey and 2006 ARMS soybean survey asked both conventional and certified organic farmers about their use of three practices that can reduce the spread of pests and GE pollen across fields and farms: cleaning equipment, adjusting planting/harvesting dates, and using buffer strips. Equipment cleaning, which happens for multiple reasons including pest management, was performed on a third of conventional planted acreage and 55-61 percent of organic acreage (table 6).

Buffer strips create a physical barrier between organic and conventional crops and were widely used by organic farmers—69 percent of the organic corn and soybean planted acres had buffer strips during the survey years, compared with less than 4 percent of conventional producers (table 6). Buffer strips provide multiple benefits, including absorption of nutrient runoff; the surveys did not ask farmers why buffers were used. However, USDA national organic standards require farmers to use buffer strips or other barriers if the adjacent land has synthetic pesticides or other prohibited materials applied to it, although a minimum width is not specified.

The distance needed to avoid GE pollen drift may be much wider than to avoid pesticide drift for some crops. The effectiveness of buffer strips at preventing commingling of GE and organic pollen depends on the outcrossing characteristics of the crop, site conditions, weather/wind patterns, and other avoidance strategies being implemented. The recently published Canadian Organic Standard noted generally accepted isolation distances for organic crops at risk of pollen flow from GE crops (when other avoidance strategies are not being used) as 33 feet for soybeans, 984 feet for corn, and 9,343 feet for canola, alfalfa for seed production, and apples (Canadian General Standards Board, 2015). European countries have proposed or imposed a wide variety of isolation distances. For example, proposed or imposed distances for organic corn are 49 feet in Sweden; 164 feet in Spain; 656 feet to 984 feet in the Czech Republic, Denmark, Germany, the Netherlands, Poland,

Table 6
Corn and soybean practices used for GE avoidance and pest management[1]

Production system	Conventional (non-Organic)	Organic
Corn (2010)		
Planted acres, 2010 (thousand acres)	81,577	163
Avoidance practices:	Percent of planted acres	
Clean equipment to reduce spread of pests[2]	33	55
Adjust plant/harvest date	15	64
Buffer strips or other physical barriers[3]	4	69
Soybeans (2006)		
Planted acres, 2006 (thousand acres)	72,767	113
Avoidance practices:	Percent of planted acres	
Clean equipment to reduce spread of pests[2]	33	61
Adjust plant/harvest date	13	42
Buffer strips or other physical barriers[3]	<1	69

[1]Producers have adopted these practices for multiple reasons, including avoidance of GE contact between GE and non-GE crops. Organic and conventional producers were asked the same question.
[2]In the surveys, pests were defined as weeds, insects and disease.
[3]Organic producers are required to use a buffer strip when substances that are prohibited in organic production are used nearby. Buffer strips were historically designed to help prevent exposure to pesticides, and the buffer size that is effective for GE pollen may be larger.
Sources: USDA Economic Research Service and National Agricultural Statistics Service, Agricultural Resource Management Survey (ARMS) Soybean Survey, 2006 and ARMS Corn Survey, 2010.

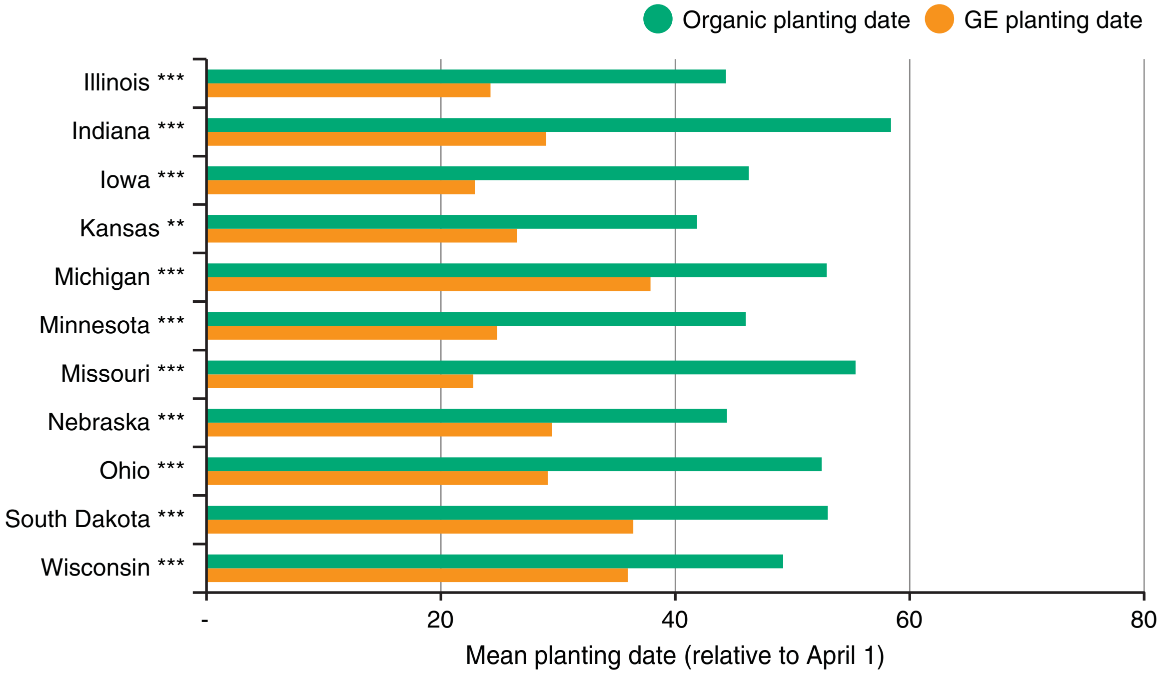
Slovenia, and Portugal; and 2,625 feet in Luxembourg and Hungary (Devos et al., 2009). Devos and colleagues (2009) concluded that the large and fixed isolation distances in some EU countries are excessive from a scientific point of view and indicated that studies mimicking worst-case scenarios have "demonstrated that isolation distances exceeding 164 feet are not always necessary to comply with the labelling threshold of 0.9% in grain maize" (Devos et al., 2009, p. 20).

Planting organic crops later than nearby GE crops reduces the likelihood that the crops will pollinate at the same time and is particularly useful for corn. Soybeans are mostly self-pollinating, and the risks of cross pollination are minimal. The risks of cross pollination are much higher for corn because most corn pollination results from pollen dispersal by wind and gravity.

Adjustments to the planting (and harvesting) date were used on nearly two-thirds of organic corn acreage in 2010 (table 6). The average planting date for organic corn producers was about 2 weeks later than for conventional GE corn producers in Wisconsin, Nebraska, Michigan, and Kansas (fig. 7).[7] In Ohio and Iowa, organic producers planted 3 weeks later than their neighbors, and a month later in Indiana and Missouri. This strategy is not always successful because cool and wet spring weather can delay plant growth such that corn plants pollinate at about the same time regardless of planting date. While delayed planting can provide protection against commingling of GE and non-GE crop pollen, growers will likely realize lower yields if planting at a suboptimal time.

[7]USDA corn surveys have not yet asked similar questions about the planning dates of conventional non-GE corn producers growing for an identity-preserved market.

Figure 7
Average planting dates for genetically engineered (GE) and certified organic corn, 2010



Note: Asterisks denote a statistically significant difference between the GE planting date and the organic planting date means at the 5-percent (**) and 1-percent (***) levels.
Source: USDA, 2010 Agricultural Resource Management Survey (ARMS) Corn Survey.

GE Testing and Economic Losses in Organic Production

U.S. organic farmers and farmers who produce identity-preserved non-GE crops must meet the tolerance levels for accidental GE presence that are set by domestic buyers, foreign buyers, and some foreign governments. Processors and handlers reject the products when GE traits test above the buyer's GE tolerance level (Carter and Guillaume, 2003). If their crops test over the expected tolerance level, farmers may lose their organic (or non-GE) premium and incur additional transportation and marketing costs to sell the crop at a discount in alternative markets.

Costs of GE Avoidance Practices

Some of the avoidance practices used by organic and non-GE farmers raise the cost of producing those crops. For example, delaying planting can reduce yields. Using non-GE seed with GE exclusion traits, and GE testing for seeds and crops, can increase input costs. Buffer zones take land out of production. Also, some organic and GE farmers may alter cropping patterns or the mix of crops and discontinue the use of crops and inputs at risk of containing GE material, raising management and production costs. Beyond the farm gate, shipment testing and labeling costs are also borne by organic and non-GE processors, manufacturers, and retailers. These higher costs at various points in the supply chain can increase prices for consumers; if consumers have an upper limit on the price increases that they are willing to bear to avoid unintended GE presence, then this price ceiling could hinder coexistence if avoidance strategies become costly.

Many U.S. processors and retailers that buy and sell organic and non-GE products are now requiring verification that GE avoidance protocols were observed. As part of the non-GE verification, testing of both organic and non-GE products has become more frequent. USDA has not collected data on the cost of avoidance practices. A recent study conducted jointly by an environmental nonprofit and organic grain cooperative estimated these costs (Food & Water Watch and OFARM, 2014).[8] In this study, USDA's comprehensive list of certified organic producers was used to identify and survey 1,500 U.S. organic grain producers; 19 percent, mostly in the Midwest, completed the survey. The total median annual cost of practices to avoid GE material in their crops was $6,532 to $8,500 per farm, including the cost of buffer strips[9] ($2,500), delayed planting ($3,312 to $5,280), testing ($200), and other measures ($520) (Food & Water Watch and OFARM, 2014). However, it is not possible to determine whether these estimates are representative of costs incurred by nonrespondents.

[8]Findings on the costs of practices were reported as median costs per farm rather than the more standard costs per acre.

[9]The median size of buffer strips for survey respondents was approximately 5 acres.

Economic Losses From Unintended GE Presence

Two USDA surveys have asked producers about their economic losses from unintended GE presence.

USDA National ARMS Corn Survey, 2010.

In 2010, 18 percent of the certified organic corn producers reported that they had their 2010 corn production tested for GE material (table 7). One percent of the organic corn producers reported that they had food-grade corn rejected by a buyer in 2010 or earlier due to the presence of GE material. Two percent of the organic corn producers reported that they had feed-grade corn rejected in 2010 or earlier. Farmers were not asked the value of the economic loss from having shipments rejected.

Table 7
Certified organic corn production, 2010: GE testing and shipment rejection

Certified organic corn/Total U.S. corn, 2010 (percent)	0.2
Producers who had their 2010 organic corn production tested for GE material (percent)	18.4
Producers who have ever had food-grade organic corn rejected due to GE material (percent)	1
Number of years that the food-grade organic corn was rejected	1
Producers who have ever had feed-grade organic corn rejected due to GE material (percent)	2
Number of years that the feed-grade organic corn was rejected	1.3

Source: USDA, Economic Research Service and National Agricultural Statistics Service, Agricultural Resource Management Survey Corn Survey, 2010.

USDA National Organic Survey, 2014.

This survey asked producers if they had "experienced economic losses that you can document due to unintended presence of GMO material in an organic crop that you have produced for sale," excluding expenses for preventative measures and testing. One percent of *all* U.S. certified organic farmers in 20 States reported economic losses from the unintended presence of GE material in their crops during 2011-14 (table 8). The percentage of organic farmers who suffered economic losses would be higher if calculated only for those organic farmers growing the nine crops with a GE counterpart (commodity-specific estimates could not be reported due to data limitations and concerns about respondents' privacy).

The share of all organic farmers who suffered economic losses due to GE presence in their crops ranged from less than 1 percent in California, Indiana, Maine, Minnesota and Michigan to 6-7 percent in Illinois, Nebraska, and Oklahoma. These latter States have a high percentage of farmers that produce organic corn, soybeans, and other crops with GE counterparts (table 8). California had the lowest share of organic farmers (0.2 percent) reporting economic losses from unintended GE material. While California has more organic farmers and acreage than any other State, most of California's organic production is for fruits, vegetables and other specialty crops that mostly lack a GE counterpart. In 2014, California accounted for only 1 percent of the U.S. harvested acreage of major field crops, which include corn, soybeans, cotton, canola, and sugar beets, the crops with widespread GE seed adoption.

Table 8

Certified organic farms reporting economic losses from unintended GE presence, 1986-2014[1]

States with certified organic farms reporting economic losses	Certified organic farms with economic loss (2011-14)	Value of economic loss[2] (2011-14)	Average loss per farm (2011-14)	Total certified farms in States with losses (2014)	Certified organic farms with losses (2011-14): All farms in affected States (2014)	Certified organic farms with economic loss (2006-10)	Certified organic farms with economic loss (2001-05)	Certified organic farms with economic loss (1986-2000)
	Number	Dollars	Dollars	Number	Percent	Number	Number	Number
California	4	664,000	166,000	2,632	0.2	-	-	-
Illinois	16	621,506	38,844	215	7.4	1	-	-
Indiana	2	(D)	(D)	251	0.8	-	-	-
Iowa	8	33,840	4,230	593	1.3	2	1	-
Kansas	1	(D)	(D)	77	1.3	1	-	-
Maine	3	45,000	15,000	444	0.7	-	-	-
Maryland	3	(D)	(D)	110	2.7	-	-	-
Michigan	2	(D)	(D)	288	0.7	-	-	-
Minnesota	3	82,440	27,480	475	0.6	-	-	-
Missouri	4	38,800	9,700	184	2.2	1	-	-
Nebraska	10	362,950	36,295	166	6.0	1	-	-
New Jersey	1	(D)	(D)	60	1.7	-	-	-
North Carolina	2	(D)	(D)	200	1.0	-	-	-
North Dakota	1	(D)	(D)	94	1.1	-	-	-
Ohio	9	119,816	13,313	499	1.8	-	-	-
Oklahoma	2	(D)	(D)	35	5.7	-	-	-
Pennsylvania	5	(D)	(D)	653	0.8	-	-	-
South Dakota	2	(D)	(D)	78	2.6	-	-	-
Texas	3	3,850,000	1,283,333	178	1.7	-	-	-
Utah	-	-	-	-	-	-	1	-
Wisconsin	6	(D)	(D)	1,128	0.5	3	-	-
United States	**87**	**6,098,642**	**70,099**	**8,360**	**1.0**	**9**	**2**	**0**

(D) = Disclosure; the estimate is not disclosed because of too few observations to maintain confidentiality.
[1]Expenses for practices to avoid GE material and conduct GE trait tests are excluded.
[2]Includes the value of losses in States where losses weren't disclosed.
Note: The percent of U.S. certified organic farms with economic losses is likely higher in the crop sectors with GE counterparts, such as corn and soybeans. However, commodity-level estimates cannot be reported due to confidentiality constraints.
Source: USDA, National Agricultural Statistics Service, 2014 Organic Production Survey.

Nationwide, a total of 87 farms in 20 States reported an economic loss in at least 1 year between 2011 and 2014.[10] These farmers reported a total of nearly $6.1 million in economic losses during this period, accounting for an estimated 0.4 percent of the total value of farm sales for all 9 crops with GE counterparts during 2011-2014. The average economic loss from unintended GE presence in organic crops varied substantially by State. The average loss among all 87 farms where a loss was reported was $70,099 per farm.[11] The largest number of farmers reporting a loss was in Illinois, where 16 farmers experienced losses during 2011-2014, with an average loss of $38,844 per farm. Although the average losses were much higher in California ($166,000 on farms with losses) and Texas ($1,283,333), only 4 farms experienced losses in California and 3 farms in Texas. Both States produce high-value fruit and vegetable crops that have GE counterparts, as well as organic production of the major GE field crops, some of which also have high-value uses. For example, alfalfa is usually used for animal feed but also has high-value uses as an herb in supplement products (National Institutes of Health, 2015).

USDA's national organic producer survey in 2014 also reported the number of organic farms experiencing an economic loss prior to 2011. In 2006-2010, only two farmers reported losses; no losses were reported prior to 2006. Reported economic losses have risen since 2010 partly because many major organic and natural food manufacturers and retailers only began using private verification services for their products after 2010, and testing for GE traits in organic corn and soybeans increased accordingly. It is not possible to tell how much of the increase in affected producers and economic losses was due to increased testing versus an increase in organic shipments testing above tolerance for GE traits.

[10]In addition, five organic producers with under $5,000 in annual organic sales, who were exempt from USDA's certification requirement, reported that they experienced an economic loss in 2011-2014 due to GE presence.

[11]In 11 of the 20 States where organic farmers reported an economic loss during 2011-14, USDA could not report the value of the loss because there were too few observations to maintain producer confidentiality.

Conclusions

The accidental comingling of GE material in organic products was seen as a major risk by U.S. organic producers as early as the early 2000s (Hanson et al., 2004). Although findings from USDA's recent organic producer survey showed that only 87 certified organic producers suffered economic losses from the unintended presence of GE material during 2011-14, the share has increased during every survey period since 2000. Also, while only nine crops were grown with GE varieties by 2014, GE varieties have recently been approved for several major fruit and vegetable crops. Coexistence may become more difficult for organic and conventional non-GE producers as more fruits, vegetables, and other crops are genetically engineered.

Whereas GE seeds are used on more than 90 percent of planted corn and soybean acres, organic production accounts for less than 0.3 percent of total acreage in these crops. Organic systems have been much more widely adopted for fruits and vegetables. Organic systems have also been adopted more widely for rice, wheat, and other field crops that are primarily used for food.

This report examines economic issues related to the coexistence of GE, organic, and non-GE crops. Research is needed on the practices used by grain and oilseed processors and other handlers to facilitate coexistence, as well as to assess the impacts of unintended GE presence on this part of the supply chain. More research is also needed to examine the cost and effectiveness of various coexistence strategies, and the impact of alternative strategies on producers and consumers.

The findings in this report reflect uneven data availability. For example, USDA collects data on the extent of U.S. acreage planted with GE seed for only three (soybeans, corn, and cotton) of the nine crops that currently have commercial GE production. Public data on GE-differentiated production systems and markets is improving, with USDA now reporting non-GE grain prices, for example. However, many data gaps on GE, non-GE, and organic production systems remain.

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